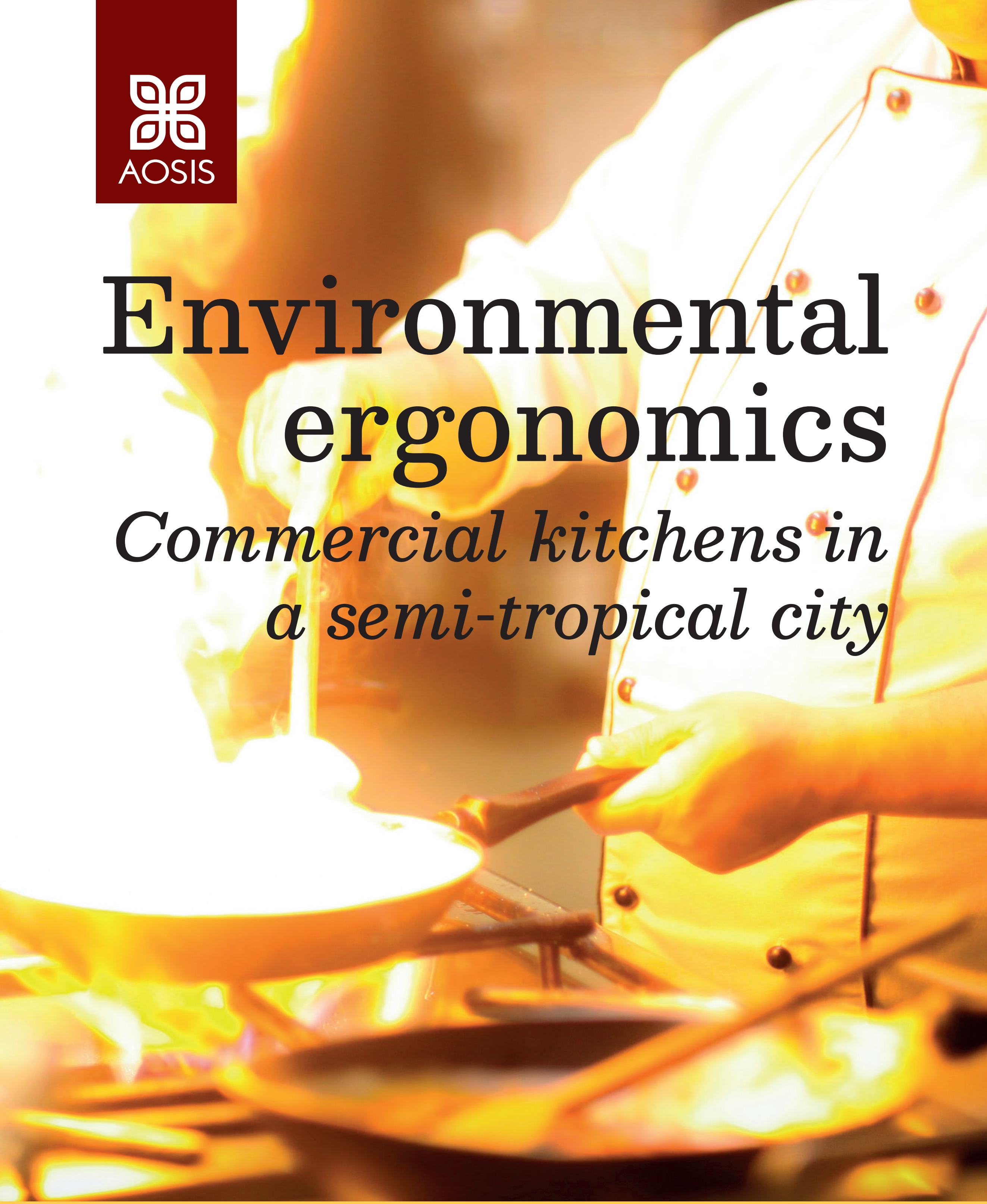


Environmental ergonomics

Commercial kitchens in a semi-tropical city

Sasi Gangiah

Environmental ergonomics

Commercial kitchens in a semi-tropical city

AOSIS

Published by AOSIS Books, an imprint of AOSIS Publishing.

AOSIS Publishing
15 Oxford Street, Durbanville, 7550, Cape Town, South Africa
Postnet Suite 110, Private Bag X19, Durbanville, 7551, Cape Town, South Africa
Tel: +27 21 975 2602
Website: https://www.aosis.co.za

Copyright © Sasi Gangiah. Licensee: AOSIS (Pty) Ltd
The moral right of the author has been asserted.

Cover image: Original design created with the use of a provided image. The image is https://unsplash.com/photos/RKdkETvcYn4, released under the appropriate Unsplash license terms.

Published in 2022
Impression: 2

ISBN: 978-1-77995-203-5 (print)
ISBN: 978-1-77995-204-2 (epub)
ISBN: 978-1-77995-205-9 (pdf)

DOI: https://doi.org/10.4102/aosis.2022.BK346
How to cite this work: Gangiah, S 2022, *Environmental ergonomics: Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town.

Printed and bound in South Africa.

Listed in OAPEN (http://www.oapen.org), DOAB (http://www.doabooks.org/) and indexed by Google Scholar.
Some rights reserved.

This is an open access publication. Except where otherwise noted, this work is distributed under the terms of a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0). A copy of which is available at https://creativecommons.org/licenses/by-nc-nd/4.0/. Enquiries outside the terms of the Creative Commons license should be sent to the AOSIS Rights Department at the above address or to publishing@aosis.co.za.

BY-NC-ND

The publisher accepts no responsibility for any statement made or opinion expressed in this publication. Consequently, the publishers and copyright holder will not be liable for any loss or damage sustained by any reader as a result of their action upon any statement or opinion in this work. Links by third-party websites are provided by AOSIS in good faith and for information only. AOSIS disclaims any responsibility for the materials contained in any third-party website referenced in this work.

Every effort has been made to protect the interest of copyright holders. Should any infringement have occurred inadvertently, the publisher apologises and undertakes to amend the omission in the event of a reprint.

Environmental ergonomics

Commercial kitchens in a semi-tropical city

Sasi Gangiah

AOSIS

Social Sciences, Humanities, Education and Business Management domain editorial board at AOSIS

Commissioning Editor: Scholarly Books

Andries G. van Aarde, MA, DD, PhD, D Litt, South Africa

Board members

Emmanuel O. Adu, Professor of Teacher Education and Curriculum Studies, Faculty of Education, University of Fort Hare, South Africa
Vusiwana C. Babane, Department of Educational Psychology, University of the Western Cape, South Africa
Elphinah N. Cishe, Professor of Nedbank Chair Faculty of Educational Sciences, Walter Sisulu University, South Africa
Llewellyn Leonard, Professor of Environmental Science, School of Ecological and Human Sustainability, University of South Africa, South Africa
Reina-Marie Loader, Programme Lead for Masters in Producing Film and Television and Lecturer in Film Production, Faculty of Media and Communication, Bournemouth University, Bournemouth, United Kingdom
Stanley Murairwa, Head of Department, Business Sciences, Africa University, Mutare, Manicaland, Zimbabwe
Jayaluxmi Naidoo, Associate Professor of Mathematics and Computer Science Education, College of Humanities, University of KwaZulu-Natal, South Africa
Piet Naudé, Professor of Ethics related to politics, Economics and Business, University of Stellenbosch Business School, South Africa
Charles O'Neill, Professor of Department of Business Administration, The British University in Egypt, El Sherouk, Cairo Governorate, Egypt
Cheryl A. Potgieter, Deputy Vice-Chancellor Research Office and head of the Gender Justice, Health and Human Development focus area, Durban University of Technology, South Africa
Zilungile Sosibo, Professor of Education, Faculty of Education, Cape Peninsula University of Technology, South Africa
Johann Tempelhoff, Professor of Research Niche for Cultural Dynamics of Water (CuDyWat), School of Basic Sciences, North-West University, South Africa
Tembi Tichaawa, Professor and Head of Department Tourism, University of Johannesburg, South Africa
Anthony Turton, Professor in the Centre for Environmental Management and Director TouchStone Resources (Pty) Ltd, University of Free State, South Africa
Christi van der Westhuizen, Associate Professor in the Centre for the Advancement of Non-Racialism and Democracy, Nelson Mandela University, South Africa
Siphamandla Zondi, Department of Politics and International Relations, University of Johannesburg, South Africa

Peer review declaration

The publisher (AOSIS) endorses the South African 'National Scholarly Book Publishers Forum Best Practice for Peer Review of Scholarly Books'. The manuscript underwent an evaluation to compare the level of originality with other published works and was subjected to rigorous two-step peer review before publication, with the identities of the reviewers not revealed to the editor(s) or author(s). The reviewers were independent of the publisher, editor(s), and author(s). The publisher shared feedback on the similarity report and the reviewers' inputs with the manuscript's editor(s) or author(s) to improve the manuscript. Where the reviewers recommended revision and improvements, the editor(s) or author(s) responded adequately to such recommendations. The reviewers commented positively on the scholarly merits of the manuscript and recommended that the book be published.

Research justification

This book focuses on the environmental ergonomics of restaurant kitchens and the challenges related hereto in a semi-tropical city, Durban, from a chef's perspective. It establishes the urgent need for commercial kitchens to be conducive to the well-being of kitchen workers, as heat illness is unreported in this industry. This research is relevant from occupational health and safety point of view. It evaluates the indoor environmental quality (IEQ) parameters such as heat, ventilation and humidity, noise and lighting in kitchens, and it is cognisant that with different cuisines, the kitchen loads are different. The goal of occupational safety is health intervention for worker comfort to enhance work performance. The book generates new knowledge regarding the factors affecting the body mass index of kitchen workers, prediction of heat and humidity near cooking stoves, discomfort near ovens, lighting in preparation areas and factors affecting reaction to stove noise. The book implements an exploratory design with multiple-case studies. The manuscript is structured into broad chapters on heat, ventilation and humidity, noise and lighting. Data analysis is an essential component of new knowledge, and a detailed description will promote certain research concepts among scholars to acquire research skills. The themes move from the hospitality industry in general and narrow down to commercial kitchens and specifically aim at students learning and training in culinary skills. The book accordingly scrutinises theory in respect of the relationship between individual differences and contextual components, and it factored these into controlled heat in a work environment and other IEQ parameters. This book advances existing physical conditions, as well as physiological and psychological influences of these parameters in commercial kitchens on worker relief-seeking behaviour adaptations. A ground-breaking new framework that optimises workstation comfort levels of kitchen workers is presented, hence offering insightful environmental contributions to improve commercial kitchen design and awareness among kitchen designers, ergonomists, academicians and management. The contents of this book have not been published before and represent more than 50% of the reworked thesis. There is no plagiarism, and all information has been given due credit. The target audience consists of academics in the discipline of hospitality and specialists in the field of environmental ergonomics.

Dr Sasi Gangiah, Department of Hospitality and Tourism, Faculty of Management Sciences, Durban University of Technology, Durban, South Africa.

A book project facilitated by the Research and Doctoral Leadership Academy (RADLA), headed by Professor Cheryl A. Potgieter

Contents

Abbreviations and acronyms, boxes, figures and tables appearing in the text and notes

List of abbreviations and acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
ACMS	American College of Sports Medicine
AHL	age-related hearing loss
ANOVA	analysis of variance
ANSI	American National Standards Institute
ARI	acute respiratory infections
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
AT	apparent temperature
AV	artificial ventilation
BE	blue-enriched
BF	body fat
BGT	black globe temperature
BMI	body-mass index
BMR	basic metabolic rate
BOSH	British Occupational Safety and Health
C&C	capture and containment
CBE	Center for the Built Environment
CCT	correlated colour temperature
CFL	compact fluorescent lamps
CHD	coronary heart disease
CIBSE	Chartered Institution of Building Services Engineers
COF	cooking oil fumes
CRE	contaminant removal efficiency
CRI	colour rendering index
CS	circadian stimulus
DA	displaced aggression
DB	dry bulb
DCV	demand-controlled ventilation
DI	discomfort index
DV	displacement ventilation

EFA	exploratory factor analysis
GBCSA	Green Building Council South Africa
HAM	heat adaptive model
HBM	heat balance model
HCP	hearing conservation programme
HEPA	high-efficiency particulate absorbing
HI	heat index
HPD	hearing protection devices
HRI	heat-related illness
HSE	health and safety executive
HSI	heat stress index
HVAC	heating, ventilation and air-conditioning
HX	humidex
IAQ	indoor air quality
IEQ	indoor environmental quality
IES	Illuminating Engineering Society
ILO	International Labour Organisation
IMC	International Mechanical Code
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LEV	local exhaust ventilation
LFN	low-frequency noise
LPG	liquefied petroleum gas
MM	mixed-mode
MRT	mean radiant temperature
MV	mechanical ventilation
NFPA	*National Fire Protection Act*
NIHL	noise-induced hearing loss
NIOSH	National Institute for Occupational Safety and Health
NV	natural ventilation
OHSA	*Occupational Health and Safety Act*
OSHA	Occupational Safety and Health Administration
PA	physical activity
PAH	polycyclic aromatic hydrocarbons
PEL	permissible exposure limit
PM	particulate matter

PMP	performance measurement protocols
PMV	predicted mean vote
PPD	predicted percentage dissatisfied
PPE	personal protective equipment
PPS	perforated perimeter supply
PV	passive ventilation
QSR	quick-service restaurant
RADLA	Research and Doctoral Leadership Academy
REL	recommended exposure limits
REHVA	Federation of European Heating, Ventilation and Air Conditioning Associations
RH	relative humidity
SABS	South African Bureau of Standards
SAD	seasonal affective disorder
SANAS	South African National Accreditation System
SANS	South African National Standard Code of Practice
SBS	sick building syndrome
SD	standard deviation
SM	spot measurements
SPL	sound pressure level
SPSS	Statistical Package for the Social Sciences
TLV	threshold limit value
TPC	total polar compound
TVOC	total volatile organic compounds
UCLA	University of California, Los Angeles
UFP	ultrafine particles
UHI	urban heat island
UK	United Kingdom
US	United States
USGBC	United States Green Building Council
UV	ultraviolet
VC	visual comfort
VCS	ventilated ceiling system
VOC	volatile organic compounds
WBGT	wet-bulb globe temperature
WHO	World Health Organization

Box list

List of figures

List of tables

Biographical note

Sasi Gangiah
Department of Hospitality and Tourism,
Faculty of Management Sciences, Durban University of Technology,
Durban, South Africa
Email: sasig@dut.ac.za
ORCID: https://orcid.org/0000-0001-5485-1861

Born in India, Sasi Gangiah relocated to South Africa shortly after marrying her husband. She is a lecturer at Durban University of Technology (DUT), South Africa, where she lectures in the Department of Hospitality and Tourism. She was awarded a PhD for her multidisciplinary research titled 'An exploration of environmental ergonomics: A case of restaurant kitchens in Durban', which comprises themes and topics catering management, human physiology, mechanical engineering, built environment, quality management and ergonomics. She has over 19 years of experience in nutrition, dietetics, and food services. Gangiah also evaluates research proposals and consults on restaurant operations. She is a member of the Ergonomic Society of South Africa and received a BSc in Nutrition and Dietetics (1989), MSc in Food Service Management and Dietetics (1992) and MPhil in Food Service Management and Dietetics (1993) from India. She was one of the recipients of the Junior Research Scholarship and Eligibility for Lectureship Grant in 1994 from the Council of Scientific and Industrial Research and University Grants Commission (CSIR-UGC), India. With her background, Gangiah opened four restaurants in Durban and Gqeberha, South Africa, which she later sold to pursue her PhD at DUT. As an occupational health representative for the department, she succeeded in maintaining zero-infection rates in practical kitchen laboratories during the COVID-19 pandemic. As a catering programme team leader, she is passionately involved in the Culinary Arts curriculum decolonisation at Durban University of Technology, South Africa.

Chapter 1

Overview and background of the study

1.1 Introduction

The current research integrates conceptual issues from human biology, anthropology, mechanical engineering, thermodynamics and the built environment and is therefore multidisciplinary in order to understand the well-being of kitchen workers. The study seeks to explore the impact of common heating, lighting, acoustics, ventilation and air-conditioning on indoor environmental quality (IEQ) and the well-being of food-service workers. According to Kaul, Khandelwal and Suthar (2022), 'indoor environmental quality (IEQ) refers to the environmental quality inside the building that affects the comfort and health of those who occupy it. It determines the indoor air quality in terms of thermal comfort, lighting condition, odour and noise pollution'. An interdisciplinary approach is necessitated based on contributions from both natural and social sciences, as highlighted by placing the person-environment relationship at the centre of environmental comfort design (Laurìa, Secchi & Vessella 2020).

The knowledge generated from this enquiry uncovers vital components in kitchen products and workplace designs that will enhance usability suited to those working and using the area. Generally, and more specifically, in commercial kitchens in Durban, South Africa, kitchen worker ethnicity, individual differences, geographic diversity and adaptability remain unexplored

How to cite: Gangiah, S 2022, 'Overview and background of the study', in *Environmental ergonomics: Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town, pp. 1–7. https://doi.org/10.4102/aosis.2022.BK346.01

research areas. A limited number of reports are available on the environmental parameters of commercial kitchens. In sub-Sahara Africa, very few studies have examined the air quality, noise, thermal comfort, and health risk assessment of kitchens (Giwa, Nwaokocha & Sharifpur 2022).

The first section of this chapter provides an outline of the study's context and background. This is followed by the rationale of the study, the problem statement, the research objectives and the research questions. This chapter includes a discussion of the study methodology and my assumptions.

Over a decade ago, Sanjog, Patel and Karmakar (2013) observed that there is an absence of attention to racial and topographical diversity, personal variances and flexibility while planning any indoor workplace facility. Formulation of standards specific to industries, locations and countries can result in an optimal design for human well-being, realising the goal of ergonomics on a global scale.

Heat illness is a frequent occurrence in many kitchens since the temperature there frequently reaches 26.66°C. Reduced temperatures are especially necessary in hot indoor spaces, such as restaurant kitchens (Metz, Prier & Miller 2021). Saif Eldin, Radwan, and Khalifa (2022)posit that several indoor workers, especially those operating close to a radiant heat source, like in kitchens, may be at risk of heat stress and its effects due to occupational heat exposure.

Given that a commercial kitchen is an intricate setting with numerous indoor elements that do not always interact in unison but rather by design or by chance (Livchak, Schrock & Sun 2005), the food-service business is disadvantaged by poor ergonomics (Gigstad 2002). Proper ergonomic conditions are necessary to prevent discomfort and fatigue. Considering that ergonomics is a key part of the planning process, these ergonomic parameters in a large-scale kitchen are heavily influenced by the indoor environment. Hence, in the context of restaurants, the health and safety of workers are vital, meaning that environmental ergonomics must be given due attention.

Catering kitchens are multifaceted workplaces with exposure to a harsh work environment. Acoustics, heat, lighting and higher levels of noxious emissions in the kitchen air are serious threats to the well-being of staff. These threats that arise from deficient environmental ergonomics have been reported in numerous studies (Alam, Arunachalam & Salve 2019; Alam, Sharma & Salve 2022; Bindu & Reddy 2016; Kabir 2019; Kundu, Alam & Salve 2022; Moumen & Delporte 2022; Park et al. 2017; Ramesh & Manikandan 2015; Simone et al. 2013; Venugopal, Latha & Shanmugam 2021). These studies have measured individual parameters to include heat, humidity and airflow that reflect thermal comfort. Marć et al. (2018) added that environmental factors, such as humidity, radiant heat and airflow, significantly influence the comfort of work and well-being of workers in commercial kitchens.

This brings up the problem of balancing the complexities of human necessities – tangible and intangible – in the determination of building standards (Altomonte et al. 2020). The importance of the control and dynamic adaptation of the environmental parameters by occupants can be better understood when considering that individual factors such as age, sex, health conditions, functional limitations, lifestyle and social context affect all human needs, including those of a 'physiological' nature. In Laurìa et al.'s (2020) critique, parameters are often treated separately and do not factor in the fact that, in perceptual experience, the senses reciprocally influence one another. Nonquantifiable characteristics – including the ability to grasp and regulate the context, the sense of orientation and the ability to manage situations of environmental stress – are just as essential as measurable factors in determining environmental comfort.

Adding to the multifaceted influences are the external environmental parameters that influence internal kitchen conditions. This study was conducted in subtropical Durban, which is known for high humidity, causing discomfort (Conradie 2012). It is essential that a working environment increases productivity through noise reduction, better lighting and a better indoor environment. Despite the requirements of technical criteria for each environmental aspect being met separately, it does not necessarily entail complete satisfaction with the environmental ergonomics of commercial kitchens. Hence, it is imperative that all five parameters are measured simultaneously in commercial kitchens to study their impact on subjective responses.

I faced several setbacks while working and managing a restaurant. Problems with IEQ parameters such as heat, noise, lighting and indoor air quality (IAQ) of a kitchen have a direct bearing on the well-being and output of kitchen workers, and thus the idea of investigating commercial kitchen compliance with ergonomic principles was born. This study will contribute to the gaps in knowledge of commercial kitchen environmental ergonomics by adding to the small pool of available empirical work on this issue. In its theory-building endeavour, the study will help to improve kitchen IEQ and inform on optimal environmental conditions for local kitchen personnel that will positively influence their health status. The book will also promote the creation of physically healthy environments for food-service workers in South Africa by assisting policymakers (e.g. the South African Department of Labour) in amending policies that regulate standards for kitchen environmental ergonomics.

I consider this research to be useful in the field of environmental ergonomics in the food-service industry. The relevance of the criteria will be supported by a framework of the physical environment and the human aspect, focusing on the demographics of food-service workers. Therefore, a platform to set standards regarding the specific requirements for the levels of temperature, humidity, noise and light will be offered. The empirical recommendations will assist food-service management in drawing attention to the need to incorporate a proper intervention programme to improve the kitchen atmosphere and maintain worker retention.

The workplace setting in a catering operation is considered exacting on health because of a hot environment, in addition to irregular working hours. Previous studies by Haruyama et al. (2010) and Matsuzuki et al. (2011) reported that work in commercial kitchens is performed under high ambient temperatures. Over the course of a long shift, kitchens can grow exceedingly hot; hence, improved thermal conditions can assist employees in feeling satisfied (Webstaurant Store 2018). Where the temperature and humidity are both high, humidity emerges as the more potent force for discomfort.

Sufficient ventilation and airflow are crucial elements in the thermal comfort of a workplace; every enclosed workspace should be equipped with appropriate ventilation by adequate fresh or clean air (Eagles & Stedmon 2004). Livchak et al. (2005) accordingly posited that a commercial kitchen is a complex environment where numerous mechanisms of a ventilation system, including extractor, chilled air vents and make-up air systems function together constantly but not in harmony. This prevents kitchens from being cool and comfortable and hampers productivity, staff retention and subsequent profit for a catering business.

Kitchen workers' health is also threatened. Due to extensive cooking, poor ventilation, and polluting fuels, kitchen air pollution is a major environmental problem (Kumar et al. 2022). According to Ghaffarianhoseini et al. (2018), poor IAQ can increase respiratory diseases, sick building syndrome (SBS) symptoms and allergies. Emissions of indoor air pollutants like volatile organic compounds (VOCs) directly affect people's comfort and health. Kosonen's (2006) review of literature on cooking and lung cancer reiterates the importance of well-designed ventilation in the kitchen. Carbon dioxide (CO_2) and carbon monoxide (CO) levels in the kitchens indicate the performance of heating, ventilation and air-conditioning (HVAC) systems and the quality of air.

According to Akbari et al. (2013), improvement in light's direct and indirect influences has decreased vision disturbance, neck and shoulder pain, eye fatigue and headache. Inappropriate lighting, such as neon lights, often causes annoyance, eyestrain and fatigue (Sanjog et al. 2013).

Similarly, noise levels may be considered directly or indirectly to affect physical and psychological aspects; managing noise will have a constructive effect on workers and their output (Akbari et al. 2013). Potential dangers include acceptable shouting in kitchens, equipment noise and extraction mechanisms, as per European Agency for Safety and Health at Work or EASHW (2008b).

The consequences of poor ergonomics go beyond the loss of performance and workplace usability (Gigstad 2002). Well-planned workspaces provide physical comfort and contribute to well-being within the work environment. There are not many firm ergonomic strategies, distinct from other workplace designs, to promote the design and utilisation of kitchens in a safe manner (Eagles & Stedmon 2004).

There is limited information on optimal environmental parameters for kitchens catering to diverse cuisines. A new framework that serves as the foundation for developing an environmental quality policy and standard operating procedures for commercial kitchens needs to be established. Hence, this exploratory study will serve as a springboard for further research into better understanding, modelling and extrapolation among various hot workplace environments for human well-being. Recommendations emanating from this study will also assist the food production sector locally and in locations with similar working environments. In South Africa, it is acknowledged that ergonomics is important. Still, there seems to be a significant gap in understanding and implementation, which this study attempts to clarify by contributing to formulating future ergonomic regulations that will assist employers in addressing ergonomic risk factors.

1.2 Aim and objectives of the study

The study aims to investigate the impact of heating, lighting, acoustics, ventilation and humidity on IEQ and the well-being of food production workers.
The objectives of the study are:

- to examine indoor airflow, humidity, lighting and acoustics in restaurant kitchens
- to determine the thermal environment and heat stress among food production workers using gas and kitchen appliances
- to investigate the perception of food production workers' adaptability to selected indoor environmental conditions
- to compose indoor environmental criteria for the design of restaurant kitchens in Durban regarding indoor airflow, humidity, thermal environment, lighting and acoustics.

The research questions of this study are as follows: what is the level of indoor airflow, humidity, thermal environment, lighting and acoustics in restaurant kitchens? How does heat stress affect food-service workers who use gas and electric kitchen appliances? What are the perceptions of the adaptability of food production workers to selected indoor environmental conditions? What indoor environmental criteria are required to design restaurant kitchens in Durban, with a semi-tropical climate?

1.3 Research methodology, design and delimitations

The research design utilised in this study incorporated a nonexperimental, exploratory case study design in different types of kitchens, forming the cases for investigation. According to Yin (2014), a case study method is relevant when research requires an extensive and in-depth description of phenomena. Multiple-case studies enabled me to explore differences within and between cases. The study utilised chiefly quantitative techniques and some qualitative data. Flick (2019) accordingly claimed that mixed methodology approaches are interesting for their value in combining qualitative and quantitative research. The purpose of quantitative research is to evaluate objective data, while qualitative research deals with subjective data that respondents and interviewees produce. It is essential to triangulate multiple data sources as a key strength in the data-gathering process. Kitchens are selected with due consideration to the type of cuisine to include diversity in cooking methods and a minimum of 10 employees.

Cross-verification of data, such as readings from special equipment, verified the worker's opinions from observations, interviews and questionnaires. The observational study design was cross-sectional, where the investigator measured the outcome and the exposures of the study participants at the same time. The sample frame comprised licensed restaurant kitchens in the eThekwini municipality. Purposive sampling was adopted to maximise what could be researched in the time available.

The primary data were gathered using scientific test equipment, such as:

- a thermohygrometer
- heat stress meter
- air temperature-humidity hygrometer
- anemometer
- noise level meter
- light meter
- IAQ monitor and laser room measure
- social research tools, such as a questionnaire, interview schedule and observational checklist.

These tools provide objective measures of environmental ergonomic design data. Rajasekar and Ramachandraiah (2010), Matsuzuki et al. (2013), Simone et al. (2013), Nassiri et al. (2013), and Akbari et al. (2013) found success in the use of one or more of the aforementioned items of equipment in their studies. Using scientific test equipment, Zuhaib et al. (2018) measured physical parameters for the IEQ variables, namely indoor air temperature (°C), relative humidity (%), mean radiant temperature (°C), air velocity (m/s), illumination (lux), CO_2 (ppm) and noise level (dBA).

The field research was conducted in the different areas of the selected kitchens during the summer months of January to March 2017 usually in the daytime. A semistructured interview schedule was administered to food production workers, which comprised a series of open-ended questions according to themes. The interviews of workers were conducted concurrently with the field measurements. The questionnaire was distributed to the kitchen managers and head chefs. The third data collection tool in respect of kitchen layout and ergonomic design for all the kitchens was evaluated by nonparticipant observation. Observation can be valuable, especially when photographs are taken, which increases the reliability of observations (Heinzerling et al. 2013).

Questionnaire data and test equipment measurements were analysed using Statistical Package for the Social Sciences (SPSS) version 25. Data analysis was undertaken using descriptive and inferential statistics. Method triangulation was used with the quantitative and qualitative data obtained from the interview schedules, and questionnaires and observation schedules were compared. The statistical tests used for the interpretation of data were chi-square analysis, factor analysis, regression and cross-tabulations. The correlation was used to assess reliability, with scores closer to 1.0 considered more reliable. Multiple logistic regression models were used to define the relationship between multiple variables. The semistructured interview schedule and the questionnaire were pilot-tested before use.

The study was limited to restaurants in Durban with kitchens that used different fuel types. Approximately nine food production workers from each establishment participated in the study. The study was limited to commercial kitchens. Most of the employed staff may not have represented all ethnic groups. Time constraint was a significant limitation of the sample size; the study was conducted among those restaurants that consented to the research study.

To conclude, Chapter 1 summarised the core findings to be inspected, made final deductions based on the analysis and interpretation of data and recommended how to improve environmental ergonomics in kitchens for the well-being of kitchen workers. Although the study was confined to the City of Durban, the findings are of general importance to almost all commercial kitchens in South Africa.

Chapter 2

Heat and thermal comfort

2.1 Heat balance model

This chapter discusses the heat balance model (HBM) and the more recent heat adaptive model (HAM) on the human ability to cope with heat, which has led to changes in world standards regarding indoor thermal comfort. The chapter will examine the effect on thermal comfort of individual factors such as age, gender, fitness, acclimation, behavioural modification and ethnicity. The two fundamental approaches to facilitate the examination of thermal comfort (Alexandru, Vartires & Angel 2016) apply to all indoor work environments, including commercial kitchens. The discussion that follows will present each of these approaches separately and highlight the relevance to kitchen environments.

The approach in the assessment of the thermal environment is centred on the heat exchange between a human body and the surrounding atmosphere and assumes that occupants are passive and have no influence on their heat environment condition (De Dear 2004). The predicted mean vote (PMV) advanced in Fanger's (1970) formative work best explains the HBM. The classic steady-state model predicts the mean thermal sensation of a group of people and their respective percentages of dissatisfaction with the thermal environment. While the measure may be useful in kitchen design, personal differences make it difficult to specify a thermal environment that

How to cite: Gangiah, S 2022, 'Heat and thermal comfort', in *Environmental ergonomics Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town, pp. 9–40. https://doi.org/10.4102/aosis.2022.BK346.02

will satisfy everybody. The ‘acceptable thermal room climate’, according to the International Organization for Standardization (ISO) Standard 7730, is reasonable for 80% of persons. A percentage of the occupants can always be expected to be dissatisfied, and this is termed as predicted percentage dissatisfied (PPD).

Qiu, Hodder and Havenith (2020) reported that criteria for the evaluation of thermal comfort (American Society of Heating, Refrigerating and Air-Conditioning Engineers [ASHRAE] Standard 55, ISO 7730) are used universally for all people irrespective of their ethnicity, nationality or country of origin. The ASHRAE Standard 55-2013 recognises that there is a variation in thermal comfort during winter and summer within the same geographic area, but it does not reflect the dissimilarities in thermal preference of people of diverse ethnicities. Hansen et al. (2013) raised the issue of neglect of the effect of the interaction between climate and ethnic diversity. Ilardo and Nielsen (2018) claimed that there is a neglect of the human ability to adapt to extreme environmental conditions. However, in the context of the HBM, Nicol and Roaf (2017) found that the ASHRAE considered people to be comfortable if room temperatures are kept within a narrow range of 20 °C to 24 °C. The authors are critical of the lack of consideration of the behavioural, attitudinal or psychophysiological aspects of human interactions with each other, the buildings and the management of environments to sustain individual comfort.

International comfortable room temperature ranges from 20 °C to 24 °C inside buildings, according to the European Standardization Organization (*Comité Européen de Normalisation* [CEN]) and ASHRAE. The more extreme the climate, the larger the HVAC plant needed to target these temperatures in buildings (Nicol & Roaf 2017), and the HBM considers opening windows unnecessary, triggering downstream impact on IAQ and the quality of life of the building occupants. They additionally criticise the possible zeal for energy-saving among building designers that fails to give due recognition to the impacts of poor ventilation. Roaf (2020) asserted that buildings should have at least a few operable windows and living spaces in natural ventilation (NV) mode. Ghaffarianhoseini et al. (2018) reported that the consequent effect of SBS symptoms and health inside buildings in the United States of America (USA) results in average office workers taking short-term sick leave. Low productivity and absenteeism at workplace caused by SBS is from inadequate lighting, ineffective ventilation, humidity, and thermal discomfort (Kaul, Khandelwal & Suthar 2022).

From another line of investigation, Simone et al. (2013) explicitly stated that the standard PMV–PPD index for thermal comfort used in workplace environments cannot be practical in commercial kitchens because of the combination of high activity levels and ambient and radiant temperatures. Hence, the HBM model is irrelevant to commercial kitchens. Arens et al. (2020) criticised that Section 5 in ASHRAE Standard 55 is a steady state and does not relate to a change in an individual's experience because of movement or activity level. This implies that PPD is invalid for kitchen workers, who are constantly moving while working in kitchens. Consequently, temperature perception can be overestimated by 2.1 °C and underestimated by 3.4 °C because of a decline in the occupants' psychological dimensions and sociocultural aspects (Rupp, Vásquez & Lamberts 2015). However, the calculated values of the thermal comfort indices (PMV, PPD, and SET) by Alam, Sharma, and Salve (2022) for different cooking periods were found greater than the ASHRAE-55 standard. Cooks were not content with the kitchen environment, as 88% expressed dissatisfaction with the thermal environment and the cooks' perception vote (TSV, TCV) did not follow the central three categories of votes (+1, 0, –1).

Sociocultural aspects influence heat stress perception in the workplace (Messeri et al. 2019). This model fails to demonstrate reliable and accurate conclusions for indoor thermal comfort (Yang et al. 2015). Wang and Hong (2020) criticised ASHRAE Standard 55 and ISO Standard 7 730, which use the PMV/PPD model or the adaptive comfort model based on obsolete data.

Even after the most recent modifications to thermal comfort standards, Fanger's (1970) PMV model is still the authorised instrument to calculate thermal comfort (Van Hoof 2008). The PMV model, which has three central sets of the ASHRAE 7-point scale of thermal sensation, is not completely valid. Fanger (1970) also stated that it is impossible to predict thermal comfort for individuals exactly, and it is irrational to presume that all individuals are satisfied within a centrally controlled environment, even when the thermal conditions meet the present criteria. These findings lead to the adaptive model and cause an important paradigm to shift away from the HBM for the aged. Forcada and Tejedor (2020) reported that the PMV–PPD model for the elderly is inaccurate when compared with HAM. Kulve et al. (2020) found that the PMV model for children seems to indicate that the experience of warmer thermal sensations in school was different from what they experienced, and there is an apparent inconsistency between how adults and youngsters perceive thermal comfort.

Furthermore, Cheung et al. (2020) concluded that the precision of PMV in forecasting observed thermal sensation is low (34%), which means that thermal sensation is erroneously predicted by 60%. Furthermore, there is a need to advance precise thermal comfort models, as ventilation strategies, building types, and weather influence the PMV–PPD accuracy.

2.2 Heat adaptive model

Unlike HBM, a heat-adaptive approach assumes that occupants are active and adapt to the thermal environment. Babu and Suthar (2020) state thermal comfort is affected by several elements, such as behavioural and cultural aspects, space layout, personal control, thermal experience and preferences. The adaptive model allows occupants to feel comfortable in a wider range of conditions than those in the PMV index (Frontczak & Wargocki 2011).

Individual variations also influence thermal comfort in attitude and social factors (Djongyang, Tchinda & Njomo 2010). Nikolopoulou (2011) added that people's behavioural, physiological and psychological adaptations are based on familiarity with heat, time of year, weather conditions, culture and lifestyles that include building design, building function, genetic factors and acclimatisation. Sanjog, Patel and Karmakar (2013) observed an increase in productivity and contentment of the occupants resulting from improved thermal comfort and workers' perceived ability to control the environment. This perception could be because of a psychological influence (Luo et al. 2016). Nicol (2020) established that the thermal comfort experiences of residents of one city in a nation could be drastically dissimilar to diverse habitations or climatic zones, and hence it is better to recognise the actual thermal preference for every major ethnic group.

Yan et al. (2020) claimed that people living in hot-arid regions have high heat resistance capacity. The authors surmised that comfort ranges vary from 22 °C to 27 °C in Brazil, 24.6 °C to 28.4 °C in Madagascar, 19.6 °C to 28.5 °C in India and 27.1 °C to 29.3 °C in Singapore, and Mexicans can withstand temperatures over 30 °C in hot-humid regions. In hot-arid regions, the comfort range in Hyderabad, India, ranges between 26 °C and 32.45 °C, while residents of Turpan accept temperatures reaching as high as 34 °C. Meanwhile, people living in the arid conditions of Mexico can stand high temperatures exceeding 35 °C, even if they do not have an air conditioner. Hitherto, simulated studies by Meese et al. (1984) in South Africa of male and female subjects from major ethnic groups found that the best performance for many tasks was in an environment with an air temperature of 32 °C (range of 20 °C to 38 °C) and relative humidity of 25%.

The HBM discourages NV, while the HAM enables NV; there are, nonetheless, International Comfort Standards for both, and these are presented later in this chapter. Holzer and Stuckey (2020) suggested that building designers must widely apply the adaptive comfort scale in naturally ventilated buildings. Ozarisoy and Altan (2021) developed a framework to optimise occupant thermal comfort to explore the influences of environmental parameters in subtropical Cyprus. The authors criticised HBM and recommended HAM, as 80% of the study respondents were slightly comfortable in a temperature ranging from 28.50 °C to 31.50 °C. The existing adaptive standards are not applicable to hot-arid regions (Yan et al. 2020).

According to Zuhaib et al. (2018), physical and personal variables affect thermal sensations. The personal variables are clothing insulation and activity level. The authors added that the human body's physiological and psychological responses to the environment are active and incorporate various physical phenomena that interact with the space, including heat, humidity, visual comfort (VC) and acoustics.

The absence of local discomforts such as draught, lack of too-high reflected heat asymmetry and absence of high vertical temperature differences can provide thermal comfort to workers. The comfort temperatures in the HAM have a much wider range. People adapt to the temperatures within buildings, and they adapt the buildings to suit their thermal preferences (Zuhaib et al. 2018). However, Cheung et al. (2020) proposed that attaining a high occupant satisfaction for certain IEQ factors is more difficult than other factors. Indraganti (2020) found that Asian women are more likely to be dissatisfied with thermal comfort perception, IAQ, lighting and noise level than men; an attitudinal change in the design of personal controls for women can enhance their satisfaction with various environmental parameters.

Rajasekar and Ramachandraiah (2010) argued that 'factors like age, thermal expectation, economic status and experience with thermal comfort play a significant role in determining comfort perception'. Rissetto, Schweiker and Wagner (2020) verified that previous experiences in a hot environment affect thermal expectation, and attitudes and values towards technology such as a ceiling fan may impact on behavioural adaptation. Guevara, Soriano and Rodriguez (2020) found that students react to heat using comfortable clothing, the experience of the climatic conditions and expectations that help to develop an adaptation to the local environment.

Sanjog et al. (2013) posited that researchers have significant disagreement on whether criteria based on laboratory experiments apply to buildings with NV. In the context of kitchen design, a good building design and conditioning of space with heating, cooling and ventilation achieves thermal comfort (Alfano et al. 2014). Kim, Walker and Delp (2018) concluded that different parts of a building could have widely varying warm spots, and even in the same settings, individuals favour different temperatures. Olesen (2020) analysed IEQ for air-conditioned buildings where the range of thermal preferences was estimated from the HBM, and in NV buildings, the HAM was used to define the boundaries of the comfort zone.

■ 2.3 Heat indices in occupational settings

'There are increasingly severe limitations on human activity in tropical and mid-latitudes during peak months of heat stress' with continued global warming (Dunne, Stouffer & John 2013). In order to calculate the anticipated repercussions from human action, manufacturing and security forces specify a standard for regulating work during a typical 8-h shift to reduce the risk of overheating and its effects.

The international standards that set the parameters for the evaluation of thermal comfort enjoy universal consensus. These are specified in:

- Standard ISO 7 730 (BSI 2005) for the HBM.
- ASHRAE and American National Standards Institute (ANSI) Standard 55 (ANSI & ASHRAE 2010).
- CEN Standard 15 251 (BSI 2007).

The two latter standards include versions of the HAM (Rupp et al. 2015). The amended ANSI–ASHRAE (2010) standard appears to be better suited to the kitchen. The standard specifies the combinations of six indoor thermal environmental factors and personal factors that will be acceptable to most of the occupants within the built space and can vary in time (Lin & Deng 2008).

These standards fail to address nonthermal environmental factors such as IAQ, acoustics and illumination that affect comfort in commercial kitchens. This book attempts to investigate some of the above-mentioned factors that could affect thermal comfort in Durban kitchens.

ISO 7 730 presents a thermal sensation scale to quantify people's thermal sensation within a built environment (Parsons 2009). However, Simone et al. (2013) disagreed with the suitability of the scale, as kitchens can be very hot. Although the 7-point thermal sensation scale has been used extensively, its appropriateness is restricted by establishing a one-dimensional relationship between physical parameters of indoor environments and subjective thermal sensation (Schweiker et al. 2017). The scale, which ranges from hot to cold, allocates indices from +3 to –3. The index assumes that people voting +2, +3, –2 or –3 on the thermal sensation scale are dissatisfied (Zuhaib et al. 2018). ISO 7 730 has been criticised because of its lack of theoretical validity (Parsons 2001), and it does not adequately describe comfortable conditions. The PMV–PPD index was developed for temperate Western conditions. The standard notes that deviations may occur because of ethnic and geographic dissimilarities and sick or disabled people, and excludes children. Indoor spaces with steady-state thermal comfort or mild anomalies from comfort are covered by the standard. This allows for interpretation and judgement. The European (EN) ISO 7 730 accepts the criteria for the PMV model guidelines in the thermal sensation scale (Olesen 2007). This standard was last reviewed and confirmed in 2015 and remains current as per Technical Committee: ISO/TC 159/SC 5 of ergonomics of the physical environment.

Regulation guidance on working temperatures in commercial kitchens appears to be elusive. The Health and Safety Executive of the United Kingdom (UK) (Health and Safety Executive [HSE] 2013) holds responsibility for regulation and contributes information about the risks of overheating when working in hot conditions; it does not address issues of thermal comfort in the workplace. In heat-stress environments such as bakeries and catering kitchens, thermal comfort remains an issue all year-round, more particularly during summer when there is a greater threat of heat stress for labour. A meaningful maximum figure cannot be given because of the high temperatures, such as those at bakeries.

The HSE (1997) stated that 'the temperature in workrooms should be at least 16 °C or 13 °C if much of the work involves rigorous physical effort'. It seems that these standards are applicable to temperate climates and are not suitable for countries with tropical or semi-tropical climates. The EN15251 permits workplace operative temperature in winter to range from 18 °C to 23 °C and 22 °C to 27 °C in summer (Olesen 2015). The South African Weather Services (2020) reported a wide temperature range in Durban, with midwinter temperatures from 16 °C to 23 °C (60 °F to 74 °F) and midsummer temperatures from 28 °C to 33 °C (82 °F to 91 °F).

The heat stress index (HSI), according to Parsons (2011), incorporates the effects of the environmental parameters in any thermal environment in a manner such that variations in thermal conditions will affect its value. The HSI indicates heat exposure and boundaries for safe temperatures. The determination of this index will contribute to kitchen design. HSI is categorised into rational, empirical and direct indices (Epstein & Moran 2006). Rational indices emerge from data concerning the heat balance equation; empirical indices are based on physiological responses from human responses such as sweating. Direct indices of HSI are established with the dimensions of environmental parameters such as wet-bulb globe temperature (WBGT), relative humidity (RH) and airflow (Roghanchi & Kocsis 2018).

■ 2.4 Wet-bulb globe temperature

Wet-bulb globe temperature was adopted by the World Health Organization (WHO) and the American College of Sports Medicine (ACMS) to provide alerts related to the prevention of heat injuries (Kumar & Sharma 2022). The WBGT, as per ISO 7 243, is widely prevalent in determining the direct HSI that incorporates heat, humidity, airflow and heat radiation (Havenith & Fiala 2016). Research work in kitchen environments has long used this measure (Rabeiy 2018). WBGT is by far the most widely used HSI throughout the world for describing environmental heat stress (Epstein & Moran 2006).

Based on the WBGT index, the American Conference of Governmental Industrial Hygienists (ACGIH), as per Spellman (2006), published the permissible heat exposure threshold limit value (TLV) that refers to temperature settings at which all employees can be frequently subjected to without any ill health. This criterion was also adopted by the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), the American Industrial Hygiene Association, the American College of Sports Medicine and the US Army (Taylor 2006).

The WBGT gained popularity owing to its simplicity and convenience of use. WBGT can be measured in extreme heat. The coefficients in this index – air temperature, black globe temperature and natural wet-bulb temperature – are calculated empirically, and the index is used universally as a safety index for workers in various occupations (Epstein & Moran 2006). WBGT is used widely for the evaluation of heat in commercial kitchens by several authors, including Alam, Arunachalam and Salve (2019). As per the Canadian Centre for Occupational Health and Safety and NIOSH, this technique reveals physiological reactions to temperature by the human body (Jacklitsch et al. 2016). The international standard limit of the WBGT is around 27 °C, and the specification is conditional on the basic metabolic rate (BMR), acclimatisation state and clothing (ANSI & ASHRAE 2010).

The discomfort indices (DI) is a significant matrix that evaluates the heat perception in humans for various climatic conditions (Xu et al. 2017). According to the Department of Environmental Affairs (South Africa), the effect of heat stress on a worker is evaluated by considering the combined effect of temperature and humidity (South African Weather Services 2020). The formula to calculate the discomfort index is:

$$(2 \times t) + (RH/100 \times t) + 24 \qquad \text{[Eqn 2.1]}$$

where t = dry bulb or air temperature in degrees celsius and RH = per centage of relative humidity. This index gives guidance on the degrees of discomfort:

- 90–100: very uncomfortable
- 100–110: extremely uncomfortable
- 110 and more: hazardous to health.

These measures formed the basis of the interpretation of discomfort experienced in Durban kitchens. Other indices such as heat index (HI), humidex (HX) and universal thermal climate index are valid for outdoors only. Table 2.1 indicates the South African limit for heat stress for mining workers.

Havenith and Fiala (2016) proposed the concept of apparent temperature (AT), which is a measure of discomfort from combined heat and humidity. A simplified hot weather version of the AT, known as the HI, is used by the National Weather Service in the US and emphasises that heat indices are only valid for shady areas.

Heat index and humidex are direct indices empirically derived from air temperature and humidity to convey a 'feels like' temperature to the public (Havenith & Fiala 2016). Humidex is used in Canada for public heat stress assessments. The relationship between humidex and comfort is subjective, and technically, it cannot be directly compared with WBGT. This index, flawed and imperfect from a scientific point of view, does not consider factors such as strong winds and whether the person is walking in the sunshine, which significantly increases how hot the person feels (Manuel 2021). Humidex very

TABLE 2.1: References for South African 'limits' for heat stress.

Category	Temperature range	Interpretation	General action
A: Abnormally hot	WB ≥ 32.5 °C or DB ≥ 37.0 °C	Unacceptable risk of heat disorders	Work may be undertaken only based on globe temperature ≥ 37.0 °C, expert risk assessment, supervision and protocols.
B: Considerably hot	29.0 °C ≥ WB ≤ 32.5 °C and DB ≥ 37.0 °C	Potentially conducive to heat disorders	HSM mandatory. Globe temperature: as for DB.
C: Slightly hot	27.5 °C ≥ WB ≤ 29.0 °C and DB ≤ 37.0 °C	Potentially conducive to heat disorders	HSM mandatory. Globe temperature: as for DB.
D: Acceptable heat	WB ≤ 27.5 °C and DB ≤ 32.5 °C	Risk of heat disorders negligible	No special precautions. Environmental monitoring globe temperature: as for DB; it must be sufficiently sensitive to detect critical upward drifts in the environmental heat load. The monitoring program to satisfy this requirement should be specified.

Source: Adapted from Webber et al. (2003).
Key: WB, wet-bulb; DB, dry bulb; HSM, heat stress monitor.

often leads to the underestimation of the workplace dangerousness, and it has poor reliability of comfort prediction when it is used in indoor situations (Alfano et al. 2011).

2.5 Climatic factors and heat stress

Regarding climatic heat factors for South Africa, temperatures are projected to increase at twice the global rate (Engelbrecht et al. 2015). Kjellstrom et al. (2014) predicted that the temperature might rise by 2 °C to 4 °C during hot periods, and this alters 'the occupational heat from "low risk" to "moderate or high risk" in most of South Africa'. However, no South African city has a specific heat risk plan because of limited research and institutional capacity, unclear responsibilities and legislative mandates (Nana, Coetzer & Vogel 2019). In other tropical and subtropical zones, climate change and global warming are aggravating conditions (Lundgren & Holmér 2013), with high temperatures and high humidity typical in these locations. Such hot-humid conditions observed by Lucas, Epstein and Kjellstrom (2014) create a thermal extreme, as heat loss from the body to the environment becomes challenging, and internal body temperature rises uncontrollably. Paterson and Godsmark (2020) commented that heat poses risks to public and occupational health, even in Ireland and other temperate regions.

Zhang and De Dear (2019) reported that the local climate considerably affects heat sensation. Ncongwane et al. (2021) lamented a considerable gap in understanding heat stress and related collaborations between African countries and international institutions. Paterson and Godsmark (2020) produced a guide for adaptation and mitigation planning and strategies for the public to meet the occupational health challenge of heat in a temperate environment.

However, an undesirable combination of high humidity and high ambient temperatures, characteristic of the tropics, exhibits an urban heat island (UHI) effect. The UHI effect is a phenomenon in which urban areas have higher temperatures than those of nearby rural areas, first observed in London. It impacts largely on the regional climate, energy utilisation, air, soil and water quality, spatial distribution and behaviour of species, and living comfort and health of residents (Liao et al. 2022). The UHI effect contributes to additional heat exposure, thus affecting housing and indoor environments in a complex way (Lundgren-Kownacki et al. 2019). Yamaguchi and Ihara (2020) predicted that heat would intensify in tropical and subtropical regions because of the UHI effect, accelerating autonomic heat loss mechanisms among workers (Schulte & Chun 2009). Xiang et al. (2014) posited that elevated workplace heat levels pose a growing challenge to workers' health and safety.

Jagarnath, Thambiran and Gebreslasie (2020) investigated the heat stress exposure index and social vulnerability index to identify areas of potential future heat stress risk in the Durban metropolitan area, South Africa:

> It is projected to increase and become a future concern, mainly as a function of social vulnerability due to household demographic and infrastructural characteristics and will be experienced in both the rural and inner-city areas of the metro. (n.p.)

Heat stress legislation deliberates on the dangers of hyperthermia when workers are employed in hot workplaces and provides regulations on how to avoid it (HSE 2013). In South Africa, the Environmental Regulations for Workplaces, 1987 by the South African Department of Labour regulate working conditions in heat, where the time-weighted average WBGT index calculated for an hour should not exceed 30 °C in the environment in which an employee works. It specifies that the employer must take steps to reduce the index below 30 °C, and where hard manual labour is performed, the worker should be certified fit to work in such an environment by a medical practitioner. Moreover, an employee needs to consume at least 600 ml of water every hour to acclimatise to working in such an environment. This implies that commercial kitchens with temperatures above 30 °C need to make provision for workers to drink water frequently. Kitchen workers self-reported dehydration symptoms and direct-heat-exposed workers drank statistically significantly fewer cups of water, according to Venugopal et al. (2021) and Saif Eldin et al. (2022).

Zlatar, Sa-Ngiamsak and Macêdo (2022) proved that there are six basic factors to consider in heat exposure: air temperature, radiant temperature, RH, air movement, metabolic heat production and clothing. Studies on human exposure to different thermal environments should consider, apart from the basic factors, several other variables that influence heat stress response, such as human physical characteristics (for example, body mass index, age, gender, ethnicity, illness history and medication intake) and acclimation of the participants. In the past, OSHA (1970) asserted that age, body weight, physical fitness, degree of acclimatisation, BMR, use of alcohol or drugs and medical conditions affect a person's sensitivity to heat, including the type of clothing worn.

A heat-related illness (HRI) occurs when there is an increase in the worker's core body temperature above 37°C. As individual susceptibility varies, it is difficult to predict how the heat will affect workers. The act claims that although heat hazards are common in indoor and outdoor work environments, HRI and fatalities are preventable. The OSHA declares that DB temperatures of less than 33 °C are low risk, whereas in South Africa it is 32.5 °C outdoors (Webber et al. 2003).

Heat stress is a significant risk for employees, especially kitchen workers in the hospitality sector. A kitchen's hot and humid environment has a cumulative health effect on the well-being and productivity of the cooks that could hinder thermal comfort (Alam et al. 2022). Extreme contact with heat conditions can cause HRI (EASHW 2008a), and prickly heat (rash) and dizziness are the early indications of heat strain. If heat stress is not recognised and treatment is not provided, it can have severe effects on the body, such as heatstroke, exhaustion, cramps, heat syncope and death. Heat can also increase workers' risk of injuries resulting from perspiration, clouded safety goggles and dizziness, and it may reduce brain function responsible for reasoning ability, which may create additional hazards (NIOSH 2015). Hansen et al. (2018) reported that the minor symptoms include a worker looking pale, feeling tired and distressed, and experiencing headaches, muscle fatigue, exhaustion and fainting. Serious cases include individuals being dehydrated, vomiting, losing consciousness or experiencing chest pain. Deaths of workers are reported even after they have pursued medical care (Totsky 2006).

Work-related heat exposure endangers a worker's well-being (Xiang et al. 2014), resulting in impaired work performance and work capacity as well as HRI (Gubernot, Anderson & Hunting 2014). Occupational environments, including hot and humid climates, create a strenuous and potentially dangerous thermal load for a worker. The author adds that heat prevention strategies and international thermal ergonomic standards to protect the worker are developed largely for temperate Western settings, and their validity and relevance are questionable for some geographical, cultural and socio-economic contexts where the risk of excessive heat exposure can be high.

According to Taylor and Cotter (2006), an individual is an active agent interacting with and adjusting to the worker-environment system. However, several studies have raised concerns that HRI is common and may be unreported in the industry (Hansen 2018). It is, therefore, necessary to review the heat adaptations and prevalent practices followed in different occupational settings to comprehend the magnitude and severity of the threats to the workers and industry. The ergonomic and food production literature has established that constant exposure to extreme heat hampers worker productivity (Hossain & Majumder 2017).

Humans are privileged to have an immense capacity to adjust physically, physiologically and psychologically to a broad range of environmental conditions (Nikolopoulou & Lykoudis 2006). Human response to heat is influenced by a range of interactions such as worker demographics, context, environmental interactions and cognition, all of which influence human responses to heat. Schweiker (2020) presented a framework for the human building resilience of occupants because of distinctive aspects like toughness, ability to cope or capacity to recover, all related to adaptation.

The potential impacts of workplace thermal experience are misjudged because of the underreporting of heat disorders (Xiang et al. 2014). Global warming and climate change will unquestionably increase the impact of heat on individuals who work in hot workplaces located in hot climate areas (Lundgren-Kownacki et al. 2019). Workers labouring in tropical locations with hot and humid climates are exposed to thermally stressful conditions that can create HRI (Krishnamurthy et al. 2017). Workers commonly at risk include cooks and bakers as well, who are exposed to extreme heat in the kitchens (Xiang et al. 2014). Kundu et al. (2022) demand that the industry assures a healthy work environment by providing thermal comfort and IAQ for the pantry workers to enable them to perform strenuous job of cooking high volume and quality food for railway passengers.

2.6 Thermal homeostasis and human adaptation

Humans can acclimate to high temperatures because of the ability to perspire (Taylor 2006) and the various thermoregulatory mechanisms in the human body that maintain heat balance. According to Parsons (2009), high heat exposure or heavy work causes heat strain as the core body temperature rises above 37 °C, which can cause malfunction of the human body and progress to death. Sweating without liquid replacement leads to dehydration during heat stress. Kitchen workers can be dehydrated because of inadequate water replacement. Individual characteristics, thermal environment, and task requirements influence an individual worker's ability to work in hot environments.

Pacing to reduce physical activity or frequent breaks reduces the body's internal heat production (Lundgren et al. 2013), called autonomous adaptation to climate change (Kjellstrom, Lemke & Otto 2013). According to Noakes (2011), muscles develop fatigue with use, and the function of the central nervous system is to maintain physiological equilibrium. Reduced work capacity in a hot, humid, noisy kitchen increases stress and negatively affects performance (British Columbia Campus 2020). Paterson and Godsmark (2020) found that older people, chronically ill people, infants, pregnant women, children, outdoor workers, socio-economically disadvantaged people and urban dwellers are vulnerable to heat. There is an increase in heat-related health concerns demonstrating the rising awareness of temperature increase, reinforcing a gap in national policy associated with the communication of and response to the heat-health challenge.

Additionally, longer shifts with strenuous work, without reasonable breaks, could lead to lower productivity (Parsons 2009). However, Zou and Li (2020) strongly recommended that workers take a break at least every 2 h in severely hot environments. In fact, Parsons (2011) showed that every degree celsius rise in temperature above 18 °C means an extra 0.36% of hospital admissions. A WBGT range of 25 °C to 40 °C that occurs at ambient temperatures in the range of 30 °C to 45 °C is typical during the summer in tropical and subtropical climates. At WBGT above 40 °C, it is challenging to perform any physical work. I will now discuss physiological adaptations, genotype, acclimatisation, psychological adaptation and behavioural adaptation.

Hellwig et al. (2020) argued that factors influencing the physiological regulations for heat govern a human body's heat balance and form the basis for steady-state thermal perception models. They are accomplished by behavioural and psychological adaptation and acclimatisation processes. Studies of physiological factors by various authors that affect heat tolerance are listed in Table 2.2. Lambert, Mann and Dugas (2008) presented physiological and morphological differences between groups living in different environmental conditions where variation in birth weight, body shape, composition, skin colour and phenotype are very clear. Under physiological adaptation, factors such as age, gender, height, weight and body-mass index (BMI), fitness and physical activity, years of employment and work experience, job position, worker shift, race and comfortable lifestyle will be discussed.

The individual factors stated by Farnell et al. (2008) comprised fitness level, body composition, age, gender and race, which influence an individual's ability to thermoregulate. Ravindra (2015) added the influence of perceived thermal comfort, such as food and caffeine. Ethnic differences in thermoregulatory responses in exposure to heat by Qiu et al. (2020) indicated that Chinese men preferred higher comfort temperatures than British men.

The next key factor is age. Soebarto et al. (2020) posited that the elderly are vulnerable to heat, and younger people acclimatised better than their older counterparts. Van Hoof et al. (2017) argued that the current models for assessing thermal comfort are not sufficiently accurate for older adults, as many factors related to thermoregulation are impaired in older adults.

TABLE 2.2: Studies of physiological factors affecting heat tolerance.

Factors	Authors
Age	Taylor et al. (1995)
	Kalkowsky et al. (2006)
	Farnell et al. (2008)
	Banwell et al. (2012)
	Hansen et al. (2013)
	Lundgren et al. (2013)
	Deschenes (2014)
	Van Hoof et al. (2017)
Gender	Farnell et al. (2008)
	Haruyama et al. (2010)
	Mathee et al. (2010)
	Lundgren et al. (2013)
	Xiang et al. (2014)
Fitness	Hanna and Brown (1983)
	Carter et al. (2003)
	Farnell et al. (2008)
	Hansen et al. (2013)
Body fat and physical activity	Hanna and Brown (1983)
	Farnell et al. (2008)
	Bedno et al. (2014)
	Parameswarappa and Narayana (2014)

Regarding gender, Alshaikh and Alhefnawi (2020) found that women are less sensitive to hot temperatures than men; sensitivity to humidity and airflow does not differ between genders (Zhang & De Dear 2019). Kumar, Jain and Mathur (2020) found that women have about a 1.5 °C higher comfort temperature than men.

Gender differences in heat loss thermo-effectors are explained by morphological variations in the ratio between body surface area and mass between men and women (Notley et al. 2017). Anderson et al. (2022) proved that gender-based differences in core temperature response are likely because of differences in body morphology and metabolic heat production. Lundgren et al. (2013) contended that women show better tolerance to humid heat than men, whereas men have enhanced tolerance for extremely hot and dry environments, which is likely to be attributed to the lower sweat rate of women (Xiang et al. 2014). According to Devlin (2017), women have a lower BMR than men, and the skin temperature of women tends to be lower. In general, women are more sensitive to cold conditions (Van Hoof et al. 2017).

Beyond this, height, weight and body mass index also play a role in adaptation to heat. According to Hillis (2018), BMI reflects health and fitness levels, with height being an essential component of BMI. The taller a person is, the greater his fitness and BMI, weight being constant. A short person should maintain a lower weight to improve his BMI. Habibi et al. (2016), in respect of weight, observed a higher risk of heat strain in overweight subjects. Workers at greater risk of heat stress included those who are overweight, as per NIOSH (2015). While kitchen workers with higher socio-economic status are more likely to be obese (Najafi et al. 2020), shift times of kitchen work render kitchen workers susceptible to raised BMI. Rupp, Toftum and Ghisi (2020) found that overweight occupants are more likely to express warm discomfort than non-overweight occupants. Lipczynska et al. (2020) found that the overweight and obese participants preferred lower temperatures compared with normal-weight and underweight participants.

A majority of food preparation and serving workers are obese, at 52.2% (Gu et al. 2014). Adopting the WHO definition of obesity when BMI is > 30, Rabeiy (2018) reported that only 16% of the bakery workers in Egypt are obese. Eighty-two per cent of the women and 36% of men aged 35 to 70 years in Langa, South Africa, are overweight or obese. Okop et al. (2016) claimed that South Africa has a high burden of obesity in this age category. Cois and Day (2015) stated that the overall mean BMI is 26.8 kg/m^2, with 42.1% of South Africans within the normal BMI range. Women have a significantly higher mean BMI (29.0 kg/m^2) than men (23.9 kg/m^2).

Besides BMI, fitness and physical activity are also crucial to heat adaptation. Schuster et al. (2017) proved that age as the most common risk factor is outperformed by fitness as a dominant risk factor. The potential of health and fitness to reduce urban heat stress risk could be an effective heat adaptation strategy. While Lisman et al. (2014) reported that higher cardiorespiratory fitness is associated with heat tolerance, Tuomaala et al. (2013) found that individual fitness seems to cause a substantial increase in thermal sensation index values. Smit, Wilders and Strydom (2011) added that physical inactivity and unfitness could lead to health problems. An inverse association is found between BMI and physical activity in China (Fan et al. 2015). D'Souza et al. (2015) mentioned that female obesity is highly dependent on race and ethnicity.

Years of employment and work experience can help in heat adaptation. Daily routine activities involving physical activity in the ambient heat lead to partial seasonal acclimatisation that improves population heat tolerance (Hansen et al. 2011). Acclimatisation may therefore be the primary component of the human coping mechanism for environmental heat exposure. Lundgren-Kownacki et al. (2019) suggested adopting a systematic heat exposure regime to induce acclimatisation. Singh et al. (2016) shared a view in respect of kitchen employees being given time to adapt to the workplace prior to taking up the job. The thermal adaptation of workers may be underappreciated (Masuda et al. 2019).

In addition, job positions can be a deciding factor for heat exposure among kitchen workers. Most executive chefs primarily handle administrative tasks and may spend less time in the kitchen (Truity 2017). Extreme heat-generating equipment is one of the perils that cooks navigate in their daily work environment (Laiskonis 2016), as in the case of a prep cook or line cook. For the same reason, a cook's occupation is considered the third worst job in America (Galarza 2015). Dishwashing and cleaning assistants are exposed to humid heat, as hot water generates humidity (Matsuzuki et al. 2013).

Another factor not given its due is worker shift. Desynchronisation of the biological clock triggered by extreme exhaustion and sleeplessness are common among shift workers and can lead to undesirable effects such as poor work performance, accidents at work, nonattendance, reduced quality of life and signs of depression (Richter et al. 2016). Moreover, working in rotating shifts can contribute to poor health, especially in the elderly and women. Bonnell et al. (2017) identified several dietary-specific shift-related issues that led to an increase in unhealthy behaviour among fire-fighting shift workers. Professional cooks spend longer time in multistation kitchens, especially as the working hours are often irregular (Marć et al. 2018). The workers' shifts affect their heat exposure (Flouris et al. 2018).

Race and a comfortable lifestyle seem to affect heat adaptation. The role of ethnicity appears debatable in the context of human heat adaptation. Schneider (2016) claimed that within each race, there is considerable variation among individuals in their sensitivity to heat and in their ability to acclimate. Race and place remain intertwined in assumptions about the way human bodies respond to their environments (Heggie 2019). The comfort of workers at the household level where they rest helps reduce the health impacts of heat (Frimpong 2015). Zander et al. (2015) claimed that hot sleepless nights might reduce productivity the following day.

The genotype and phenotype of an individual also play an important role in thermal adaptation (Chevin & Hoffmann 2017). The predominant current-day meaning of genotype is the set of genes in the DNA that are responsible for a particular trait. The phenotype is the physical expression and behavioural traits of the organism, for example, size and shape, metabolic activities and patterns of movement (Taylor & Lewontin 2017). Examples of genotypes are the genes responsible for eye colour, hair colour, height, the shape of the nose, and skin colour. To better adapt to an environment, natural selection will favour people with different skin colours, skin types, hair types and numerous other characteristics. The genotype factors to be discussed are skin colour, hair type and type of nose. A list of authors on ethnic adaptation to heat is given in Table 2.3.

TABLE 2.3: Ethnic adaptation to heat.

Factors	Authors
Skin	Thompson (1954)
	Roberts (1977)
	Jablonski and Chaplin (2010)
	Meyer (2012)
	Tang et al. (2015)
	Zaidi et al. (2018)
Nasal index	Crognier (1981)
	Collins (1999)
	Church (2010)
	Noback et al. (2011)
	Meyer (2012)
	Holton et al. (2013)
	Patki and Frank-Ito (2016)
	Szalay (2017)
	Zaidi et al. (2018)
Hair	Marshall (2014)
	Eaaswarkhanth et al. (2014)
	Thwaites (2017)

Less frequent in the literature are investigations of the role of skin colour and thermal adaptation. White skin has greater potential to experience severe sunburn damage, disturbing the functioning of sweat glands and thus heat regulation. The Fitzpatrick scale included skin types I–IV (moving from 'light, always burns' to 'dark, never burns') but was later modified to include darker skin types V and VI (Tang, Heath & Silverberg 2015).

Okada (2020) claimed that skin colour does affect body temperature, as melanocytes, a type of skin cell that stimulates melanin production, have a major impact on the skin's heat sensitivity. According to Powell (2017), it may seem that black people do not blush simply because their darker skin tone hides it. Flushing is an indicator of heat discomfort and probable heat stress (Gao et al. 2018) or being too hot (Villines 2018). It, therefore, seems that the heat discomfort of dark-skinned people may be ignored, as they do not show visible heat stress symptoms in hot kitchens. According to Handzlik (2018), skin colour adaptation is not enough for survival in hostile environments.

To better adapt to an environment, natural selection will favour people with different skin colours, skin types, hair types and numerous characteristics. Eaaswarkhanth, Pavlidis and Gokcumen (2014) noticed that changes in specific genes responsible for keratin structure played a significant role in the final shape of an individual's hair. With temperature as a factor, curly hair has a protein called trichohyalin that primarily influences hair curl. Those with curly and coiled hair, as well as darker skin and wider noses, are scientifically linked to the continent of Africa, where the climate is hot. Curlier and drier hair types are beneficial in hot climates.

Hair contributes to protection against direct sunlight, absorbs water and sweat, and provides a cooling effect. Straight and oily hair in hot climates would be vulnerable to scalp burn and overheating (Marshall 2014). Thwaites (2017) expressed that Afro-textured hair evolved as a defence against sunlight to protect the scalp from harmful ultraviolet (UV) light.

A further genotype affecting heat dissipation is the individual nasal index. Variations in the nasal index are reported to represent an adaptation to climatic conditions (Patki & Frank-Ito 2016). Zaidi et al. (2018) claimed that the nose shape might be a local adaptation to climate, as the width of the nostril is strongly correlated with temperature and humidity. Wider noses are more common in warm and humid climates, while narrower noses are usually found in cold and dry environments. The marked diversity of nasal shapes among living human populations has long been considered a consequence of adaptation to a wide range of climatic conditions for optimising respiratory heat and humidity exchange in the nasal mucosa (Yokley 2009). Unlike in excessively dry and cold environments, aquiline or 'beak-like' noses are adaptations to cold, as they provide a larger region for air to be warmed and humidified before being transferred to the lungs (see James 2010).

Acclimatisation refers to the adaptive changes within an organism occurring in response to its natural climate and can occur in both the short term and long term (Zhang & De Dear 2019). Accordingly, Lundgren-Kownacki et al. (2019) suggested adopting a systematic heat exposure regime to induce workplace acclimatisation. Heat acclimation is essential for heat safety and physical performance enhancement in warm-to-hot conditions (Pryor et al. 2019). Malgoyre et al. (2020) reported that naturally, heat-acclimated soldiers have a higher level of heat tolerance during exercise in the heat. Buonocore et al. (2020) reported that occupants from tropical climates seem to be more tolerant of the warmest thermal sensations than subtropical climate occupants in Brazil.

The next adaptation to heat is psychological adaptation. Nikolopoulou and Lykoudis (2006) offered three distinctive psychological adaptive processes: firstly, habituation that includes naturalness, experience and period of exposure; secondly, environmental stimulation; thirdly, expectation and perceived control. Critical parameters for satisfaction with thermal environments include individual choice, recollection and expectations. Kumar et al. (2020) found that students having access to the closing of windows and doors and regulation of fan speed to improve their thermal conditions were psychologically adapted to heat. Day, Moore and Ruiz (2020) reported greater thermal satisfaction in hot and humid climate buildings, which may be attributed to the control factor. It allowed occupants to control lights and fans and operate windows and ventilation louvres.

As per Hellwig et al. (2020), another response to thermoregulation is behavioural response; comfort and distress awareness initiates behavioural adaptation. Table 2.4 indicates empirical work on behavioural factors affecting heat tolerance. Culture and genetics are increasingly being thought of as intimately connected, each influencing the natural progression of the other, leading to a 'gene-culture co-evolution' (Goldman 2014). The author further suggests that traditions and cultural practices can influence the path of human evolution. People of different ethnic backgrounds possess different attitudes,

TABLE 2.4: Empirical work on behavioural factors affecting heat tolerance.

Factors	Authors
Social	Budd (2008)
	Hansen et al. (2013)
	Gubernot et al. (2014)
Cultural	McCollough (1973)
	Pool (1987)
	Lambert (1992)
	Brake and Bates (2002)
	Hyatt et al. (2010)
	Boyd et al. (2011)
	Cronin-De-Chavez (2011)
	Lundgren et al. (2013)
	Kenawy and Elkadi (2013)
	Goldman (2014)
Economic	Hansen et al. (2013)
	Kjellstrom et al. (2013)
	Lundgren et al. (2013)
	Gubernot et al. (2014)
	Lucas et al. (2014)
	Frimpong (2015)
	Van Hoof et al. (2017)
Health	Tawatsupa et al. (2010)
	Banwell et al. (2012)
	Montero et al. (2013)

values and norms that reflect their cultural heritage (Idang 2015). Variations in thermal tolerance are intensified by ethnicity and cultural differences. Schweiker et al. (2017) were convinced that behavioural adaptation plays an important role in workspaces with and without mechanical cooling.

Van Hoof et al. (2017) found that to achieve thermal comfort, the elderly first adjust their behavioural actions, such as reducing physical activities, staying indoors, wearing cool, light clothing, drinking more fluids and using an air conditioner if possible. New et al. (2020) proposed that workers could wear comfortable clothes with natural fibres. Likewise, according to Fanger's (1970) comfort equation, clothing is a critical factor in thermal comfort. Behavioural adaptation varies with season and needs to be considered to assess perceived thermal satisfaction (Park, Loftness & Aziz 2018).

However, several studies indicate that workers refrain from behavioural modifications. Lucas et al. (2014) added that income and livelihood factors could force workers to ignore psychophysiological indicators of heat strain and work extended hours while enduring longer periods of high temperatures in poor working conditions. Similarly, Gronlund (2014) added that social and economic conditions that affect people are positively associated with their health (Hansen et al. 2013), where persons with poor health are at risk because of heat (Banwell et al. 2012) and are not able to make behavioural adaptations. A preliminary study in Thailand revealed that ill health is widespread, particularly when workers who are exposed to excessive heat cannot cool down. They can experience severe psychological distress caused by heat exhaustion (Tawatsupa et al. 2010) because of limitations on behavioural changes.

Along with personal control, technological adaptation has come to the fore. André et al. (2020) claimed that Roving Comforter (a personal comfort device application) videos escalate users' thermal comfort. These are dominated by the modification of the surroundings that commonly include opening windows and shades, turning on fans or operating HVAC controls. Rissetto et al. (2020) added that attitudes and values toward technology, such as a ceiling fan, may impact behavioural adaptation.

■ 2.7 Kitchen worker risks

Workers are exposed to heat in many workplaces, including kitchens (Zare et al. 2019). Simone et al. (2013) found that the indoor climate in commercial kitchens is often unsatisfactory, and the climate zone can influence thermal conditions in the kitchens. Zhao and Zhao (2018) added that Chinese cooking practices generate a large amount of heat. Chinese cooking, which is characterised by stir-frying and braising, can produce large amounts of heat and cooking fumes during the cooking process, due to intensive cooking equipment and a greater volume of production (Zhang et al. 2022). Welch (2017) documented WBGT ranging from 26.5 °C to 38.9 °C in commercial kitchens. Rabeiy (2018) reported that the heat stress in bakeries reached 31.6 °C, exceeding the TLV of 28 °C.

Alam et al. (2019) reported the cause and effect of discomfort while cooking because of inadequate airflow in railway pantry kitchens. A standard effective temperature (SET) index of 28.6 °C to 30 °C is a comfortable thermal sensation during cooking periods, which is a sustainable improvement in the thermal environment of a 'non-air-conditioned' pantry car kitchen in Indian Railways. Installing four exhaust fans on the front wall of the kitchen and two carriage fans on the roof sequentially reduced indoor temperature, improving thermal comfort (Alam & Salve 2021). Liu et al. (2020) reported that the thermal environment in Chinese residential kitchens was highly non-uniform and too hot in summer. The air temperature could increase by 5.3 °C for cooking two dishes prepared by stir-frying in a typical kitchen. According to recent data, kitchens still have high WBGT readings. As per Saif Eldin et al. (2022) the mean WBGT in the cooking areas was 32.4 ± 1.4, which is higher than the ACGIH's TLV of 28°C. Venugopal et al. (2021) found with an average exposure of 30.1°C (±2.7°C), 66% of workers were exposed to WBGT levels above the safer TLV.

The type and size of cooking equipment affect the heat generated in the kitchen (Mealey 2019). Everyday Health (2017) indicated that cooks prefer the instant heat of liquefied petroleum gas (LPG) stoves. However, Fameke et al. (2022) claim that electricity and LPG were the preferred fuels, followed by natural gas and coal. Although cooks claim that LPG cooks more evenly, gas is the least efficient fuel source for heat transference; up to 60% of the heat produced by a gas burner is wasted as it escapes into the air (Joachim & Schloss 2017). Almost 74% of the energy produced on an electric stove is transferred to food, compared with about 40% in the gas range. Gas cooking appliances will increase the moisture generated, as water vapour is a by-product of gas combustion. Fittings and layout can also affect comfort levels in a kitchen.

The most uncomfortable workplaces in kitchens are near a frying pan, a stove or a grill because of the heat and humidity from the cooking process. Higher levels of humidity are found at the kitchen worker's waist height. An ergonomically correct countertop height varies from 0.76 m (30 in) for a 1.21 m tall cook to 1.07 m (42 in) for a 1.82 m tall cook.

Regarding symptoms of heat stress and heat strain, HRI is a physiological condition that occurs when the body cannot dissipate heat adequately, leading to dysfunctional thermoregulation (Gauer & Meyers 2019). Over-exertion in hot weather, exercising or working in hot, poorly ventilated areas can increase the risk of heat stress (Better Health Channel 2020). Roghanchi and Kocsis (2018) claimed that hot and humid environments can cause HRI such as thermal stress, heat cramps, heat rash and heatstroke. Giwa et al. (2022) find that HI assessment of indicated heat cramps and heat exhaustion in the household kitchens of sub-Saharan Africa. A comparative summary of different occupations with heat stress and kitchens is given in Table 2.5; the commercial kitchen section is adopted from Gangiah (2021) and other occupations from Gangiah and Naidoo (2021).

The Electric Power Research Institute identifies the six most common types of major cooking appliances with the likelihood of their applications in various food-service establishments. The researcher observed that these cooking appliances are commonly found in most restaurants in the study area. Haruyama et al. (2010) reported that heat was much higher in LPG kitchens than in electric ones, with mean ambient temperatures of 29.6 °C versus 25.7 °C, respectively. According to Tanaka (2007), the mean WBGT in gas-fuelled kitchens was expected to induce hyperthermia among workers. Overall, the work environment in kitchens using induction cookers was more comfortable and safer than in kitchens with LPG stoves (Wong et al. 2011). Walker (2022) finds that induction stoves are 88% efficient, electric 74% and gas 42% for heating water. As regards bakeries, Rabeiy (2018) reported that the WBGT index in Egypt indicated that the mean value of heat stress in bakeries reached 31.6 °C, exceeding the TLV of 28 °C and action limit of 25 °C recommended by the American Conference of Government Industrial Hygienists as per Spellman (2006).

Appliance use in kitchens is not constant. Zhang et al. (2010) posited that an appliance would not be used daily. Appliances are powered up in many food-service operations as soon as preparation starts. The researchers added that the amount of time each appliance is utilised for cooking depends on the number of meal periods and the number of meals served. Therefore, it is implied that the larger the volume of meals cooked, the higher the use of appliances utilised, increasing heat in kitchens and heat stress risks among food-service workers.

According to Xiang et al. (2014), many ecological studies have revealed that without adequate heat dissipation, extreme heat exposure leads to an increase in core body temperature and results in HRI. Heat cramps, excessive perspiration, headaches, dizziness, tiredness and excessive thirst are all indications of occupational HRI ($p < 0.001$) (Eldin Saif et al. 2022). According to Venugopal et al. (2021), 82% of the exposed kitchen workers reported having heat stress symptoms such as profuse sweating, exhaustion, headaches and adverse renal function. Physical exertion is common among the occupations mentioned in Table 2.5. Exertional heat illness affects the

TABLE 2.5: High-risk occupations and behaviour modification to overcome heat stress.

Source	Location of study	Type of workplace or occupation	Heat-generating factors – temperature at workplace, body heat and PPE	Danger to worker – effect on worker physiology and work	Adaptation adopted	Adaptation recommended
Hunt et al. (2014)	United States of America	Surface mine	Core body temperature 37.46 °C, exertional heat, air temperature and PPE	Dehydration and heat illness leading to heat exhaustion and heatstroke	Consumption of water, tea, coffee, soft drinks and sports drinks	Preventative hydration
Miller and Bates (2007)	Western Australia	Outdoor workers at surface mines	WBGT ≥ 30 °C	Hypohydration reduces productivity and increases the risk of accidents and injuries	Habitual fluid intake	Monitor hydration status. Education on adequate hydration - 1 l/h of cool water or industrial rehydration fluid, consume food at meal breaks to replace electrolytes and maintain energy, limit intake of caffeine, provide shade or increase ventilation.
Kolkowsky et al. (2006)	Germany	Coal mine	Core body temperature 37.7 °C, exertional heat, air temperature, humidity and average PPE weight of 14 kg	Dehydration because of high sweat rates	Increased sweat rates. Acclimatisation permitted for beginners under 21-years-old and over 51-years-old, needs medical approval	Preventative hydration
Donoghue et al. (2000)	Queensland, Australia	Metalliferous mine	WBGT 29°C, exertional heat, humidity and PPE	Dehydration, muscle cramps, heat exhaustion, headache, nausea, weakness, dizziness, clammy skin, rapid heart rate and irritability	-	Increased fluid intake, improved ventilation and air cooling at all sites
Donoghue (2004)	United States of America	Mine	Exertional heat, air temperature, humidity, PPE	Heat illness is greater in dayshifts in summer	-	Self-pacing, training and a medical clinic on-site

Table 2.5 continues on the next page→

TABLE 2.5 (cont.): High-risk occupations and behaviour modification to overcome heat stress.

Source	Location of study	Type of workplace or occupation	Heat-generating factors – temperature at workplace, body heat and PPE	Danger to worker – effect on worker physiology and work	Adaptation adopted	Adaptation recommended
Bates et al. (2001)	Australia	Mine	Outside temperature 40 °C, exertional heat and PPE	Heat strain and dehydration	-	Monitor heat stress index
Shearer (1990)	South Africa	Gold mine	Exertional heat, air temperature, radiant heat from rocks, 55 °C, RH 92% and PPE	Muscle cramps, dehydration and salt depletion, heat exhaustion	Water not palatable all the time, voluntary hydration, education	Heatstroke till 1970, A/C reduces temp from 55 °C to 28 °C. Citrus flavoured tablet or powder, training program, improve ventilation and cooling systems in all areas.
McLellan and Selkirk (2006)	Toronto, Canada	Fire fighters	Body temperature 39°C, air temperature, PPE and self-containing breathing apparatus load	Heat stress	Passive cooling	Fluid replacement and active cooling. Rest and self-pacing. Shorts and t-shirts under bunker pants reduce heat strain.
Kales et al. (2003)	Cambridge, United States of America	Fire fighters	Air temperature and PPE	Heatstroke and heat exhaustion and CHD leading to death		Activities of fire suppression, training and alarm response had higher rates of CHD
Biggs et al. (2010)	South Africa	Forestry workers	Exertional heat from logging wood, air temperature and PPE	Dehydration and hyperhydration and hyponatremia	Water provision, inadequate, inconvenient and inadequate toilet facilities	Rehydration strategies and education
Maeda et al. (2006)	Japan	Forestry workers	Exertional heat from logging wood, air temperature and PPE	Heatstroke in summer. Higher frequency amongst younger persons because of lower adaptation but frequent amongst the elderly because of a decline in thermoregulation capabilities.	-	Isotonic drinks for an efficient source of water and electrolytes. Temporary tents for rest, electric fans for ventilation and automated machine cool drinks.

Table 2.5 continues on the next page→

TABLE 2.5 (cont.): High-risk occupations and behaviour modification to overcome heat stress.

Source	Location of study	Type of workplace or occupation	Heat-generating factors – temperature at workplace, body heat and PPE	Danger to worker – effect on worker physiology and work	Adaptation adopted	Adaptation recommended
Bates et al. (2001)	New Zealand	Forestry workers	WBGT 12.4 °C to 21.7 °C, exertional heat from logging wood and PPE	High metabolic heat, hypohydration or dehydrated	-	Maintain hydration status. Increase fluid intake without caffeine and sugar. Slices of lemon to flavour water, cool in insulated containers and CamelBak fluid carrier.
Stoecklin-Marois et al. (2013)	California, United States of America	Farm workers	Weather conditions, air temperature, radiant heat, humidity and PPE	Heat-related illness and death	-	Potable water, shade, toilets and rest. Training on gender-specific heat-related illness approaches.
Cortez (2009)	Nicaragua	Sugarcane farm workers	WBGT 28 °C to 30.4 °C		Rehydration solution, cool water, 1 l of water before work and 500 ml every 30 min	New rehydration measures improved productivity, with 5.8 to 8 tons of sugarcane cut per worker per day
Mirabelli et al. (2010)	North Carolina, United States of America	Agricultural workers	Climate in summer, air temperature and PPE	Heat illness, fainting, sudden muscle cramps. Heat-related fatalities	-	Change in work hours and activities, drinking more water, rest in shade, air-conditioned places. Reduce workers' environmental heat exposure.
Knowlton et al. (2009)	California, United States of America	Agricultural workers	Air temperature and PPE	Heat wave causes hospitalisation and death	-	Potable water, shade, toilets and rest
Mirabelli and Richardson (2005)	North Carolina, United States of America	Agricultural workers	Summer temperature 90 °F (°C) or higher climate and exertional heat	Heat stress. Heat-related death among Latino and African-American workers, especially young men	-	Medical attention

Table 2.5 continues on the next page→

TABLE 2.5 (cont.): High-risk occupations and behaviour modification to overcome heat stress.

Source	Location of study	Type of workplace or occupation	Heat-generating factors – temperature at workplace, body heat and PPE	Danger to worker – effect on worker physiology and work	Adaptation adopted	Adaptation recommended
Rowlinson et al. (2014)	China	Construction workers	Human factors, metabolic heat and clothing and climate	Heat-induced illness and fatigue	-	Control environmental heat stress exposure, control continuous work time with a mandatory work-rest regimen and self-pacing
Marioka et al. (2006)	Japan	Construction workers	WBGT 23 °C to 34 °C, exertional heat, PPE	Increased blood pressure	Break during work, tents and electric fans, cool drinking water	Restrict work hours, monitor water intake, health education and training
Bates and Schneider (2008)	United Arab Emirates	Construction workers and expatriates	WBGT 28.6 °C, DB 42.5 °C, globe temp (radiant heat) 52.1 °C at noon in summer	Fatigue	-	Adequate fluid intake (2 l of water every 2 h–3 h) and self-pacing
Inaba and Mirbod (2007)	Japan	Construction workers and traffic controllers	WBGT exceeding exposure limit values, WBGT 28.1 °C–32.0 °C (9:00 to 13:00), PPE and uniform	Heat-related subjective symptoms, fatigue, impatience, headache and dizziness	-	Traffic workers sunglasses, cover their face and neck, and change clothes frequently. Improve acclimatisation, work and rest cycle, increase fluid intake, altering clothes frequently, access to A/C places and sunscreen.
O'Connor (2010)	United States of America	Military	Exertional heat, air temperature and PPE	Exertional heatstroke and acclimatisation cannot cope with over-exertion	-	Improved biomarker in testing recovery. Induce acquired thermal tolerance.

Table 2.5 continues on the next page→

TABLE 2.5 (cont.): High-risk occupations and behaviour modification to overcome heat stress.

Source	Location of study	Type of workplace or occupation	Heat-generating factors – temperature at workplace, body heat and PPE	Danger to worker – effect on worker physiology and work	Adaptation adopted	Adaptation recommended
Carter et al. (2008)	United States of America	Armed forces	Ambient temp ≥ 40.0 °C, exertional heat and PPE	Heat illness and heat injury. Fluid and electrolyte imbalances, hyponatremia. Heat exhaustion and heatstroke are higher in infantry soldiers, Caucasians from the northern US and women.	-	Vigilant medical personnel, strategy to identify high-risk personnel
Dang et al. (2014)	Texas, United States of America	Aluminium smelter	Ambient temp 78.0 °F pot room	Heat strain, unacclimatised person core body temp > 100.4°F (38°C), off work for 4 days or more within 2 weeks. Acclimatised > 101.3°F (38.5°C). Blood and urine samples significant.	-	Adequate hydration and acclimatisation
Parameswarappa and Narayana (2014)	Karnataka, India	Steel workers	WBGT 28 °C –34 °C, hot rolling areas, casting platforms, furnaces. Local temp 43 °C, PPE. 50% had discomfort in PPE. Work not suitable for ≥ 50-year-old men.	High core body temp, more than the permissible limit and heat strain	-	Reduced work period, intermittent rest, cool thermals and A/C-equipped rooms
Bates et al. (2010)	Middle East	Manual workers	Construction site workers less hydrated than industrial workers	Inadequate hydration status	-	Pre-work fluid intake, programs to improve hydration and monitor heat in the environment

Table 2.5 continues on the next page→

TABLE 2.5 (cont.): High-risk occupations and behaviour modification to overcome heat stress.

Source	Location of study	Type of workplace or occupation	Heat-generating factors – temperature at workplace, body heat and PPE	Danger to worker – effect on worker physiology and work	Adaptation adopted	Adaptation recommended
Chen et al. (2010)	Hong Kong	Steel workers	WBGT 25.4 °C to 28.7 °C and WBGT 30 °C to 39 °C, electric arc melting and casting	Fatigue and thirst, heat strain and poor reflexes	-	Self-pacing, air cooling, increase fluid intake and preventative drinking before work and provide drinking fluids at work sites
Balakrishnan et al. (2010)	South India	All industries	WBGT 34 °C core body temp 39 °C (reduces by 4 min–5 min per 1°C increase of WBGT)	Tolerance time for heavy work is < 1h, heat stress and reduction in physical work ability because of heat exposure	-	Monitor discomfort, disability to work, work performance
Ayyappan et al. (2009)	Chennai, India	Automotive industry		28% of workers' heat stress	-	Assess the efficacy of heat interventions
Brake and Bates (2003)	Australia	Industrial workers	Environment, WBGT 30.9 °C	Dehydrations, hypohydration before a work shift	Awareness of hydration and consuming lunch and fluids during meal breaks	Urinary specific gravity limits before shift starts = 1.022. Workers exceeding this value were not allowed into the workplace. Improve workforce awareness.
Kjellstrom et al. (2013)	Australia, India, Nepal, Ghana, Thailand, Vietnam, Costa Rica, Nicaragua	All workplaces, pregnant women and children included	DB 37 °C–40 °C	Heat stress, decreased productivity	-	Public message and information on heat exposure and risks
Simone and Olesen (2013)	United States of America; different cities in summer and winter	Kitchen workers	DB up to 41.2 °C (106.1 °F). Heat from cookers, stoves, grillers and humidity from water usage	Uncomfortable environment	-	Opening windows
Li et al. (2012)	China	Kitchen workers	DB varied from 18.5 °C to 54.0 °C in different kitchens. Heat from cookers, stoves, grillers and humidity from water usage	Thermal dissatisfaction decreased productivity	No data	The improved ventilation system in the naturally ventilated kitchen

Table 2.5 continues on the next page→

TABLE 2.5 (cont.): High-risk occupations and behaviour modification to overcome heat stress.

Source	Location of study	Type of workplace or occupation	Heat-generating factors – temperature at workplace, body heat and PPE	Danger to worker – effect on worker physiology and work	Adaptation adopted	Adaptation recommended
Matsuzuki et al. (2011)	Japan	Kitchen workers	WBGT 27.5 °C, DB 22.8 °C. Heat from cookers, stoves, grillers and humidity from water usage	Heat stress, fatigue and dehydration, kitchen workers taking breaks to rest	No data	Recommendation: rest and pacing
Haruyama et al. (2010)	Japan	Kitchen workers	MRT up to 36.4 °C	Thermal strain	No data	Dry floors reduce humidity in the kitchen
Eagles and Stedmon (2004)	London, United Kingdom	Kitchen workers	DB temp 22.8 °C heat from cookers, stoves, grillers and humidity from water usage	No data	No data	Open kitchen windows, install more extractor fans and ventilation hoods
Totsky (2006)	Michigan	Chefs, kitchen workers	WBGT 25.5 °C to 35.7 °C and outside temperature 35.5 °C	Heat exhaustion and heat fatigue	Circulating fans, drink water, acclimated workers	Preplacement screening of susceptible workers, monitor cool drinking water (1 cup every 20 min), use proper clothing, rest in cool place, provide shielding from radiant heat, adequate ventilation, A/C in kitchen, training on symptoms of heat stress and pacing
Logeswari and Mrunalini (2017)	Telangana, India	Cooks, kitchen workers	WBGT 84.2 °F (27.8 °C), mean ear temperature 39 °C, higher than WHO permissible limit	Heat stress	-	Training on heat stress, improve ventilation, loose-fitting clothing, adequate drinking water (5 l per day) and breaks between work

Key: A/C, air conditioner, CHD, coronary heart disease; DB, dry bulb; MRT, mean radiant temperature; PPE, personal protective equipment; RH, relative humidity; WBGT, wet-bulb globe temperature.

lives of security forces, sportspersons and employees and is an incessant cause of illness among the apparently healthy and active population (Carter III et al. 2005).

However, both commercial and non-commercial enterprises often have little incentive to proactively incorporate heat adaptation into decision-making or innovation (Richter et al. 2016). This inertia could be attributable to policy gaps or simply the failure of management to plan long-term. Regrettably, I feel that collective responsibility for safety and human health only fosters a vague sense of duty for individual action. Ncongwane et al. (2021) believed that associating contemporary knowledge gaps through interdisciplinary research funded by local, regional and international bodies will have the greatest impact.

2.8 Capacity for preventative behavioural control measures

According to Ravindra et al. (2019), ambient temperature peaks during the midday hours in summer; cooking at dawn or dusk could avoid creating indoor heat unnecessarily during the daytime and increase occupant thermal comfort.

Dietary changes, hydration, acclimation, clothing and window film will be discussed next. Behavioural control measures aim to diminish exhaustion, maximise endurance and enable sustained activity over the workday. An early study by McCullough (1973) found that biocultural adaptation behaviour among the Yucatan during work in a hot climate prevents heat strokes and heat cramps. The practice of consuming indigenous food with specific heating and cooling effects is also reported in Latin America, Morocco, Southeast Asian countries and India, as per Lambert (1992) and Pool (1987). Most Asians consider certain foods ‘hot’ and ‘cold’. Foods such as cucumber, watermelon, yoghurt, ice-cream and orange are considered cold and consumed to cool the body (Cronin-De-Chavez 2011). It seems that humoral beliefs in South Asian countries are influenced by Ayurvedic medicine, an extremely important concept of maintaining balance in the body. Lundgren-Kownacki (2018) reported that in Chennai (India), buttermilk is widely consumed among workers as a traditional way of mitigating heat strain.

Bates and Schneider (2008) observed mandatory hydration and thermal work limit in the workplace. Kitchen workers are also likely to avoid frequent visits to toilets because of time management issues, as well as hygiene, thus leading to dehydration. This is likely to increase heat strain among cooks, bakers and dishwashers. Nikolopoulou and Lykoudis (2006) also raised the issue of physical adaptation, taking into account changing environmental conditions.

Tian et al. (2011) found that acclimation training could improve the adaptability of the human body to extremely hot environments. Self-pacing, rest and change of work hours are advocated by Miller et al. (2011) to avoid physiological strain by way of work rate adjustments and consequent retention of normal body temperature; work hours should be reduced in extreme environments. Australian Army personnel are recommended to undertake work durations for four repeated bouts of work and then rest when working in extreme heat (Anderson et al. 2022).

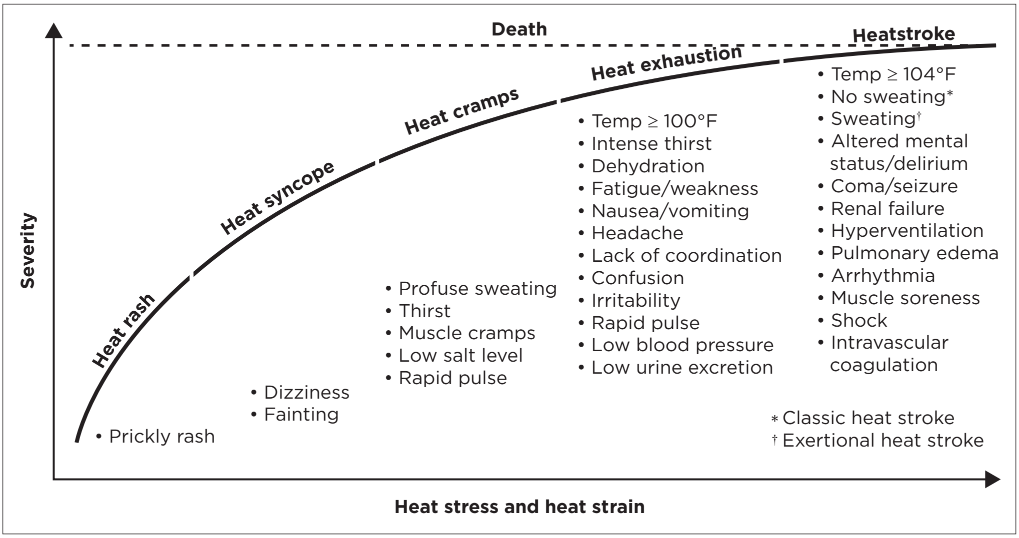
Rijal et al. (2020) demonstrated the scope of human adaptation to deliver satisfactory surroundings by selecting appropriate clothing, keeping windows open or closed and switching on cooling when desired. Another new technique is a heat-rejecting film that reflects 70% of heat from sunlight in a building's windows (Chu 2018) and can reduce heat in kitchens. This film can cover exterior-facing windows, which is embedded with tiny thermochromic microparticles to reduce the building's air-conditioning costs by 10%.

Heat stress can be experienced with the onset of heat rash, dizziness and fainting. When the body temperature increases to 40 °C (104 °F), heatstroke can occur. Abdoulaziz (2020) reported that although temperatures and humidity in a factory are perceived as normal, 86% of the workers reported getting thirsty and drinking fluids. Additionally, several prevention measures were administered at the workplace such as cold drinking water, cool rest areas, additional breaks and electric fans during warm weather days. Even though multiple heat mitigation practices were implemented and followed, employers were still recommended to continue to create awareness by disseminating specific heat-related policies, regulations and regular training on heat stress risk and prevention behaviours.

The review of literature elicits a combination of approaches for HRI prevention. Common in these combinations are practices that encompass:

- monitoring hydration status and preventative hydration, as well as provision of adequate potable, cool water and rehydration fluid
- ventilation and air cooling
- self-pacing and rest in the shade
- change in work hours and activities, as well as restricting work hours
- improving acclimatisation, training, and health education
- monitoring discomfort and work performance.

The WHO (2018) listed the direct (Figure 2.1) and indirect health impacts of exposure to extreme heat.



Key: Temp, temperature.
Source: Adapted from Jackson and Rosenberg (2010).

FIGURE 2.1: Heat stress and heat strain.

2.9 Conclusion

In conclusion, Chapter 2 illustrates that the adaptive heat model refutes ASHRAE's narrow range of temperature for thermal satisfaction. The PMV model appears not to apply to hot environments such as commercial kitchens and bakeries. Physiological mechanisms set limits to the worker's capacity for physical work; fatigue can set in because of hot temperatures in kitchens. Preventing occupational heat stress is especially important in developing countries. The next chapter discusses the significance of ventilation and humidity in commercial kitchens.

Chapter 3

Ventilation and humidity

3.1 Airflow and thermal comfort predilections

This chapter examines the role of ventilation in providing comfortable and productive working conditions and protecting kitchen workers' health. Architectural design can be influenced by several factors, including air circulation and movement. Natural ventilation of buildings can inspire the achievement of breathing architecture (Stavridou 2015). A space to accommodate human life should essentially include air that contributes to the promotion of the well-being of occupants.

Natural ventilation and mechanical ventilation (MV) that affect IAQ include airflow, kitchen space, cuisine and humidity. In the penultimate section, an in-depth examination of air composition affected by cooking processes, fuel, oil, cooking methods, extraction rates, canopy size, filters and capacity of hoods is undertaken. This is followed by a critical look at humidity and its effects in kitchens.

The key principle of ventilation is to provide clean indoor air, produce comfort and prevent detrimental effects on well-being because of contaminated air (Hueda 2020). ASHRAE standards impart evidence on the permissible levels of pollutants in the air, which relates to the health and comfort of building occupants. The introduction of improved energy performance standards leads to a better

How to cite: Gangiah, S 2022, 'Ventilation and humidity', in *Environmental ergonomics Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town, pp. 41–74. https://doi.org/10.4102/aosis.2022.BK346.03

insulated, and more airtight building; natural and decentralised building ventilation systems provide good air quality. Osaro, Cookey-Gam and Iyerefa (2022) prove that NV and MV systems can be equally efficient for pollution control. Natural ventilation cools the area, lowers humidity and promotes thermal comfort (Du et al. 2022).

The indoor environment is dynamic and is further affected by several parameters, including HVAC systems, the presence of human beings and pollution sources such as office equipment and cleaning procedures (Moya et al. 2019). These parameters cause air pollution, and it is necessary for a holistic approach directed at the efficient removal of impurities from indoor air. The 'health effects of air pollution are aggravated when polluted air takes a long time to be flushed out of the cooking area' (Shah & Dufva 2017:14).

The thermal comfort inside a building is influenced by ambient temperature, the BMR of a worker, radiant temperature, humidity and airspeed (Babu & Suthar 2020). Most people prefer a RH of 40% to 60%, and air motion also plays a vital role in human comfort as it improves heat loss by both convection and evaporation. André, Vecchi and Lamberts (2020) claimed that increased air velocity is a useful approach to boost thermal comfort in the tropics. According to Mehta (2019), fenestrations create porosity in buildings to permit ventilation.

Lotfabadi and Hançer (2019) proved that vernacular architecture construction techniques are successful in their context and time. Atriums, limited plan depth, and maximum window sizes can achieve natural ventilation, and daylight with outdoor air for ventilation and cooling are crucial facets of any classical architecture (Osaro et al. 2022). Timerbaeva (2010) explained that only NV is present in small or old facilities. Traditional house occupants had a strong sensational scale level, a preference for their homes and a high level of satisfaction with the indoor thermal comfort. Some residents living in modern buildings wish to return to traditional homes (Hailu 2020). Traditional houses regulate the indoor air environment using locally available material and through proper openings and orientation.

Yan et al. (2020) recommended airspeeds of more than 1.0 m/s and a cooling effect in the air temperature above 33.5 °C in hot-humid regions. Zhai et al. (2015) recommended airspeeds of 1.2 m/s at 30 °C with an RH of 80%, which exceeded the upper limit set in the ASHRAE Standard 55 (0.8 m/s). The ASHRAE Standard 55 recommends temperatures between 20 °C and 25 °C for buildings without significant air movement if the maximum velocity does not exceed 0.2 m/s (ASHRAE Standard 55 2004). Natural ventilation with higher airspeeds of 0.8 m/s, for a maximum temperature of 28 °C, is sufficient (Rupp 2015).

However, South African Weather Services (2020) reported that the average outside wind speed varies from 0.1 m/s to < 8 m/s in South Africa, with a mean wind speed of 5.14 m/s. On the Beaufort Wind Scale, humans feel the wind when the speed exceeds 1.5 m/s. These winds can influence thermal comfort and the effectiveness of ventilation in kitchens with fenestrations. The mean daily RH levels vary between 54% and 71% (South African Weather Services 2020). Such high humidity levels can cause thermal discomfort and require higher airspeeds to improve ventilation in kitchens (Rahmillah, Tumanggor & Sari 2017). Sufficient NV is nonetheless vital to prevent dampness in the air and reduce pollutant concentrations effectively for indoor thermal environments in hot and humid climates without MV (Walker 2016).

According to Wong, Tan and Adelia (2020), NV plays a vital role in improving indoor thermal comfort and air quality. NV has great potential to create desirable IAQ and reduce energy consumption in buildings where passive cooling of the internal environment occurs (Walker 2016). It plays an important role in providing better IAQ, thermal comfort and energy-saving in buildings (Muhsin et al. 2016). The natural forces of wind and buoyancy deliver fresh air into buildings, alleviating odours and increasing thermal comfort in indoor environments (Oropeza-Perez 2019). According to Asfour (2015), NV has a high potential for improving thermal comfort in hot climates by implementing wind-induced ventilation. Revit (2018) claimed that stack ventilation uses such air pressure differences because height pulls air through the building and functions naturally, without any pressure. Draughts of air move through the kitchen to push stagnant, polluted air out (Cameron & Vila 2020).

As with MV, NV is unsuccessful in decreasing the dampness of inbound air. This prevents the potential efficiency of NV in tropical environments, even though most historic buildings are ventilated naturally (Walker 2016). The author contends that NV provides an economical ventilation rate because of draughts and large fenestrations such as doors, windows and vents. The temperature and air velocity distributions within a building because of natural convection can be complex, especially when external factors such as wind patterns and directions influence the flow patterns within a building. Natural convection can cause temperature and air velocity distributions to be complicated, especially when external influences such as wind patterns and directions influence the flow patterns within a building (Stoakes, Passe & Battaglia 2011). Al-Obaidi, Ismail and Rahman (2014) reported that individuals occupy buildings almost 87% of the time, which has implications for kitchen design. Openings between rooms, such as transom windows, louvres, grills or open plans, are techniques to complete the airflow circuit through a building.

Adamu (2013) cautioned that NV is beset by challenges such as airflow's irregularity because of the unreliable wind forces. Gough et al. (2018) claimed that NV becomes less effective in urban areas because its performance in buildings is affected by factors such as opening shape, size, location and fluctuations in wind direction and wind speed. Moreover, purpose-built design strategies to enhance NV include windows, doors, solar chimneys, wind towers, trickle ventilators, wind catchers, venturi-shaped roofs, saw-tooth roofs and atria (Muhsin et al. 2016).

The primary task of kitchen ventilation is to remove sufficient convective heat and contaminants from the occupied zone with a minimum airflow rate (Han, Li & Kosonen 2019). Kosonen (2006) added that a properly designed and located exhaust hood is essential for effective kitchen ventilation. The ventilation system also brings in the air to refresh the working place by replacing the exhausted air. Alexandrova (2009) suggested measures to prevent poor air quality and inadequate ventilation, such as:

- filtering air
- maintaining sufficient air replacement and ventilation rates
- appropriate sealing of any openings to unfiltered air or gases (including subterranean spaces)
- improving maintenance of air quality equipment to maximise their efficacy
- installing high-efficiency particulate absorbing (HEPA) filters and electrostatic precipitators to collect grease vapour and improve particulate matter efficiency
- installing UV-light technology or cold plasma, a new filtration system that can kill 99.99% of pathogens in a single pass.

■ 3.2 Architectural features suitable for kitchen ventilation

Nicol and Roaf (2017) insisted that architectural science holds a mandate for the universal restoration of NV in buildings to make them habitable during power failures, especially during heat waves. Sada and Salih's (2019) experimental work indicated an improvement of IAQ by source control, suitable purification and ventilation system use. Additionally, openings located on opposite walls are more effective for cross-ventilation (Asfour 2015). Van Hoof et al. (2017) concluded that thermal comfort could be achieved through a sensible combination of structural designs, including shades, blinds, doors, operable windows and balconies, and active technological solutions.

Four primary architectural design features will be discussed in the sections to follow: chimney or smokestack, ceiling height, open plan, doors and windows.

According to Asfour (2015), heated air rises from a cavity and leaves through the top opening, bringing in the cool fresh air provided by wall openings inside the space. Air circulation is accelerated when prevailing wind currents pass over the chimney. Chimneys are helpful while burning solid fuels, for example, in wood-fired pizza ovens. However, an unswept chimney increases sooty build-up, which could restrict smoke and potentially harmful emissions from escaping (Christie 2019).

The height of the ceiling must be correctly stated at the planning stage to optimise the airflow rate. The Queensland Food Safety and Public Health Working Group (2019) regulated a minimum ceiling height of 2.4 m above the floor area in kitchens. Higher ceilings assist NV, and this value must not be lower than 2.5 m, as per Oropeza-Perez (2019). The City of Milwaukee (2020) established a volumetric difference of almost 1 m^3/s between a height of 2.3 m and 2.8 m, with a temperature difference of 5 °C. Lotfabadi and Hançer (2019) added that increasing ceiling height leads to improved thermal comfort in summer, particularly in hot and humid climates; the air volume is greater and creates more vertical temperature differences and air movement.

The open kitchen is becoming a hallmark of good restaurant design. The open kitchen is great for entertaining guests, and an open kitchen is also a good opportunity to maximise a small space (Rankin 2019), as seen in some high-end restaurants. Natural ventilation through building fenestrations such as open-plan is a technique for cross-ventilation in a building (Walker 2016).

Doors and open windows provide NV through openings when the long façade of the building faces the prevailing wind direction (Passive Design 2018). Behavioural adaptation of opening windows allows airflow and alternated temperature that may advance IAQ (Nicol 2020). However, the City of Milwaukee (2020) stated that all living rooms should be provided with a minimum of a single window or skylight that is operable or any other mechanism that will sufficiently air the room. Abdel-Salam (2022) reported that households with NV through frequent opening doors and windows had higher air exchange rates in Alexandria, with stronger associations between indoor and corresponding outdoor levels of measured air pollutants compared with mechanically ventilated homes. Xiang et al. (2021) advised that opening kitchen windows and using portable air cleaners in the kitchen can drastically reduce indoor $PM_{2.5}$ levels.

Next, I am going to discuss kitchen spaces, kitchen sizes and worker density. Armstrong (2020) verified that kitchen design is based on several business factors, such as whether the operational concept is fast-food or fine dining. The type of food prepared, the volume of business, customer preferences and the environment will be among the primary drivers and regulations, particularly health and safety. The space required for all functional areas of kitchens, such as receiving, storage, preparation, cooking and dishwashing, depends upon many factors to produce menu items. Sethi and Malhan (2015) posited that space should be planned and organised to be comfortable for kitchen workers. Conversely, Maruthi, Hossain and Hari (2013) reported that cooks work at stoves in congested kitchens in the food parlours of India. Atkinson et al. (2009) suggested that furniture layout and internal partitioning must permit the intended flow path and open access to airflow.

Astolfi and Filippi (2004) observed variations in kitchen volume from 99 m^3 to 191 m^3 in restaurant kitchens. The standard minimum formula for a full-service dining establishment is 5 ft^2 (0.46 m^2) of kitchen space per restaurant seat: a 40-seat restaurant requires a 200 ft^2 (18.58 m^2) kitchen. Fast-food quick-service operations and restaurants use pre-packaged convenience foods and need smaller storage and preparation areas with less space (Perkins 2018).

According to the City of Durban (2020), the Food By-law (Provincial Notice No. 627 of 1950) requires a food preparation area, exclusive of the scullery, with a floor area of 18.5 m^2, a scullery with a floor area of 4.6 m^2, a storeroom with a floor area of 16.75 m^2 and a shop with a floor area of 28.0 m^2. Various measures for kitchen space have been advanced. For example, 0.46 m^2 space for every seat in the front of the house (Die-Pat 2016a); 30% of the total square footage of the restaurant in full-service restaurants; a 60:40 ratio as a baseline for allocating space; and 40% allocation to the kitchen, storage and preparation areas (Perkins 2018). The minimum size of a kitchen with accommodation of up to 50 seats must be, at least, 20 m^2 including the washing area. For greater receptivity, 0.5 m^2/seat is calculated (ContekPro 2021). A kitchen size metric is the number of guests served at any given time. The rule of thumb is to allocate at least 5 ft^2 (0.445 m^2) for every seat in the dining area (Manu 2019).

Fine dining food requires two to three times the kitchen space necessary for banquet service, and fast-food establishments can have smaller kitchens and larger dining rooms. These kitchens can occupy as little as 25% of the total floor space for a 4:1 dining area to kitchen ratio (Decker 2019). To maintain effective movement through spaces, the area per person according to the equipment used by Aluline Group (2019) has been established by the *Building Act (1984) of Workplace Health, Safety and Welfare Regulations 1992*. It is recommended that in a kitchen, each staff member needs 10 m^2.

According to the UK Homes and Communities Agency (2015), the Employment Density Guide has full-time employees of 15 to 20 for restaurants and cafés. Rasmussen (2015) reported that the City of Sydney has 22 m^2 per employee in the food and drink industry, whereas it is 18 m^2 per employee in restaurants and cafés in the UK. A survey of existing kitchens in the UK by Pawas (2018) revealed that the space varies from as little as 2 ft^2 (0.185 m^2) per meal served to as much as 7 ft^2 (0.650 m^2) or more. This figure includes the area for ancillary rooms as well as for the main kitchen. The workspace ratio measures the amount of floor space per worker (13 m^2 per employee in restaurants in the UK), whereas the national average is 18 m^2 per employee in the USA (Smith 2018).

Simmons (2019) claimed that workspaces of 7.4 m^2 to 13.9 m^2 per employee are considered high density. I feel that a workspace ratio of 18 m^2 per staff member may be suitable in warmer countries, unlike the temperate UK. Under Facilities Regulations of the South African Legal Information Institute

(1993), *the Occupational Health and Safety Act 85* recommended 2.25 m^2 of unimpeded space of open floor area to be available for every employee working in an indoor workplace. However, no mention of the hospitality and catering industry is made. As per Energy Ace Code (2013), the recommended value for California Building Code commercial kitchen occupant densities is 200 ft^2 per occupant (18.58 m^2 per occupant).

3.3 Artificial ventilation

Without artificial ventilation (AV) to provide fresh air, moisture, odour and other impurities can accumulate in a building. Mechanical ventilation systems use mechanical systems with fans to supply and exhaust air from a space, provide humidity control and, if required, possible filter contaminants (ASHRAE 2019). AV includes air curtains, air conditioners, coolers and other mechanical devices.

Air doors consist of a forceful blower that creates an undetectable obstruction, which efficiently divides one environment from another (Airtècnics 2020). Air curtains, or doors mounted at entrances, activate automatically when kitchen doors open and deliver a strong, stable air stream blowing downwards (Black 2019). Food-service operators commonly use air curtains to separate indoors from outdoors, facilitate cooling and deter insects. Utilising the air curtain system near cooking zones lowers temperature and RH, enhancing the chef's thermal comfort (Moumen & Delporte 2022).

Likewise, HVAC units can facilitate IAQ, control odour and dust, and provide cooler temperatures in the kitchens. As per Quest (2020), air-conditioning systems protect kitchens from dampness and other moisture-related issues, but they are extremely inefficient for removing moisture. Coolers can decrease air temperatures at a fraction of the cost of refrigerated cooling (Newair 2019). Ideally, commercial kitchens should have at least 20–25 air changes per hour to deal with the heat (Intelligent Cooling Solutions 2019).

Air coolers help to air condition kitchen spaces. In addition to purifying and refreshing the space, it dehumidifies a moist kitchen. John and Liu (2020) indicated that a high level of thermal mixing of the conditioned air with the room air had been proven to correlate with high levels of occupant thermal comfort.

Once kitchens are constructed as green buildings, NV in kitchens will be taken earnestly; well-ventilated kitchens will ensure that this heat is not transferred to other parts of the buildings (Master Builders 2021). According to Keuter (2008), the *National Building Regulations and Building Standards Act*, *No. 103* of 1977 in South Africa controls the approval, design, location and testing of AV systems in buildings. All commercial kitchens must use MV systems to create a comfortable working environment that promotes health and safety at work as well as good hygiene and food safety (Advanced Control Solutions 2018).

In a positive pressure system such as a room, the room's air leaks out through openings. In a balanced MV system, air supplies and exhausts are adjusted to meet design specifications. Mechanical means can provide make-up air, but it should be fresh and unadulterated from the outside (Electricians Forum 2017).

Let us discuss whirlybirds or fans and ventilated ceilings. Whirlybirds are widely used for improving IAQ. They draw air from the interior space, create a more favourable climate inside the building, work without any external supply of electric energy (Wang et al. 2021a) and are driven by natural wind force. Whirlybirds are heat escape ports located high in the building; the primary motive forces are stack effect and wind induction, and they are operational even in the absence of wind flow because of the stack effect (Jadhav, Ghanegaonkar & Garg 2016).

A ceiling fan in the kitchen helps remove unwanted odours by dispersing them while providing much-needed cooling comfort (Best Ceiling Fans.net n.d) in a kitchen's general area. Ceiling fans deliver airflow during the hottest time of day and provide thermal comfort (Nicol 2020). Arens et al. (2020) recommended that the fan aim at different parts of the human body and provide airspeed ranging from 0.36 m/s to 0.8 m/s (70.9 fpm–157.5 fpm).

Reverse flow fans in kitchens remove air contaminants by pulling them out through an exhaust fan (Fantech 2019). Present et al. (2019) found that ceiling fans have the potential benefits of downsizing HVAC equipment. Ceiling fans increase occupant comfort and decrease energy use. Tower fans discharge air perpendicularly that spreads across a broad area (Honeywell 2017); they have a simple dust filter and are compact in design.

The ventilated ceiling system (VCS) consists of a modular exhaust pod installed in a grid. The VCS is individually custom-sized and engineered for light- and medium-duty commercial cooking applications (Halton 2020). According to GIF Active Vent (2021), the flat VCS can be installed where no direct exhaust is required in adjacent or ancillary areas which are not exposed to thermal loads and steam. Capture Jet ventilated ceilings claim to optimise hygienic conditions, health and safety, and these features appear to be desirable in commercial kitchens (Halton 2020). Table 3.1 lists the different types of extraction mechanisms in the kitchen environment. Hybrid ventilation seems common, with seven studies (37%) mentioning it. However, displacement ventilation seems to be the trend, as studied by several authors (52.6%).

TABLE 3.1: Review of extraction systems by the author.

Source	Passive ventilation	Active ventilation	Hybrid ventilation	Others				
	Natural	Mechanical		Dilute	Displacement	LEV	DCV	Mixing
ASHRAE (2004)	√	√	√ Passive + active ventilation					
Yuan, Wang and Liu (2013:61)					√			√
Lin (2014:41)								√
Daaboul et al. (2017)			√ Passive + active ventilation					
Jimoh (2017:55)	√	√	√ Passive + active ventilation					
Timerbaeva (2010:3)			√ Passive + active ventilation	√	√			√
Zolotareva (2011:13)	√	√	√ Passive + active ventilation					
Hou et al. (2012:1 100)							√	
Ng (2012:1)					√ LEV			
Cao et al. (2014:173)		√	√ MV + DV	√	√ LEV	√	√	√
Zhou et al. (2019:182)					√ PP			
Manshoor et al. (2014:1)					√			
Li et al. (2012:150)					√			
Mikeska and Fan (2015)		√		√				
Clark (2012)					√ PP			
Southern California Edison (2009:1)							√	
Kosonen (2010:1)					√			
Velux (2017)			√					

Key: DCV, demand-controlled ventilation; DV, displacement ventilation; LEV, local exhaust ventilation; MV, mechanical ventilation; PP, push-pull ventilation.

The emerging technology in respect of demand-controlled ventilation (DCV) in commercial kitchens is 16%. According to Better Buildings (2015), the energy and cost savings of a DCV is determined by a variety of factors, including cooling and heating loads in a kitchen.

3.4 Heating, ventilation and air-conditioning system

For hospitality operators and kitchen workers, effective emission control in commercial and industrial production kitchens has always been a major problem (Han et al. 2019). The type of space plays a key role in determining the necessary ventilation requirements. A well-run kitchen requires a well-designed HVAC system. The heat loads generated in a commercial kitchen from cooking activities contribute to most heat gains to the space. Li, Hou and Yang (2019) claimed that there are two widely-applied ventilation modes: mixed-mode (MM) ventilation and displacement ventilation (DV). Li and Kosonen (2019) reported that a low-velocity DV system reduces exhaust airflow by 15% compared with a conventional mixing ventilation system.

Commercial kitchens can have a single ventilation method or a combination of methods in different areas of a kitchen. A strategic design to use NV for most occupied hours can be supported by mechanical devices with maximum cooling (Breathing Buildings 2021). Mixed-mode ventilation facilitates greater thermal comfort levels and worker satisfaction (De Vecchi et al. 2017), although the mean thermal perception in air-conditioned spaces is considerably lower than that in NV and MM spaces.

Regarding airflow movement in commercial kitchens, indoor air distribution determines IAQ and human comfort (Li et al. 2019). A minimum airflow of 0.5 m/s in every kitchen zone can be ideal. Kumar, Jain and Mathur (2020) found the acceptable range of indoor airspeed to be 0.32 m/s–2.00 m/s and 0.00 m/s–0.50 m/s during autumn and winter season, respectively, with male students accepting slightly higher airspeed than females. Yan et al. (2020) reported that airspeeds of more than 1.0 m/s have a cooling effect on air temperature above 33.5 °C in hot-humid regions. Zhai et al. (2015) recommended an airspeed of 1.2 m/s at 30 °C with a RH of 80%, which exceeded the upper limit set in the ASHRAE Standard 55 (0.8 m/s). Kumar et al. (2020) reported that because of an increase in airflow, some of the occupant conditions are found in the acceptable range even at a higher operative temperature of 30.5 °C.

In actual kitchen conditions, disturbing draughts may arise from cooking behaviour, movement of people, open windows, doors and make-up air systems (Han et al. 2019). Higher air movement can be desirable for cooling in hot conditions; however, thermal discomfort can be caused by cool draughts as well (Sansaniwal et al. 2020).

Draught management involves the inflow–outflow rate. Caple (2018) posited that all extractor hoods remove emissions and humidity; to ensure that the thermal plume rises vertically up for extraction and is not disturbed by the inbound air, steady air circulation must be provided in the kitchen and intrusive crossflows must be avoided. Halton (2007) argued that opening windows in the kitchen creates draughts and affects the ideal shape of the thermal plume. A Finnish study (Shah & Dufva 2017) argued that a higher airflow rate does not necessarily help to remove pollutants from the kitchen environment. Instead, a lower airflow rate helps with proper mixing of the air and contaminant removal with a lower energy cost. Dobbin et al. (2018) stated that extractors must run at maximum for a short time after cooking to exhaust heat and pollutants efficiently.

Kuehn (2009) reported that a commercial kitchen extractor is a 2.44 m long by 1.22 m wide, Type I, wall-mounted canopy. Zhao et al. (2013) observed differences in traditional Chinese-style cooking hoods, which affect exhaust efficiency because of the small hood volume. Hueda (2020) reported that the main problem found in kitchen hoods is inadequate exhaust airflow; the minimum required airflow varies depending on the size and shape of the hood. Kim et al. (2022) found that the pollutant capture efficiency of a hood is affected by the geometric shape of the hood frame and the environmental conditions; a canopy hood has the most advantageous structure for collecting PM.

The American- or European-style hoods have cuboid hoods wherein the length of the overhang calculates the volume. Allen (2014) recommended that the efficiency of a hood can be maximised by placing cooking appliances as close to the wall as possible and ensuring that the hood covers the entire cooking area. Chandler (2019) suggested that the hood be installed between 61 cm and 76 cm from the stovetop. Many hoods are simply installed too high, drastically reducing their effectiveness. Placing the hood at a distance far above the appliance increases opportunities for leakage of the thermal plume that dissipates quickly with an increase in distance (Han et al. 2019).

Babu and Suthar (2020) asserted that there is scope for improving the IAQ and thermal comfort by implementing proper NV and MV with air-cleaning. MM ventilation can be used to maintain IAQ and internal thermal temperatures year-round using both natural and MV systems (ASHRAE 2019). Parkinson, Raftery and Present (2020) claimed that a MM design could minimise HVAC energy demand without compromising occupant thermal comfort. Liu et al. (2020) designed a new system wherein conditioned air is supplied from the lower part of the cabinet under the cooking stove and make-up air from the air curtains around the stove. This integrated air curtain and air-conditioning system improve the thermal environment and IAQ.

3.4.1 Mixing ventilation

The common and easily observable mixing ventilation is described by Lin (2014), and horizontal air movement is not possible because of ceiling-mounted air inlets and outlets. If the requisite air movement in the occupied zone occurs because of the distances between the diffusers and the occupants, mixing ventilation will have a high fan energy consumption. It is also not applicable for heating because of the short-circuiting of the warm airflows. Authors have described mixed ventilation as hybrid ventilation, including Daaboul, Ghali and Ghaddar (2018) and Ayodeji (2017).

'A typical supply ventilation system is simple, inexpensive and consists of a fan and duct system for introducing fresh air into one or several rooms', as per Zolotareva (2011). In a well-mixed ventilation system, the global contaminant removal efficiency (CRE) will still become 1.0. The absolute value of outdoor contaminant concentration has no effect on CRE. For some years, mixing ventilation was the most popular way of ventilating rooms. The main disadvantage was that contaminants always mixed with the air inside the room (Timerbaeva 2010).

In a mixing ventilation system, contaminated room air is diluted as it is mixed with supplied fresh air that lowers the contaminant concentrations. In practice, active and passive mixing conditions result from both supplied airflow and internal heat sources (Cao et al. 2014). Thermal plumes affect airflow distribution significantly as convective flow tends to dominate. Mixing ventilation from the ceiling increases the turbulences in front of the hood and reduces the extraction efficacy of the hood compared with efficient displacement ventilation from the wall (Moumen & Delporte 2022).

3.4.2 Dilution ventilation or general exhaust system

Timerbaeva (2013) reported that dilution ventilation is often used in residential or industrial buildings. The contaminants that emanate in the facility are extended by fresh supply air to maximum permissible concentration. The surpluses of the heat and moisture integrate supply air that needs to have lower temperature and humidity. Yuan et al. (2013) posited that traditional kitchens cool the space by adopting mixing ventilation. Efficient mixing of supply air with room air needs high velocity that can create an air jet with high momentum. This is not necessarily the best fit for air distribution in a commercial kitchen, as high-discharge velocity creates unwanted air movement. Cross-draughts in the kitchen are uncomfortable for workers and problematic to capture with hoods. Traditional MV diffusers create discomfort for occupants as they provide large volumes of fresh air into a space. A large perforated ceiling area with a diffuse ceiling inlet with fresh air can solve the problem (Mikeska and Fan 2015).

3.4.3 Displacement ventilation

Unlike mixing ventilation, a ventilation system that uses displacement (DV) works by replacing contaminated room air with fresh air from the outside. Cool air is often provided at or near the floor at a low velocity (about 0.5 m/s) to induce upward air movement (thermal plumes) as heat sources in the room warm it. Vertical gradients of air velocity, temperature and pollutant concentration are usually created as a result (Cao et al. 2014). With air movement flowing upwards from the floor level, DV is thermally driven. When compared with mixed ventilation with the same airflow, it generally gives superior air quality and ventilation efficiency. Horizontal air movement would be incompatible with DV because it would disrupt the heat plume near the occupants. Overcooling of the lower zone is also a common side effect of DV, producing discomfort in the occupants' leg. Because the warm supply air is buoyant, adopting DV for heating would produce short-circuiting of the airflow, similar to mixing ventilation, according to Lin (2014).

Yuan et al. (2013) showed that DV could maintain a thermally comfortable environment with a low air velocity, a small temperature gradient between the head and ankle level, and a low percentage of dissatisfied people, and it may provide better IAQ in the occupied zone. Hence, using thermal DV in kitchen environments reduces kitchen temperature without increasing the air-conditioning system capacity. Air and Odour Management (2015) reported that as the plume rises by natural convection, it is captured by the hood and removed by the suction of the exhaust fan. Air in the proximity of the appliances moves to replace it. If the plume is weak, draughts within the kitchen will push the contaminants away from the hood. DV ensures that the stagnation period of the air around the worker is less. Hence, the IAQ of the DV is better than that of mixed ventilation with the same magnitude of flow velocity (Yuan et al. 2013). The *displacement* system also maintained 33% less carbon dioxide in the breathing zone than the *dilution ventilation* system. Kosonen (2002) stated that in hot and humid regions, thermal DV creates a moisture gradient in room spaces. Measurements evince that the humidity gradient is as significant as the temperature gradient.

Displacement ventilation is also referred to as push-pull ventilation. Clark (2012) endorsed a combined scheme for a push-pull ventilation system entailing air supply through slot air curtains or perforated perimeter supply (PPS) and air exhausted through range hoods. The push-pull ventilation system improves IAQ inside a kitchen. The terminal velocity at the cook's head should be at 0.25 m/s (50 fps) to avoid any feeling of a draught. Li et al. (2012) argued that when an air supply outlet was installed on both sides of the duct and fresh air was supplied at a 45° angle; the supply air flowed directly to the head of the cooks. This would not only cause thermal discomfort but also decrease the hood performance.[1] There are several strategies to supply make-up air-displacement ventilation or diffuser, air curtain diffuser, short-circuit supply, front face diffuser and PPS (Manshoor et al. 2009).

The hoods' exhaust requirements are sized to peak the cooking usage of each appliance under the hood. When the hood is on, its exhaust and make-up air fans are on at full speed or not at all. In reality, food is not always being cooked, and therefore the peak exhaust requirements are not always needed, as a significant amount of energy is wasted on venting unnecessary cubic feet per minute of air when appliances are not fully used (Li et al. 2012). Zhou et al. (2019) showed that the push-pull ventilation system could effectively improve the capture efficiency of the range hood, and the low-momentum make-up air and the air distribution around the stove provide good performance. The optimal working condition of the push-pull ventilation system is a range hood mid-gear, plus an air curtain velocity of 0.5 m/s when the kitchen window is closed.

3.4.4 Hybrid air distribution

Although a DV system is normally a more effective form of air supply, it has two major drawbacks: (1) it cannot be utilised in the heating mode to avoid full mixing and (2) the air supply has a restricted penetration distance along a room with intense internal heat sources. To alleviate the drawbacks of the DV system, a hybrid air supply system incorporates the properties of both MV and DV systems (Cao et al. 2014).

3.4.5 Personalised ventilation

Personalised ventilation differs from local ventilation technologies in that it controls pollutants on a local level. PV can deliver high-quality air directly to the exposure region, utilising a variety of air supply methods. Fresh customised air with a supply flow rate of less than 3.0 l/s could comprise up to 80% of inhaled air. In addition, PV has been demonstrated to save up to 60% and 51% of energy in cold and hot climates, respectively, as compared with mixing ventilation. Furthermore, the usage of filtration improves the ventilation process's efficacy (Cao et al. 2014).

Lin (2014) claimed that the established criterion of IAQ could be met by adopting personalised or task ventilation. This air distribution method provides occupants with air from adjacent nozzles and a general air supply. It provides horizontal air flow by distributing fresh air through nozzles near the occupants. It is quite effective in terms of supplying acceptable IAQ

1. the ability of an exhaust hood to remove all the grease, smoke, heat, moisture and other cooking effluents from a kitchen space.

while also being energy-efficient. On the contrary, connecting ducts and equipping nozzles to various indoor places are typically complicated and costly. It would also be tough to manage if the occupants needed any kind of mobility or repositioning.

3.4.6 Local exhaust ventilation

Local exhaust ventilation (LEV) is basically an extract ventilation system that is extremely effective in rooms with confined pollutant sources, such as industrial facilities or kitchens. An extractor hood is usually placed above the source of pollution to remove it before it spreads into the room. According to Cao et al. (2014):

> [*L*]ocal exhaust ventilation (LEV) is primarily an extract ventilation system which is very effective in rooms where localised contaminant sources can be identified, such as in industrial premises or kitchens. Normally, an extractor hood is placed above the source to remove the pollution before it can spread into the room. (n.p.)

Local exhaust ventilation is an engineering system designed to reduce employee exposure to airborne contaminants such as dust, mist, fume, vapour and gas in the workplace by capturing the emission at the source and transporting it to a safe emission point or to a filter (Health and Safety Authority 2014). LEV captures contaminants close to the generation point of emission. It is achieved using inlet hoods, ducts, air cleaners, fans and discharge. An overall exposure reduction of 92% was achieved by using a LEV system. However, this reduction highly depends on the way it is installed and used by occupants.

3.4.7 Demand-controlled ventilation system

The DCV is a commercial kitchen hood energy management system. By lowering the exhaust and make-up air fan speeds, it improves energy efficiency. This is performed by determining the lowest amount of exhaust air required to capture and contain effluent from the cook line using an infrared and temperature sensor (Southern California Edison 2009). In demand ventilation, the best air change rate is 30 times per hour, and the air supply temperature is 301.15K (28 °C) for kitchens; the mean value of the minimum velocity is 0.410 m/s, and the maximum average concentration of CO_2 is 659.78 ppm, which is lower than the acceptance criteria (CO_2 < 1 000 ppm); hence, this air supply mode can optimise IAQ (Hou et al. 2011).

Demand-controlled ventilation with CO_2 as an operating parameter is a ventilation system that resets outdoor air supply rates (ASHRAE 2007a). Even though CO_2 is not dangerous, high levels of CO_2 in interior spaces displace oxygen in the air and can result in a lack of oxygen for breathing. Carbon dioxide is a good predictor of occupancy in indoor environments, which is the most essential element of CO_2 in DCV. As a result, CO_2 is a useful metric for regulating ventilation based on occupancy. As technology developments make its implementation more possible and interest in environmentally responsible building design rises, CO_2-based DCV has become more widely employed to optimise energy use in ventilation systems (Lee 2012).

3.5 Kitchen ventilation classification

Zhang and De Dear (2019) reported that workers' sensitivity to temperature, humidity and airflow significantly varies between different ventilation modes. A properly designed commercial kitchen ventilation system will improve the well-being of kitchen workers (Greenheck 2020). The type of cooking, the scale of cooking and the location of the kitchen premises dictate the design of a kitchen ventilation system (Nisbets 2019).

According to the International Code Council, the International Mechanical Code (IMC 2018), as supported in ASHRAE 62.1 (2013), kitchens are classified based on the type of equipment used in kitchen operations that are highly pertinent to the type of cuisine prepared.

To control IEQ in commercial kitchens, as per Twin City Fan (2020), the Department of Fire endorsed Type I or Type II hoods to be mounted over cooking equipment as per the municipality by-laws of most countries. Commercial kitchen extractors are designed to trap and contain vapours and emissions. It is a requirement that extractors are in commission during food preparation. Both types of hoods seem relevant in South Africa, as the cuisine covers a wide range of cooking styles.

As per Duravent (2020), heat, smoke, moisture and other greasy by-products of cooking are all removed by IMC 507.2 Type I hoods. Grease and grease-laden fumes are produced when animal protein is cooked. Cooktops, deep fryers, griddles, grills, woks, char-broilers, tilting skillets, braising and frying pans, infrared broilers, stoves, ranges, barbecue equipment, salamanders and open-flame stoves should be covered by Type I hoods (grease hoods). These hoods must be installed above medium-, heavy- and extra-heavy-duty cooking appliances, and they must be cleaned on a regular basis to avoid grease fires.

IMC 507.3 Type II hoods must be positioned over appliances that produce heat or moisture but no grease or smoke during the cooking process. Type II hoods (condensate) are used for exhausting excess heat produced by ovens, pasta cookers and commercial dishwashers. They assist in removing excess heat from the air, allowing personnel to work in a more pleasant environment. Class 2 culinary operations were determined according to the City of Penticton (2013). Class 2 cooking operations include equipment if they are > 6 kW with

Type II hoods. Clark (2009) concurred that ventilation systems are selected on the heat output from the cooking appliances.

High-efficiency extractors are requisite to contain emissions and sustain good IAQ in kitchens (Han et al. 2019). Kosonen (2005) stated that commercial kitchen equipment is categorised according to the cooking appliance convective heat output, the area of exposure, the distance of the extraction unit from the cooking equipment and the effect of the general ventilation for CRE.

In a balanced MV system, air supplies and exhaust are adjusted to meet the design specifications. Air and Odour Management (2015) reported that as the plume rises by natural convection, it is captured by the hood and removed by the suction of the exhaust fan. Commercial food-service hoods exhaust a minimum net quantity of air determined in accordance with Sections 507.5.1 through 507.5.5. As required by ASHRAE Standard 62.2–2016, there must be a minimum airflow rate of 100 cfm or 50 l/s. This would maintain a desirable CO_2 level and thermal comfort in kitchens (IMC 2015).

According to Adam (2013), the minimum required cfm per linear foot of hood for listed and unlisted hoods is given by IMC. 'UL listed' means that the product has been tested by Underwriters Laboratories (USA) to nationally recognised safety standards and is free from a reasonably foreseeable risk of fire, electric shock and related hazards. Paradoxically, unlisted hoods require higher exhaust flow rates. Kosonen, Koskela and Saarinen (2006) explained that the primary guide for designing kitchen ventilation had been the calculation of the airflow rate based on thermal plume; undersized airflow rates could lead to indoor air problems. Exhaust rate and the type of hood will inform the kitchen load and the appropriate equipment that can be installed.

3.6 Air composition and quality

The well-being of workers is impacted indoors by different categories of contaminants present indoors which are released by natural or human activities (Babu & Suthar 2020). In this regard, kitchens have an appropriate setting for microbes to flourish. A buildings' issues with dampness, peeling walls, and mould are primarily caused by poor ventilation (Du et al. 2022). Sick building syndrome with unknown causes may emerge, and the situation is exacerbated because of poor ventilation, energy-saving considerations, closed windows, lack of NV and daylighting, and minimal replacement of fresh air with HVAC systems (Nag 2019). In a restaurant kitchen, operating environments are particularly challenging, and high emission rates of contaminants are released from the cooking process (Kosonen 2005).

Due to the excessive heat and vapour in commercial kitchens, the working conditions deteriorate. A proper ventilation design is required to reduce the risk of contaminated air and the heat generated by cooking products can be efficiently exhausted (Osawa et al. 2022).

As per Marć et al. (2018), the pollutants discharged in the indoor environment are considerably impacted by the method of cooking, the cooking equipment, the cuisine, the cooking temperature, the volume of the kitchen, the efficacy of the extraction system and the worker density. A further consideration is to be given to the nature of the pollutants in the air that is affected by the food being prepared, the quality of ingredients used and the cultural factors. Zhao et al.'s (2020) results showed that the IEQ of the test restaurants depended mainly on the cooking fuel, cooking method and ventilation system.

The main pollutants released are CO_2, nitrogen dioxide (NO_2) and water vapour (Greiner 2020), whereas Fameli et al. (2022) find CO_2, CO and NO_2 to be the dominant pollutants from cooking. As per the International Standard for Refrigeration and Air-Conditioning Engineers Draft (ISHRAE 2019:24), the main source of indoor pollutants is cooking, especially from frying or biomass. Incomplete combustion of biofuels in kitchens with inadequate air circulation increases the concentration of impurities (Ravindra, Kaur-Sidhu & Mor 2020).

Akbar-Khanzadeh et al. (2002) observed that during complete meal service, the level of CO_2 rises as the air-circulation rate declines. Simone et al. (2013) and Timerbaeva (2010) therefore concurred that CO_2 concentrations indicate the adequacy of the HVAC systems' performance and quality of air in each kitchen.

Khovalyg, Chatterjee and Lichtenbelt (2020) stated that the IAQ could be gauged by the concentration of CO_2. Bierwirth (2018) conveyed that CO_2 > 800 ppm is associated with SBS. Greiner's (2020) study found that the constant functioning of a stove generating 800 ppm CO_2 without additional ventilation can cause CO_2 levels to increase rapidly to undesirable levels. The safe levels of indoor CO_2 levels, as published by Kane International (2020), are 350 ppm–1 000 ppm (1.8 g/m^3). Carbon dioxide levels of 1 000 ppm–2 000 ppm have resulted in complaints of drowsiness and poor air.

Satish et al. (2012) cautioned that with CO_2 levels of 1 000 ppm, moderate and significant decrements occurred in the decision-making performance of volunteers. Exposure to CO_2 as low as 1 000 ppm may have adverse effects on humans (Maniscalco et al. 2021). Barnes et al. (2006) reported acute respiratory infections (ARIs) and poor lung function in the Eastern Cape.

Not surprisingly, the Institution of Gas Engineers and Managers (IGEM 2015) reported that when testing installations in kitchens and the CO_2 level exceeds 2 800 ppm, the system needs to be made safe by isolating individual appliances or increasing ventilation. In such cases, the reports add that provision of ventilation is reviewed to achieve CO_2 levels not exceeding 2 800 ppm. Demand-controlled ventilation has a CO_2 sensor installed to monitor the air levels and can maintain adequate IAQ (Shriram & Ramamurthy 2019).

In another line of enquiry, Kim et al. (2011) posited that humans are open to dangers from meal preparation irrespective of ethnicity, lifespan and traditional food favourites, as cooking is a significant part of civilisation. El–Sharkawy and Javed (2018) found heavy concentrations of CO_2 that surpassed Iranian permissible limits in restaurant kitchens, a major cause of growing indoor air contamination.

Besides CO_2 levels, CO and O_2 levels are monitored to indicate air quality, as per Mukhtar (2018). The permissible exposure limit (PEL) for O_2 is set between 19.5% and 23.5% (OSHA 1997). The NIOSH (2004) defined an oxygen-deficient atmosphere as any atmosphere containing oxygen at a concentration below 19.5% at sea level.

Chang et al. (2021) claimed that particulate matter (PM) is an invisible element leaving people vulnerable to the health effects of COVID-19. Shen et al. (2021) revealed that there was an increased air pollution exposure during the quarantine because of the freezing of rural to urban migration in China. COVID-19 restrictions required people to spend more time at home, and the exposure to air pollutants derived from domestic interiors was higher (Ezani et al. 2021). Malkawi, Al-Yousf and Mandil (2021) advised advancing the quality of air as air pollution increases the likelihood, vulnerability and severity of succumbing to COVID-19. The increasing $PM_{2.5}$ exposure in kitchens requires investigations to estimate the health impact of the global COVID-19 lockdown on the Chinese community in rural homes using solid fuels (Du et al. 2021).

The International Agency for Research on Cancer (IARC 2010) stated that 'cooking fumes' is a word generally used to label the apparent smoke produced during meal preparation. In addition to ultrafine PM, cooking methods generate aerosol oil droplets, combustion products, organic gaseous pollutants and vapour from the moisture in the food. Zhou et al. (2019) suggested that using a suitable ventilation system along with some ancillary procedures effectively reduces cooking oil fumes (COF).

■ 3.7 Constituents of cooking fumes

The air quality in the kitchens is deteriorated by the cooking fumes produced during meal preparation (Famali et al. 2022). The main source of pollutants is the burning of fuel used for meal preparation or the cooking process itself. Singh et al. (2016) found that indoor air pollutants such as CO_2, total volatile organic compounds (TVOC) and polyaromatic hydrocarbon (PAH) emissions are above the recommended guidelines in kitchens. Frying produces significant quantities of airborne PM, including ultrafine particles (UFP) and fine $PM_{2.5}$ (Zhai & Albritton 2020). The measured TVOCs and $PM_{2.5}$ concentrations exceeded the limits set by the Chinese National Standard in Chinese residential kitchens (Liu et al. 2020). A field study by Kulve et al. (2022) indicate that there is a high risk of restaurant chefs being exposed to $PM_{2.5}$ concentrations on a daily basis that are substantially over WHO standards. El-Sharkawy and Javed (2018) found levels of PM_{10} and $PM_{2.5}$ surpassing their IAQ recommendations, while the other air pollutants are lower but high enough to cause lasting sickness among food-service workers. However, non-stick pans generate less particles (Walker 2022). By-products such as free fatty acids, products of oxidation and polar compounds are formed when cooking oils are subjected to heat (De Alzaa, Guillaume & Ravetti 2018). Cooking fumes contain several chemical compounds, as discussed below.

Total volatile organic compounds are a wide range of organic chemical compounds present in ambient air or emissions. Singh et al. (2016) found that indoor air pollutants such as TVOC are above the recommended guidelines in kitchens. Wong et al. (2011) stated that poor lung function and higher respiratory symptoms among Chinese workers in gas kitchens are associated with exposure to higher concentrations of TVOC generated during gas cooking compared with those in electric kitchens. The TVOC mass concentration of 70 species is produced from heating cooking oils, as per Wang et al. (2020), from certain types of Chinese cooking that are toxic to human bronchial epithelial cells.

The PAH generated during cooking has carcinogenic characteristics (Wu et al. 2019), predominantly from cooking practice and COF. Solid fuels such as biomass and coal smoke contain many pollutants and known carcinogens (Ezzati & Kammen 2002). Nayek and Padhy (2020) reported exposure to benzene, toluene and xylene as important pollutants of incomplete combustion among rural women, where exposure time emerges as the single greatest contributor to solid biofuel burning in household kitchens in India. Over the past ten years, the use of solid biomass for cooking has decreased in developing countries. Despite this, 50% of the world population is subjected to IAP (Chakraborty et al. 2022).

Several carcinogens are reported in a study in Shanghai in a fried snack kiosk, a candy fritter kiosk and a commercial kitchen (Lee & Gany 2013). Chrysene, a human carcinogen, is a PAH, like naphthalene and anthracene, and is a natural constituent of coal tar. Yousefi et al. (2018) reported that frying oil in Iran is high in chrysene. Grilling, followed by frying and then steaming, produced PAH in the highest following order: naphthalene, toluene and benzene (Huang et al. 2021). Cooking fumes have significant carbonyl emissions. Formaldehyde is generally the most abundant carbonyl, reaching up to 60% (Ho et al. 2006). Cooking food generates particles, formaldehyde, acetaldehyde, acrolein, and H_2O (Walker 2022). Carbonyls such as acrolein are emitted from kitchens that use heated cooking oils. Dai et al. (2018) reported that acetaldehyde is possibly carcinogenic to humans. Lee and Gany (2013) found increased levels of acrolein and formaldehyde in smaller restaurants where frying and grilling are common. Katragadda et al. (2010) and Fullana et al. (2004) reported that low molecular weight aldehydes from olive oils are lower than canola oil under similar conditions with increased emission of volatiles above the smoking point. Dai et al. (2018) found the highest total quantified carbonyls concentration in Chinese barbecue, followed by Szechwan hotpot and Indian restaurants. In comparison, much lower concentrations are found in Italian, Shaanxi noodle and Chinese vegetarian restaurants.

Particulate matter, gaseous oxides, alternate fuel emission, frying oil safety and other chemicals will now be highlighted briefly. Gabdrashova et al. (2021) and See and Balasubramaniam (2008) posited that gas cooking is an important indoor source of PM. Deep-frying caused the largest increase in particle concentration and contained the highest proportion of nanoparticles (90%). The concentrations of all chemical species in the $PM_{2.5}$ were highest in one restaurant that served Cantonese dishes and applied oil frying methods, suggesting the cooking ingredients and conditions could be the determining factors for higher emissions (Bandowe et al. 2021). Cooking oil at deep-frying temperatures releases a variety of VOCs, PM and UFPs. Olive oil and lard produced the highest aerosol mass concentrations at 180 °C. (Sankhyan et al. 2022).

Deepthi et al. (2020) observed that PM concentrations are highest when cooking wheat roti and lowest when boiling tea in South Indian kitchens. Mandal et al. (2020) reported a cafeteria in Delhi with a maximum concentration of PM_{10} because of continuous cooking activities. Abdullahi et al. (2013) reviewed that Asian-style cooking emits more PM than Western cooking; barbecue emissions have higher levels of $PM_{2.5}$ concentrations than Chinese cooking styles. Lean meat cooking produces less concentration of particles than regular meat on charbroiling. Kulve et al. (2022) observed that pan fried pancakes resulted in the highest $PM_{2.5}$ concentrations in the breathing zone, followed by broiling hamburgers and stir-frying in a Chinese wok.

Siddiqui et al. (2008) established high concentrations of PM during cooking with wood. As per Fameli et al. (2022), the use of coal (and wood) to produce grilled dishes was responsible for 98.1% of the total emitted particulates (PM_{10} and $PM_{2.5}$). Seltenrich (2014) reported that fine and ultrafine particles (UFP) are released by heated spiral burners in stoves, electric ovens and toasters. Gas burners can generate NO_2 and other pollutants. Gas cooking produces CO_2 & H_2O, particles, NO_2, NO, CO and formaldehyde (Walker 2022).

Jiang et al. (2012) found CO_2 concentrations of 1420 ppm, 1370 ppm and 1470 ppm near gas stoves, which are higher than the acceptance criteria (CO_2 < 1000 ppm). Wong et al. (2011) stated that poor respiratory function and illness symptoms among Chinese workers in gas kitchens are associated with higher concentrations of toxic air pollutants such as nitric oxide (NO), NO_2, CO and CO_2. Nitrogen dioxide is a respiratory irritant produced in the burner, and CO_2 can cause drowsiness, headache and a 'stuffy' feeling.

Levels of CO_2 and other pollutants also often exceed international guidelines (Sharma & Jain 2019) in rural India. A high concentration of CO of 29.4 ppm was found by Siddiqui et al. (2008) in Pakistan from the use of wood cooking, significantly higher than the WHO maximum guideline of 9 ppm. Barnes et al. (2009) found that domestic use of solid fuels is linked to morbidity from childhood ARI in the Eastern Cape (South Africa).

Lee et al. (2001) reported that the indoor CO_2 concentration levels at a barbecue and a hot pot restaurant are 4–6 times higher than that at a dim sum restaurant and a continental canteen, where the indoor CO_2 concentrations ranged from 636 ppm to 2344 ppm. Due to insufficient ventilation, dining areas with cooking activities have indoor CO_2 levels exceeding the Hong Kong IAQ standard of 1000 ppm. Zhao et al. (2020) reported that:

> [*B*]oiling food in soup (hot pot) raised the relative humidity; without sufficient ventilation, cooking with radiation (barbecue) results in high personal heat exposure and low RH near the heat sources. A substantial rise in the CO level is observed with the burning of charcoal, whereas an increase in the CO_2 concentration was detected with the combustion of natural gas. (p. 2925)

At 180 °C, a common deep-frying temperature, oils with lower smoke points (olive oil and lard) generated the highest aerosol mass concentrations among all oils tested (Sankhyan et al. 2022). The European Union is the only region globally with guidelines on the safety of cooking oil and frequently assesses the oil quality based on the total polar compound (TPCs) test (Sebastian et al. 2014). The rejected frying oil in a Toronto commercial centre showed extremely high levels of peroxide value, free fatty acid (FFA) content and TPCs. Esfarjani et al. (2019) reported over-degradation of samples of discarded frying oils collected from 50 fast-food restaurants in Tehran.

Test strips can also indicate the FFA content of oil as colour strips chemically react to the presence of FFA in the oil when dipped. The colours that appear on the strip are compared with the colour reference chart to determine FFA levels. The lower the p-anisidine value, the better the quality of fats and oils analysed (Pucci 2014).

According to the National Cancer Institute (2017), heterocyclic amines are formed when animal protein is cooked using high-temperature cooking methods such as pan-frying or grilling over an open flame. As per Seow et al. (2000), inhalation of heterocyclic amines generated during the frying of meat (such as beefsteak) may increase the risk of lung cancers among Chinese women. Chinese cooking is found to release 30 times more dicarboxylic acid than Western cuisine (Lee et al. 2001). Air pollutants like methane (CH_4) are generated in higher amounts during gas cooking when compared with electric kitchens (Wong et al. 2011).

According to the FCSI (2006), the appropriate exhaust rate from the cooking process depends on several factors such as the menu, the type and the use of cooking equipment under the extractor hood, the style and geometry of the extractor hood itself and how the make-up air is introduced into the kitchen. Relevant cooking appliances are categorised in Table 3.2. When cooking, the fumes rise in a disorderly pattern, and diverse cooking methods have different surge characteristics (Timerbaeva 2010).

Keil, Kassa and Fent (2004) found that 39% of the hoods met the flow rate guideline of the ACGIH (Spellman 2006), but a lower 24% complied with the ASHRAE standard. Extractors for heavy-duty cooking, such as charbroilers and woks, have a low compliance rate of 18%. Bhatia (2012) suggested that ovens and pressure fryers may have very little plume until they are opened to remove the food product. The author added that open-flame equipment exhibits strong, steady plumes. The company added that as the plume rises and is captured by the hood, it is removed by the exhaust fan suction.

According to Shah (2013), tandoor ovens, which are fashioned from clay and common in kitchens serving authentic Indian cuisine, can reach temperatures of 480 °C. There seems to be a widespread preference for tandoori dishes in Durban, and the tandoor oven generates heat over 700 °F (371 °C), which contributes to foods' unique flavour and texture. A temperature gradient, according to the author, in a fully heated tandoor ranges from 588.5 °F (309 °C) at the bottom to 722.5 °F (383.61 °C) at the top of the cylindrical oven. Also, the repeated daily use of teppanyaki in proximity to the oil-sustained flames on a tabletop cook surface can predispose the chef and staff to lipid inhalation of injury-causing exogenous lipoid pneumonia

TABLE 3.2: Equipment classification and kitchen load.

Source	Light	Medium	Heavy	Extra-heavy
Greenheck (2020)	Gas and electric ovens	Combi-ovens	Upright broiler	Gas charbroiler
	Gas and electric steamers	Gas and electric fryers	Electric charbroiler	Mesquite
	Gas and electric ranges	Griddles		Infrared broiler
	Food warmers	Tilting skillets		Lava rock charbroiler
	Pasta cookers	Tilting braising pans		Wok
	Pizza ovens	Grill		Chain broiler
	Smoker	Hibachi grill		
	Rotisserie	Salamander		

(Rahaghi et al. 2016). Huang et al. (2021) reinforced that kitchen pollution can affect oxidative stress levels by influencing exposure levels among chefs, and inhalation is the main pathway of exposure to PAH among chefs when cooking.

Ventilation is diluting the air inside a building by extracting old air or injecting fresh air (Sandberg, Kabanshi & Wigö 2020). For human comfort indoors, the ASHRAE 62.1 standard recommends nominally 0.0025 m^3/s–0.005 m^3/s (5 cfm–10 cfm) per occupant for various types of living spaces and human activity in it. These measures are important criteria for maintaining IAQ in commercial kitchens. Depending on the size of the space, this usually works out to 5–10 air changes/hour. This is supported by South African National Standard Code of Practice (SANS) 10400 (2017), which confirms it to be 10 air changes per hour and 17.5 l/s per person for commercial kitchens. The IMC Section 403.3 requires 7.5 cfm per person (3.5 l/s) plus 0.18 cfm per ft^2 (0.08 l/s per m^2) of the occupied space. A report from Kumar et al. (2022) indicate that low-income residential kitchens in 12 global cities had 43% ACH < 3/h and ventilation rate < 4 l/s per person, hence unacceptable from ideal ventilation. The results of Yi, Kim and Bae (2016) indicated that heat and gas capture efficiencies would increase as the ceiling exhaust outflow rate increases.

In summary, Singer, Delp and Zhao (2021) concluded that cooking is among the largest sources of air pollutant emissions, with substantial adverse health impacts. Gas cooking burners produce carbon monoxide (CO), nitrogen dioxide (NO_2), formaldehyde and ultrafine particles (UFPs), while electric burners generate UFPs.

■ 3.8 Hoods and canopies

Hoods and canopies ensure functional and energy-efficient ventilation of catering areas (Kong & Zhang 2016). Park (2018) stated that the main purpose of a kitchen canopy is to extract excess heat, steam, fats, smoke and odour arising from cooking processes. Removing these by-products of kitchen activity helps achieve a reasonably comfortable and safe working environment and prevents the spread of odours to other parts of the building. Bhatia (2012) proposed that the removal of hot vapours at the source should help prevent the kitchen from becoming too hot. This section will review multiple types of hood systems commonly mounted in commercial buildings to remove effluent from cooking appliances.

The inside lower edge of canopy-type Type I and Type II commercial hoods has an overhang or extends a horizontal distance of not less than 15.2 cm (6 in) beyond the edge of the top horizontal surface of the appliance on all open sides (Park 2018). The vertical distance between the front lower lip of the hood and such surface should not exceed 121.9 cm (4 in) (IMC 2015). However, Clark (2012) argued that the front overhang should be a minimum of 22.9 cm

(9 in), and the side overhang should be a minimum of 15.2 cm. When hoods serve on convection ovens, the overhang should be 15.2 cm (6 in) past the door opening at 90° from the oven. This often translates to a 45.7 cm (18 in) front overhang. The grilling and broiler units should not be at the end of the hood. These high heat and smoke-producing devices should be towards the centre of the hood's length (Clark 2012). Kitchens installing additional equipment as an afterthought can have appliances extending beyond the hood range. Zhang et al. (2020) reported that stir-frying stoves installed at the end of the appliance lines might challenge the hood capture and containment (C&C) performance and increase the exhaust volume required for capture. It is better to position the heavy-duty stoves in the middle of the appliance lines and the light-duty appliances at the end. The capture area of range hoods should cover most of the range surface. Notwithstanding, McNulty (2003) recommended that the hood be extended 7.5 cm (3 in) beyond the left and right edges of the cooktop.

The cross profile of American or European-style cooking hoods is usually rectangular (Han et al. 2019). The traditional Chinese style of cooking hoods is different, and the front lower edge of the hood is designed at a 30° angle, but this reduces the volume of the exhaust hood. Jeong et al. (2016) stated that:

> [/]n the case of the canopy hood, which is one of the existing local exhaust ventilation systems, a partial amount of effluent seeps out and accumulates on the upper workspace when the rate of ventilation is insufficient or when the buoyancy effect of the effluent is significant. (n.p.)

Livchak, Schrock and Sun (2005) verified that a commercial kitchen is often characterised by high heat loads and air change rates. Kitchen workers can partially compensate for a low flow-rate exhaust fan by continuing to run the fan after cooking (Dobbin et al. 2018). Rim et al. (2012) showed that range hood flow rate and burner position (front vs rear) could have strong effects on the reduction of indoor levels of ultrafine particles (UFP) released from the stove and oven, subsequently reducing occupant exposure to UFP. Higher-range hood flow rates are generally more effective for UFP reduction, although the reduction varies with particle diameter. Dobbin et al. (2018) suggested the use of a kitchen exhaust fan after the cooking process to reduce UFP levels near the gas stove. Sjaastad (2010) recommended letting the kitchen exhaust hood run for 30 min after the frying process, and it led to a significant reduction in the level of particles in a much shorter time than when the extractor is turned off immediately after frying is finished.

The influence of the range hood exhaust is larger for the back burner than for the front burner (Rim et al. 2012). Reduction for the front burner was recorded between 31% and 94%. It seems that the use of the back burner favours extraction with 54% to 98% and from 39% to 96% for the oven. While a detailed study of extraction rates is not within the scope of this study, it is useful in understanding what is needed in designing commercial kitchens.

Cooking emissions are captured, contained and removed from the kitchen space by a variety of factors, including kitchen hood design, user behavior, cooking methods, airflow rates, cooking position and ventilation configurations (Swierczyna et al. 2022). In addition to the amount of exhaust air factor, hood style, structural features and installation alignments, the make-up air inlet, as well as the arrangement of equipment below the hood, has a strong impact on the capacity of the hood to capture and inhibit the spread of emissions (Han et al. 2019). However, attributes such as end panels, appliance location, overhang, space behind cooking equipment and size of the hood attributes are frequently ignored within the commercial kitchen ventilation design specifications (Fisher, Swierczyna & Karas 2015).

Let us look at the types of hoods, hood overhang, height and size of hoods, efficiency and flow rates, and hood maintenance. The following types of listed hoods, wall-mounted canopy hoods, island canopy hoods, either single or double and proximity hoods such as back-shelf, pass-over or eyebrow, all have different capture areas and are mounted at different heights and horizontal positions relative to the cooking equipment (Fisher et al. 2015). Kulve et al. (2022) report that canopy hood is more efficient compared to backshelf hood in extracting $PM_{2.5}$. Kim et al. (2022) support that canopy hood is efficient for removal of PM and beneficial to the health of a cook. According to Han et al. (2019), wall-mounted exhaust canopies require lower air velocities to exhaust thermal plumes. The performance of different styles of exhaust hoods varies significantly.

To meet the required C&C, a single-island canopy hood requires a greater exhaust airflow rate than a wall-mounted hood, and a wall-mounted hood requires a greater exhaust airflow rate than an engineered proximity hood (California Energy Commission 2003). Back-shelf or pass-over are not allowed for extra-heavy-duty loads, and eyebrow hoods are not permitted for solid fuel and gas equipment or extra-heavy equipment and heavy-duty equipment, but they are suitable for medium and light-duty equipment (IMC 2015).

A large overhang is also appropriate for appliances that create thermal plumes once doors or lids are opened (Fisher et al. 2015). Stipulating a deeper hood such as 1.5 m versus 1.2 m will directly increase overhang, provided appliances are positioned as far back as possible in the hood (Han et al. 2019:8). Increased overhang and a reduced rear gap of appliances improve the hood performance. Hood must overhang or extend a horizontal distance of at least 15.2 cm (6 in) beyond the outer edge of the cooking surfaces on all open sides. Additional overhang 25.4 cm to 30.5 cm (10 in to 12 in) can help improve capture effectiveness for open-flame equipment such as char-broilers. An integral 7.62 cm (3 in) air space between the back of the hood and the wall should be provided to meet *National Fire Protection Act* 96 (NFPA 96) clearance requirements against limited combustible walls (Bhatia 2012).

The width of the plenum and hood mounting height should be considered when determining the supply of air to the unit (Clark 2012). Sjaastad and Svendsen (2010) verified that the varying heights could have a greater influence on the individual exposure of a chef, as the mass concentration of chemicals in the inhaling zone of the cook is greater when the distance between hood and stove is 50 cm than when it is 60 cm. The authors added that if the extractors are not able to remove all the thermal plume and food preparation smoke, some of the effluents will escape to the edges of the hood. However, Bhatia (2012) claimed that higher hood height improves capture efficiency. The depth of the hood should be a minimum of 60.96 cm (24 in) and should not exceed 91.44 cm (36 in). Moreover, Han et al. (2019) claimed that a deeper hood of 1.5 m increases the overhang and decreases the rear gap, thus improving the ability to capture and contain the thermal plume. They put it in this way: 'a larger exhaust hood depth has a greater impact on hood performance than that of the reservoir volume when the hood ceiling is lowered' (Han et al. 2019).

According to Fisher (2015), a deeper hood enables a larger overhang and accompanying decrease in exhaust airflow for C&C. This reduction in exhaust rate is attributed to the increased hood tank; increasing capture chamber volume will increase the interior hood height. This is not applicable universally, as the ceiling height of kitchens is set. A proximity hood can outperform a canopy hood. A mounting height of 1.1 m (3.5 ft) is unreasonable for a canopy hood; a low exhaust is required to restrict the cooking emission. However, Halton (2007) claimed that the installation height of the hood should be 1.1 m above the appliances or 2 m above the floor. Undersized range hoods inevitably lead to positive pressure, which manifests itself into smoke and effluent from cooking remaining in the kitchen, making it both a hot and uncomfortable working environment (McGowan 2009).

Zhao et al. (2013) analysed Chinese-style kitchen hoods and found that increasing hood volume did not improve capture performance. However, side panels did improve the capture efficiency, especially at higher positions. In addition, when the exhaust opening is located at the rear of the hood, the hood capture efficiency improvement is enhanced. The results of the flow pattern in a commercial kitchen hood system show that the highest velocity of plumes has more tendency to flow past the lower part of the filter (Pairan 2017). From the simulation work, the velocity of airflow tested is 0.28 m/s, which is enough to control the heat and give enough comfort to the working space for the size of the kitchen simulated (Manshoor et al. 2014). For a comfortable indoor environment and effective purification, the Chinese commercial kitchen fume exhaust system should be operated at the optimum airflow (Zhang et al. 2022) Sound application of the make-up air in the kitchen hood can advance IAQ in a commercial kitchen and keep the kitchen areas comfortable for the workers. The study of make-up air is beyond the scope of this research and will not be discussed further.

The net exhaust volumes for hoods can be reduced during part-load or no cooking conditions. The *National Fire Protection Act* 96 (NFPA) in the USA and Canada permits the exhaust duct velocity to reduce to a minimum of 2.54 m/s (500 fpm). It is also important to reduce the make-up air parallel with the exhaust rate to keep the facility pressure relationships constant (Clark 2012). Allen (2014) reported that inadequate make-up air could cause a negative pressure condition in a building. However, drawbacks are seen in areas that are draughty or stuffy, doors that slam, poor air quality, reduced energy efficiency and back-venting of combustion gases from HVAC equipment.

The air velocity for Type I ducts should not be < 2.54 m/s (500 fpm) for variable flow and reuse of existing ducts and should not be > 12.7 m/s (2 500 fpm) for reasonable noise levels. Variable-speed controls regulate the net exhaust volume for hoods. Moreover, duct hood exhaust collars are sized to provide a velocity of 9.1 m/s (1.800 fpm). Measures of airspeeds in different areas of a kitchen will influence thermal comfort and help determine the criteria for the design of restaurant kitchens.

Food-service establishments should clean exhaust hoods regularly and display a certificate. As outlined by NFPA 96 guidelines, routine hood cleaning will keep hood, baffle filters, grease ducts, fans and grease tray areas free from dangerous grease build-up, preventing fire hazards in kitchens. The NFPA is the governing body providing the minimum codes of standards for the kitchen exhaust cleaning industry via the NFPA 96: Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations. Hood Products (2020) proposed a schedule of inspection for grease build-up in Table 3.3.

A kitchen exhaust fan removes grease, smoke, steam and odours while cooking. To ensure that the exhaust system is not at risk for a grease fire, the kitchen hood exhaust system should regularly be cleaned according to fire code standards (Bare Metal Standard 2020). The exhaust system must be inspected and cleaned to comply with the health department and fire inspectors. Further to Table 3.4, the amount of cleaning required depends on how busy the kitchen is. Also, Burt (2017) added cleaning interventions for average restaurants to be every 90 days; for fast-food restaurants, it is once in a 30-day period; for oven hoods, it is once in 180 days, whereas for hoods over

TABLE 3.3: Annual cleaning schedule of extractor systems.

Type or volume of cooking frequency	Frequency
Systems serving solid fuel cooking operations	Monthly
Systems serving high-volume cooking operations such as 24-h cooking, charbroiling, or wok cooking	Quarterly
Systems serving moderate-volume cooking operations	Semi-annually
Systems serving low-volume cooking operations, senior centres	Annually

Source: Hood Products (2020).

TABLE 3.4: Summary of cooking fumes affecting IAQ in kitchens.

Category	Author and country	Source	Pollutants	Health
Cooking appliances and cooking process	Ho et al. (2006) **Hong Kong**	Cooking fumes	Carbonyl emissions: formaldehyde	
	Katragadda et al. (2010)	Carbonyl emissions	Acrolein	
	Srivastava et al. (2010)	Carbonyl emissions	Acrolein	
	Wong et al. (2011) **China**	Gas-fuelled kitchens	NO, NO_2, CO, CO_2, CH_4, TVOC	Poor lung function
	Jiang et al. (2012)	Cooking areas	CO_2	Impact on the staff's physical health
	Singh et al. (2016) India	Cooking appliances, process of cooking	CO, TVOC, PAH	Decline in lung functions
	Wu et al. (2019) Taiwan	Cooking process: Chinese, Western fast-food	PAH, aldehydes	Tumour-promoting characteristics
	Mandal, Nagesh and Mandal (2020) Delhi, India	Cooking activities	PM_{10}	
Cooking fuels	Ezzati and Kammen (2002)	Solid fuels: biomass and coal	PM, SO_2, NO_2, CO, benzo[*a*]pyrene	Acute respiratory infections, COPD, cancer
	Lissowska et al. (2005) European countries	Solid fuels	Indoor pollution	Lung cancer
	Barnes et al. (2006) Eastern Cape, South Africa	Wood and cow dung		ARI
	Siddiqui et al. (2008) Pakistan	Wood fuel	CO, $PM_{2.5}$	Hazardous concentrations
	See and Balasubramaniam (2008)	Gas cooking	$PM_{2.5}$	
	Wong et al. (2011)	Gas kitchens	NO, NO_2, CO, CO_2, CH_4, TVOC	Poor lung function and respiratory symptoms
	Seltenrich (2014)	Electric coil burners in stoves, ovens and toasters; gas burners	UFP, NO_2	
	Zhao et al. (2014) China	Increases in temperature, wine and marinade	CO_2, TVOC	
	Sharma and Jain (2019) India	Wood, crop residue, dung cake or coal		It affects the health of cooks
	Nayek and Padhy (2020) West Bengal, India	Incomplete combustion	Benzene, toluene, xylene	The hazard index indicates cancer risk

Table 3.4 continues on the next page→

TABLE 3.4 (cont.): Summary of cooking fumes affecting IAQ in kitchens.

Category	Author and country	Source	Pollutants	Health
Cooking oil	Lin and Liou (2000) **Taiwan**	Preheating oil, stir-frying, pan-frying	Benzo[a]pyrene, dibenz[a,h]anthracene, benzene, formaldehyde	Carcinogens
	Metayer et al. (2002) China	Cooking oil fumes: rapeseed oil	Mutagenic substances	Risk of lung cancer
	Fullana et al. (2004)	Deep-frying oil	Low molecular weight aldehydes	
	Chatzilazarou et al. (2006)	Oil deterioration		
	Alomirah et al. (2010) Kuwait	Olive oil and cooking oil	Benzo[*a*]pyrene (BaP)	Carcinogen
	Srivastava et al. (2010)	Repeated heating of vegetable oils	PAH	Changes in the liver
	Svendahl et al. (2012) Finland	Cooking fumes	Aldehydes, alkanoic acids, PAH, heterocyclic compounds	Deleterious health effects
	Lee and Gany (2013) Singapore	COF, Chinese, Malay stalls	Condensate of fumes from cooking oils, PAH, PM	Genotoxic, mutagenic, lung cancer
	Sebastian, Ghazani and Marangoni (2014) Toronto, Canada	Used oil	PV, TPC, FFA	High levels of oxidation
	Yousefi et al. (2018) Iran	Frying oil	BaP, PAH 4, PAH 8, PAH 13	
	De Alzaa et al. (2018) Australia			
	Wang et al. (2020)	Chinese cooking	FFA polar compounds	Toxicity of human bronchial epithelial cells
Cuisine	Seow et al. (2000) China	Frying of meat: beef, pork	Heterocyclic amines: carcinogens	Risk of lung cancers
	Abdullahi, Delgado-Saborit and Harrison (2013)	Charbroiling: fatty meat	Higher $PM_{2.5}$	
	Wang et al. (2015)	Barbecue: cooking fumes	High mass fractions of organic acids	
	Deepthi, Nagendra and Gummadi (2020) Delhi, India	Roti	PM	
	Bandowe et al. (2021)	Cantonese dishes: frying	$PM_{2.5}$	
Cooking methods	Lee, Li and Chan (2001)	Barbecue	CO, PM_{10}, $PM_{2.5}$	
	See and Balasubramaniam (2008)	Deep-frying	Nanoparticles, PM	
	Lee and Gany (2013) Finland, Norway	Frying and grilling	High levels of fat aerosols, acrolein, formaldehyde	
	Peng et al. (2017)	COFs	Deep-frying	
	Zhai and Albritton (2020)	Frying	UFP, $PM_{2.5}$	
	Huang et al. (2021)	PAH	PAH: naphthalene, toluene, benzene	Increase oxidative stress levels among cooks

Key: CH_4, methane; CO, carbon monoxide; CO_2, carbon dioxide; COPD, chronic obstructive pulmonary disease; FFA, free fatty acid; IAQ, indoor air quality; NO, nitric oxide; NO_2, nitrogen dioxide; PAH, polycyclic aromatic hydrocarbons; PM, particulate matter; TPC, total polar compound; TVOC, total volatile organic compounds; UFP, ultrafine particles.

nongreasy appliances, cleaning once a year will suffice. Grease Cycle (2018) stated that grease and debris build up in the filter and slowly start to decrease the effectiveness of extractor fans. With delayed cleanings, a clogged grease filter can become a dangerous fire hazard. Zhao and You (2021) declared that effective emission control of COFs, particularly for grease particles, is always a cause of great concern for the catering industry. Zhang et al. (2020) reported that when the filters and exhaust duct were cleaned within the specified cleaning period of three months, there was no or little grease around the discharge outlet; the influence of the cleaning period was more significant than the purifier. The cleaning period and the number of burners in the kitchen were the major influencing factors for grease accumulation.

Grease filters in a hood are designed to remove grease particles from the exhaust air. Clark (2012) emphasised that the primary purpose of a filter is to prevent cooking flames below from entering the exhaust duct. The quantity of exhaust air keeps the filter's surface temperature at 93 °C. The configuration of the filter's baffle is to facilitate condensing of the moisture and grease vapours to be captured by centrifugal separation as they pass through the turns and cooling surfaces.

Grease filters are baffle filters, and multicyclic filters are easy to clean without any obstruction. This is to avoid the increase in pressure drops across the filter and the decrease in exhaust airflow, which will affect the system's efficiency (Pairan 2017). Baffle filters are commonly observable in Durban kitchens. The baffle plate increases the capture velocity by reducing the opening area of the hood; therefore, the ability to capture the contaminants from the thermal plume can improve (Han et al. 2019).

Basic hood grease filters also include an extractor cartridge and an extended surface filter (Clark 2009). The filter type designated should match the estimated performance of a hood. Simple baffle filters can be installed in light-duty and medium-duty hoods, as per IMC (2015) and NPFA 96 regulations. The extractor filters with a greater baffle length path are suitable for heavy and extra-heavy hoods as they permit additional condensing of the vapours before they are centrifugally separated.

Thomas (2014) added that UV technology could be applied to improve IAQ for HVAC systems that kill mould and bacteria in HVAC systems. Ultraviolet technologies in air-cleaning systems include a UV oxidation process that has a disinfection effect of killing bacteria (Alexandrova 2009). Ultraviolet technology appears to be unknown in commercial kitchens in Durban.

Electrostatic precipitators are highly efficient filtration devices that minimally impede the flow of gases through the device and are suitable for high-volume, high-grease catering establishments (Airclean 2018). Clark (2009) recommended that static precipitators should not be used to control the stack effluents until all the basic options have been exhausted, such as utilising a longer baffle path or an extended surface filter. Zhao and You (2021) indicated that the optimisation of the mechanical separation – filtration – electrostatic deposition purification system using rotating mesh plates instead of a baffle filter could reduce the environmental impact of global warming and eutrophication by about 35%, which reduces the emissions of CO_2 and SO_2.

3.9 Relative humidity

Parrott, Emmel and Beamish (2003) claimed that moisture is generated in a kitchen through cooking. Boiling foods such as rice, pasta or soup release a large amount of steam, increasing humidity (Caple 2018). Lester (2021) posited that humidity could wreak havoc in a commercial kitchen or a bakery. Kitchens are naturally hot environments with higher moisture levels in the air. Improper ventilation increases RH because warmer, moister air collects on kitchen surfaces. A commercial kitchen or bakery should strive for RH of around 60%. However, there is just too much moisture in the air for some delicate cooking techniques.

Zhang and De Dear (2019) claimed that high humidity intensifies warm sensations in hot weather and cold sensations in cold weather. People can tolerate a wide range of humidity levels within a comfortable temperature range. However, occupants' thermal sensations and humidity may be positively or negatively associated in warmer seasons, depending on the indoor temperatures. As the humidity in the air increases, sweat does not evaporate readily and stops entirely when at 90% RH (Ghasemkhani & Naseri 2008). According to Lan et al. (2008), women are more sensitive to temperature and less sensitive to humidity than men.

The RH plays a large part in conjunction with temperature to influence discomfort. EN ISO 7 730 recommends a humidity range of 30%–70% RH, mainly for IAQ reasons (Boduch & Fincher 2009). High levels of RH can work against the evaporative cooling effects of sweating and leave the body prone to overheating (hyperthermia). The authors added that human beings are sensitive to slight temperature changes yet cannot perceive differences in RH levels. Hence, Ahola, Säteri and Sariola (2019) found less attention to humidity in the comfort range of temperatures as it has a minor impact on the thermal sensations of the human body. Also, the influence of humidity on the preferred ambient temperature in the comfort range is relatively small according to EN ISO 7 730 (2005) and ASHRAE 55-2017 (2020).

According to Faizal et al. (2014), human thermal sensations react naturally towards the air temperature to maintain thermal comfort within an indoor RH of 30% to 60%. The authors added that a low RH causes dryness and itching, whereas a high RH increases skin temperature and residual skin dampness and encourages fungi. Humidity is a comfort indicator in subtropical Durban. A determining dry air supply is needed to keep the RH at a comfortable level. Thermal DV makes it possible to reach the same indoor target with relatively higher humidity in the air supply (Kosonen 2010).

Relative humidity in different kitchen zones tends to vary. Simone et al. (2013) revealed that the highest RH (76%) is in the dishwashing area. Similar high humidity levels are recorded in food preparation and cooking areas with spot measurements. However, Li et al. (2012) reported very high indoor temperatures during cooking and low RH that made the chef feel very uncomfortable in a Chinese kitchen. For optimum occupant comfort, RH of 40% to 60% is recommended (Passive Design 2018). Boiling food in soup (hot pot) raised the RH inside the dining area (Zhao et al. 2020).

In another line of enquiry, Rosone (2016) theorised that poor humidity control is not only a discomfort issue for restaurant kitchens but results in condensation, including mould and mildew growth. Moisture extraction through HVAC and provision for NV in commercial kitchens is usually observed to help reduce humidity. According to the Environmental Protection Agency (2017), 60% RH levels are enough to encourage mould growth; humidity levels less than 60% provide an ideal environment in the kitchen. On heat stress in the café and restaurant industry, McGowan (2009) advises that an ideal working environment should have a temperature range of 20 °C to 26 °C and RH between 40% and 70%.

A Tehran restaurant kitchen's study by Ghasemkhani and Naseri (2008) reports that at an RH below 30%, dry air affected eyes, skin, and the mucous membrane, while RH above 60% supported the growth of pathogens or allergens. Additionally, high humidity causes vent diffusers to drip water on the floor and form droplets on glass entrances and openings. Floors that stay damp or need a lengthy period to dry will further raise the humidity. Hence, the high quantity of water vapour produced is not a direct health concern but can contribute to high indoor humidity and related mould and pest issues (Kim et al. 2018). Notably, Munters (2004) found that when staff become too hot and want to turn the thermostat down, RH increases.

■ 3.10 Conclusion

Finally, with Huang et al. (2021), this chapter recommends that:

> [*C*]ommercial kitchens should establish an excellent ventilation system, introduce indoor air pollutant standards for kitchen environment, and at the same time, strengthen scientific and technological innovation in this field, and improve the mechanization of cooking operations. (pp. 52–55)

Chen, Su and Chen (2020) suggested that indoor pollutants can be well-controlled, and good thermal comfort can be obtained when exhaust volume is around 11 m^3/min to 14 m^3/min. To assess IAQ, creating a 'ventilation index' may be a useful concept (Ramasamy & Mukhopadhyay 2022).

This chapter discussed natural, artificial and MV, as well as architectural features of the building that affect ventilation. It then proceeds to deliberate on how IAQ is affected by the pollution because of the cooking process and factors affecting exhaust flow, and how to prevent inadequate ventilation.

Chapter 4

Noise and its effect on workers' health

4.1 Introduction

The previous chapter discussed the factors that influence thermal comfort in kitchens through ventilation. This chapter discusses how noise penetrates the workplace and creates a disturbance that increases the risk of hearing impairment and the strategies to prevent hearing loss.

At a basic level, noise may be defined as any unwanted sound (Jariwala et al. 2017). The Noise Management Policy, City of Tshwane (2004), added that noise nuisance in the noise regulations is any sound that disturbs the convenience or peace of any person. In terms of the *Environment Conservation Act* (73 of 1989) and the Noise Control Regulations in South Africa, 'to prove that a noise nuisance exists, a rational person must find a particular noise unbearable or acutely affecting the enjoyment of their property' (Hatchuel 2018).

Consistent with other municipalities, constraints on the behaviour of Durban residents are enforced by the gazetted by-law *Nuisances and Behaviour in Public Places*, implemented in 2011 (Ethekwini Municipality 2015a). Yelling, shrieking, ear-splitting noise or deafening noise is forbidden by local legislation. This does not include an emergency or rescue announcement, as per South Coast Sun (Konig 2019).

How to cite: Gangiah, S 2022, 'Noise and its effect on workers' health', in *Environmental ergonomics Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town, pp. 75–88. https://doi.org/10.4102/aosis.2022.BK346.04

Currently, no assessment of noise research in Durban restaurant kitchens has been conducted, so it is essential to correlate with occupational health control measures. Unsurprisingly, Gladieux (2015) established the cause for concern as little data exist regarding noise in the restaurant industry. Although numerous food-service workers toil in noisy environments, not much is known about the acceptable level of noise in kitchens and the effect of noise exposure on workers.

4.2 Noise in commercial kitchens

Occupational noise-induced hearing loss (NIHL) is the most prevalent occupational disease in the world (Chen et al. 2020). Lao et al.'s (2013) comparative studies on NIHL among Chinese restaurant employees and entertainment workers reported an average noise level of 86.9 decibels (dBA) while cooking. Wok cooking occurs at high temperatures by using high-pressure gas stoves that generate a higher noise level. Such pressure gas stoves seem to be a common feature among Indian, Chinese and Thai kitchens in Durban. Alonso and O'Neill (2010) reported that the sounds of small equipment, such as rattling pots and pans in open kitchens, created a loud noise. Even equipment as small as a spoon, when dropped on a plate, produces 110 dBA–115 dBA (Teder 2019). Equipment such as air conditioners, fans, food blenders and coffee grinders have noise rating indications, and they produce lower noise levels compared with other equipment commonly used in most food-service establishments (Engineering Toolbox 2004). Fischer et al. (2014) reported that noise levels of different blenders varied from 82 dBA to 91 dBA, hand mixers 77 dBA to 86 dBA, electrical coffee grinders 71 dBA to 83 dBA, espresso machines 61 dBA to 71 dBA and extractors 54 dBA to 68 dBA.

Draughts from fans and oven fans seem to interfere with normal communication in the kitchens (Figure 9.4). The National Academy of Sciences (2019) claimed that the intake noise is dominant on a large fan with an open intake. While there might be constant noise, it seems that kitchens' noise can vary before and during service, depending on the food production system. Chef Services Group (2020) stated that food suppliers use cook-chill systems nationwide. Such a cooking method in advance may help reduce noise levels during rush hour in kitchens.

Moreover, Rusnock and Bush (2012) added that noise from outside the restaurant, such as traffic, other businesses and airport locations, increases normal kitchen noise. The combined internal and external noise sources seem to have the potential to be uncomfortable, if not hazardous. Achutan's (2009) study of a dietary department found that the noise level from the dishwashing machine is within tolerance. However, combining the noise from the adjacent food preparation area from grinders, utensils and metal-to-metal contact between stainless steel pots and pans and metal racks increases the noise level above the NIOSH's recommended exposure limits. Jiang and Wang (2008) established that noise pollution is higher during cooking than before cooking in restaurants of varying capacities. These ranged from 74 dBA to 79 dBA exceeding the environmental noise limit of the city.

Green and Anthony (2015) similarly affirmed that the threat of hearing loss to millions of kitchen workers is unidentified. Kitchens are notoriously noisy, but they do not have to be (Serfozo 2018). According to SANS10400 (2017), the maximum equivalent continuous rating level for ambient noise recommended in restaurants and cafeterias is 45 dBA and 55 dBA, respectively; 55 dBA is recommended for hotel and hostel kitchens.

The causes of noise in kitchens include the following points. Noise is created because of poor upkeep and improper functioning of equipment; for example, parts of equipment can become unfastened over time or become worn (Twin City Fan 2020), and there may be a lack of lubrication at the appropriate times as per the OSHA technical manual (2008). Noise in equipment is caused by vibration, as in the case of fans, grinders, air conditioners and refrigerators. Fans mounted on supports have a natural vibration frequency, and the structure will tend to continue to vibrate once it has been set in motion. Mechanical vibration pertains to rotating parts, fasteners and structural supports that create noise. Duct attachment to the support structure may be loose; for example, a fan not supported could be the cause of extractors making a loud noise in kitchens (Fischer et al. 2014).

Regarding types of noise, Vardaxis, Bard and Persson Waye (2018) envisaged low-frequency noise (LFN) as a long wavelength and 45 Hz from the humming of a refrigerator. Low-frequency noise is broadband noise with a low frequency (10 Hz–250 Hz). Other environmental LFN includes ventilation systems, pumps, compressors and diesel engines, as well as indoor network installations. Sound with low-frequency characteristics can be more distressing when transmitted through lightweight building material.

In addition to LFN, other types of noise include continuous, intermittent and fluctuating. The continuous noise is produced by machinery that continuously runs without interruption from factory machines, air conditioners and extractors. Intermittent or variable noise rises and declines swiftly, such as in workshop machines that function in rotations. Impulsive noise is usually found in the building and demolition industry, where there are unexpected high noise pulses (Noise News 2015).

■ 4.3 Adverse health effects of noise

Occupational hearing loss resulting from workplace noise causes health hazards and is a slow and progressive condition. Akbari et al. (2013) ratified that exposure to noise at work causes deafness and the progression to NIHL, and it depends on factors such as frequency, intensity and duration of noise exposure (Sayapathi, Su & Koh 2013). Welch et al. (2013) confirmed the link between environmental noise and health problems. William and Short (2022) sum it up as, 'Noisy environments can have a negative impact on well-being. While most research related to noise has focused on hearing, sleep, performance and cardiovascular health, investigations of the detrimental effects of noise on mental health show conflicting evidence in relation to depression, anxiety and chronic stress'.

Blackwell, Lucas and Clarke (2014) reported that NIHL is the third most widespread chronic health condition in the United States. The potential health effects of noise pollution are said to be numerous, pervasive, persistent, and medically and socially significant (Goines & Hagler 2007). Noise impedes the learning process, psychological development, social activity and verbal communication, and impairs workplace performance and safety (City of Tshwane 2004).

Noise produces direct and cumulative adverse effects that impair health and degrade the residential, social and working environment with economic and intangible losses (Jariwala et al. 2017). It disrupts the balance of human life and affects health, directly and indirectly. Kerns et al. (2018) confirmed that along with hearing impairment, noise exposure is associated with many illnesses, including sleep disturbance, negative effects on the cardiovascular and metabolic system, and cognitive impairment in children (Peris 2020), not to mention annoyance. The WHO (2015) accordingly revealed that noise sensitivity is related to poor health outcomes and loss of well-being (Graydon et al. 2019). Hence, strategies for creating quieter kitchens will increase kitchen staff productivity and reduce accidents (Serfozo 2018).

Let us examine personal factors and the social and behavioural effects of noise. Besides age, gender and genetics are also associated with hearing loss (Nolan 2020). Nonmodifiable risk factors related to noise-related hearing loss include increasing age, genetics, male gender and race. The modifiable risk factors are voluntary exposure to loud noise, not using hearing protection, smoking, lack of exercise, poor diet, tooth loss and the presence of diabetes and cardiovascular disease. Noise interferes with concentration and communication, and well-being (Daniel 2007). Serious effects of environmental noise, among others, include general annoyance, sleep disturbance and reduction in quality of life, but it also contributes to a higher prevalence of hypertension and cardiovascular diseases (Münzel et al. 2014).

Several extra-auditory effects of noise are shown to be psychophysiological. Zare et al. (2019) found that during the night shift, sound pressure level (SPL) and exposure time significantly increase cortisol concentrations, a biomarker of noise-induced stress. Prashanth and Sridhar (2008) and Singh, Bhardwaj and Deepak (2010) claimed that higher noise levels result in irritability and outbreak of psychological distress among industrial workers, heart disease and absence because of both work illness and tiredness. Credence to the findings is afforded in the Noise Management Policy; a correlation is found to exist between high exposure to noise and increased admissions to mental hospitals.

Goines and Hagler (2007) posited that social and behavioural effects of noise exposure are multifaceted, understated and unintended. These effects include deviations in everyday behaviour such as closing windows and doors to eradicate outside noises, avoiding using balconies, patios and yards, and increasing the volume of radios and television sets. The authors observed that the changes in social behaviour range from hostility and aloofness to disengagement, contributing to accidents and depression. William and Short (2022) found statistical significance for noise sensitivity and noise annoyance as strong predictors of self-reported anxiety.

Noise pollution seems to have a significant impact on psychological health and well-being. Picard et al. (2008) found an association between accident risk and workers' hearing sensitivity. Occupational noise exposure and NIHL are associated with work-related injuries leading to admission to hospital (Girard et al. 2015). Besides, loud restaurant noise may hinder conversation and dining satisfaction and raise the possibility of negative health impacts for both customers and staff (Eichwald, Murphy & Scinicariello 2022).

Dzhambov and Dimitrova (2014) underlined the impact of noise on displaced aggression (DA) among youngsters from lower socioeconomic backgrounds and the quality of life in Bulgaria. Loud noises, higher noise sensitivity and continuous noises are associated with higher levels of DA. Therefore, the social climate might modify the way people perceive and react to environmental noise. Jariwala et al. (2017) reviewed the effects of noise exposure: changes in social behaviour include aggressiveness, unfriendliness, nonparticipation or disengagement; changes in mood include increased reports of depression.

Although there is a low sensitivity of the human auditory system to low frequencies, this type of noise causes much more discomfort and long-term, nonauditory effects (Alves et al. 2020). Greater annoyance is perceived when vibrations that comprise low-frequency components accompany noise. Exposure to noise, particularly LFN, negatively affects the variation in heart rate, which harms health in terms of cardiovascular diseases. Low-frequency infrasound at high decibels can cause tremors inside human organs, and it is painful (Cone 2017).

■ 4.4 Acoustic comfort and productivity

Locally, the Green Building Council South Africa (GBCSA) leads the transformation of the South African property industry to ensure that buildings are designed, built and operated in an environmentally sustainable way

(GBCSA 2017). Leadership in Energy and Environmental Design (LEED) is a standard green building guideline that includes acoustic credits, but it is not a mandatory element yet. On the contrary, the Global Sustainability Assessment System guideline does incorporate acoustics. Notwithstanding the impact of acoustics on occupant comfort and productivity, while it is established in the literature, this factor is often neglected in the design criteria of green buildings (Golbazi, El Danaf & Aktas 2020). For instance, Lee's (2019) assessment of the performance of IEQ in LEED-certified homes found the acoustic quality to be a low priority.

Frontczak and Wargocki (2011) posited that acoustic comfort is 'a state of contentment with acoustic conditions'. Vardaxis et al. (2018) added that acoustic comfort is a concept that can be characterised by the absence of unwanted sound and provides opportunities for acoustic activities without annoying other people. Al-Horr et al. (2016) stated that the acoustic comfort of buildings is the capacity to protect occupants from noise. Hence, the provision of a good acoustic environment is mainly associated with preventing the occurrence of annoyance. Of relevance to the commercial kitchen is Mujeebu's (2019) claim that acoustic comfort can be affected by factors such as the geometry and volume of space, the generation of sound within or outside the space, airborne noise transmission, impact noise and acoustic characteristics such as absorption, transmission and reflection of sound of the interior surfaces. Schiavon and Altomonte (2014) lamented that despite existing knowledge in this area, acoustic comfort is still lacking.

Managing acoustic comfort consists of minimising intruding noise and maintaining satisfaction among occupants (Saint-Gobain 2010). In a related line of enquiry, Frontczak and Wargocki (2011) suggested that acoustic comfort is affected by the country of origin. Acoustic comfort is greatly influenced by environmental, cultural and behavioural factors (soundscape) as per Laurìa, Secchi and Vessella (2020).

There is a direct relationship between acoustic comfort and occupant productivity in commercial buildings (Al-Horr et al. 2016). Acoustic problems arise from airborne sounds, outdoor noise, noise from adjacent spaces, noise from workplace appliances and the sound of nearby facilities (ANSI & ASHRAE 2010). André et al. (2020) confirmed that the noise produced by the fan is an obstacle to increasing airflow. Acoustic problems, therefore, need to be anticipated and addressed at the design stages of the building (Bluyssen et al. 2011). Despite being recognised as an important parameter, Andersen et al. (2009) indicated that acoustic comfort is not considered a high priority in building design leading to post-occupancy productivity-related issues. Göçer et al. (2019) indicated that the noise level and acoustic problems still exist, although the design of the building was satisfactory.

Noise affects human health and attentiveness, as well as increased fatigue and absenteeism from work, necessitating increased relaxation during work

(Nassiri et al. 2013). According to Naravane (2009), these indicators result in serious consequences for the performance and productivity of workers, with mental health effects. Goldsmith (2013) mentioned that workplace studies have established that noise in the workplace lowers productivity by two-thirds. NIOSH (2015) reported that noise corruption impacts the hearing of workers and affects worker productivity; optimal noise management seems to result in better productivity. Therefore, unavoidable noise and bustle in a commercial kitchen require careful layout and efficiency of kitchen operations as preventative measures.

Demographics such as age, gender and ethnicity also influence sensitivity to hearing. Although age is associated with hearing loss, there is no known singular cause. Hearing loss is caused by changes in the inner ear that occur as one grows older (MedlinePlus 2019). Daniel (2007) claimed that NIHL is common mostly among people above the age of 65 years, while hearing loss amongst children and young adults is increasing. Noise seems to be more of a problem for the 25–39 years age cohort (EASHW 2008b). Yamasoba et al. (2013) listed the risk factors for age-related hearing loss (AHL) in humans from epidemiological studies.

Nyilo and Putri (2019) reported that Indonesian hospital workers with NIHL are mostly kitchen workers (68.75%) comprising women (58.33%). Lao et al. (2013) claimed that being male and elderly is notably related to an increased risk of hearing loss in both the food service and entertainment industries. There are differences in the way men and women experience acoustic environments, as women are more sensitive to sound. EASHW (2017) found that noise exposure is higher than average in hotels and restaurants. A quarter of the time, exposure to noise is reported by 38% of men and 30% of women. Amongst women, the moderate or worse hearing difficulty is common among caterers and cleaners. The financial and health costs of occupational noise exposure are enormous for both individuals and society (Chen et al. 2020). The economic burden on society is extremely high and constantly growing. Nelson et al. (2005) reported that the worldwide morbidity of occupational NIHL was 16% in 2000; the effects of exposure to work-related noise are predominant in men more than in women in sampled subregions. Yang and Moon (2019) found that women have higher scores for acoustic comfort at 55 dBA than those of men with statistical significance.

Concert halls, nightclubs, sports stadiums and a variety of other recreational environments all have high sound levels that can permanently damage the ear (Pienkowski 2021). Fligor, Levey and Levey (2014) reported from a survey on noise that 40% of Africans did not exceed the daily and weekly allowance for noise, compared with 14% of African-Americans who did not exceed the daily and weekly allowance. Lin et al. (2012) reported that public health reports of hearing impairment have confirmed that the likelihood of hearing disorder is considerably more minor in black persons than in white persons.

TABLE 4.1: Noise classification in restaurants.

Noise levels in restaurants	Category
70 dBA or lower	Quiet
Between 71 dBA and 75 dBA	Moderate
Between 76 dBA and 80 dBA	Loud
81 dBA or higher	Very loud

Source: Farber and Wang (2017).

A darker-skinned individual has higher inner ear melanin, which offers protection from hearing disorders. Yamasoba et al. (2013) found that because of the genetic disinclination of the African race, there is a 60% to 70% lower odds of NIHL and AHL amongst them compared with white subjects.

According to Crandell, Mills and Gauthier (2004), African-Americans are less likely than Caucasians to identify symptoms of excessive noise; the former are at risk of hearing damage, with the latter being less likely to participate in activities that are potentially hazardous to hearing. This difference among African-Americans might be because of the absence of a connection between hearing protection information to self-perceptions, goals and activities. This observation may be pertinent in the context of the proportionally high African staff in South African commercial kitchens.

■ 4.5 Acoustics classification

At an elementary level, building noise may range from being unbearable to being quiet. According to Rasmussen (2014), acoustic classification schemes for acoustic conditions in commercial kitchens do not seem to be available, although they are invaluable for the quality of work-life amongst food-service workers. Farber and Wang (2017) reported on the sound levels of restaurants and their impact on health and hearing advice that classified sound level thresholds guided by Hearing Health Safety Standards in Table 4.1. Moderate and loud categories of noise affect the ability to hear and converse with others.

Fligor et al. (2014) cited the class descriptions for acoustic comfort in residential units, suitable for office environments that are much quieter when compared to a busy commercial kitchen. It seems unrealistic to expect noise levels lower than 70 dBA in a busy kitchen in cooking areas. An evaluation of noise levels in kitchens will indicate, among others, the need for sound absorption fittings and an improved maintenance schedule for mechanical equipment.

■ 4.6 Occupational risk from noise and assessment

The NIHL, because of occupational exposure, represents nearly one-third of all occupational diseases in Europe, irrespective of the economic sectors

(Arezes, Bernardo & Mateus 2012). According to Starkey Hearing (2017), deafness is a protracted illness in the United States, subject to loud noise. Simone et al. (2012) reported from a survey of 100 kitchens in the United States that noise in the kitchen environment is distracting.

To throw some light on NIHL, Green and Anthony (2015) examined predisposing elements associated with noise exposures amongst food-service workers and that interventions be undertaken to prevent NIHL. It seems that cooking operations can lead to loud noises, from pounding meat to blenders and grinders, as well as loud workers. While there is no NIHL in commercial kitchens, NIOSH (2015) reported that any worker can be at risk for NIHL in the workplace.

While compliance with occupational regulations in some sectors can assist management, it seems that there is no regulation on acceptable noise levels in commercial kitchens, as is the case for mines. According to Edwards et al. (2011), 73.2% of miners in South Africa are exposed to noise levels above the legislated occupational exposure limit of 85 dBA. Ninety per cent of coal miners and 49% of miners have NIHL by the age of 50 years, NIOSH (2015) explained. This may be attributable to a lack of compliance.

Smoking is associated with a higher risk of hearing loss, and the risk tends to be higher with a greater number of cigarette packs smoked (Lin et al. 2020). Wang et al. (2021b) found that age, gender, tobacco and alcohol consumption were confounding influencing factors of hearing loss other than noise exposure. Using hearing protection devices (HPD) in an environment with loud noise exposure for hours every workday likely protected individuals from NIHL.

Although noise is not the subject of many empirical studies, it should be a concern in the hospitality industry, especially from the duration of exposure. Gardner et al. (2014) stated that staff in cafés might be at moderate risk with a daily noise exposure level of 74 dBA. A study of army kitchens in China revealed noise levels between 77.70 dBA and 83.50 dBA, which is higher than in dining room and storeroom areas, and the tingle and tinnitus of ears in the kitchen worker group are higher than in other staff (Yu et al. 2010). The authors added that some cooking rooms have the highest noise levels affecting the hearing abilities of kitchen workers. Noise levels in different areas of a kitchen, therefore, influence acoustic comfort (Yu 2009). Zhang et al. (2020) reported that 89.6% of the chefs felt that the kitchen noise interfered with their work and health, indicating that the current acoustical environment in commercial kitchens was poor.

The next section will discuss the assessment of noise levels, prevention of NIHL and strategies for noise reduction. As a significant component of environmental criteria in the kitchen, the measurement of noise is an important feature in the kitchen environment. Arezes et al*.* (2012) recommended measurement of the acoustic characteristics of the sources, duration of exposure, the type of equipment and procedure. This study will observe the sources of noise and noise levels before and during cooking operations.

As with most measures, there is a need to eliminate subjectivity. The use of measuring instruments reduces measurement uncertainty and includes the use of dosimeters, sound level meters, the selection of the measurement period and workers' observations (Arezes et al. 2012). Also included are components in evaluating health effects (Prashanth & Sridhar 2008). Measuring noise frequency is, however, outside the delimitations of this research. Noise levels in different areas of a kitchen will influence acoustic comfort and help understand the nature of this essential criterion in the design of commercial kitchens in Durban.

Traditionally, the prevention of NIHL is addressed by providing HPD and reducing noise emissions. Engineering controls could diminish the burden of NIHL to reduce noise production at its source. However, this is insufficient for many occupations, especially when noise levels exceed 130 dBs–140 dBs (Lynch & Kil 2005). Effective management of noise at work is essential, as workers are not timeously motivated to take any action because NIHL occurs gradually, is invisible and has an ambiguous time course in an individual (Gardner et al. 2014).

Hansia and Dickinson (2010) argued that in South African gold mines, NIHL might persist because of the limited use of HPDs and suboptimal knowledge of noise as a hazard. Comparable results are found in India regarding ignorance amongst workers about the harmful effects of noise on hearing and health.

Hearing loss and prevention programmes should be targeted at occupations identified with high noise exposure and in those industries with the highest proportion of noise-exposed workers where HPDs are not used. Occupational and Safety Health (2019) specialists confronted noise-related issues in the workplace with the grading of noise to regulate noise by elimination or substitution of noise sources, collective control measures through engineering and work organisations, and personal protective equipment (PPE). The different techniques must be optimally balanced to avoid extreme behaviour amongst workers. If noise-masking does not reduce the noise sufficiently, occupants will speak louder than normal to be heard, causing further annoyance amongst fellow workers.

Measures such as audiometric monitoring of workers' hearing to reduce noise pollution in the Chinese army benefitted staff. Arezes et al. (2012) observed that because of the magnitude of the noise problem, the European Directive had set exposure limits for workers' protection according to their exposure profile (EASHW 2008b). Hearing protectors should be worn if the source of the noise cannot be enclosed or isolated. OSHA 3 074 recommended the introduction of a hearing conservation programme (HCP) that contains audiometric testing and training. It seems that only manufacturing units have a HCP in Durban, where all workers on the factory floor must wear HPDs.

A noise contour map has become useful in managing noise. A noise contour is a map line that symbolises equal noise exposure levels. Forouharmajd and Shabab (2015) proposed that two measures can display the noise contour charts as emission profiles on a floor plan, including SPL and noise intensity. Noise contour maps, with workplace layouts, give important data on zones of low sound levels. High-risk noise pollution areas determined by the noise map have the potential for kitchen noise management.

The blame for all the noise comes from the clean, slick, modern look favoured by many restaurant operators and their customers. The sound is reflected because of the restaurant’s hard floors, bare tables and high ceilings, according to the Zagat survey of restaurants in 2015. Glass reflects sound, and a slap-back effect can occur when angles and surfaces bounce noise from one to the other. Noise absorbent panels reduce noise.

The use of absorptive materials such as rubber to insulate buildings reduces heavy vibrations and disturbing sounds. According to OSHA (2014), reflected sound that reverberates from the walls, ceiling and floor will add to the sound wave propagating directly from the source to the receiver, increasing the overall noise level within a room. Acoustical absorptive materials installed on walls and ceilings reduce the reflected sound, absorbing and dissipating the sound before it can be reflected. Special acoustic tiles can also be fixed to the kitchen ceiling, but polystyrene is not permitted in commercial kitchens. Ceiling absorption is the most effective method to enhance the acoustic environment of a restaurant.

Other ways to reduce noise in the kitchen (Fischer et al. 2014) include preventative maintenance such as properly lubricating and aligning moving parts and decreasing equipment speed (OSHA 2014). Extractor fans must be securely supported. It seems that this could be the cause of extractors making a loud noise in kitchens. Noise excitation reduction can be achieved by damping, decoupling and encapsulation, with reduced noise emissions up to 3 dBA.

Regarding kitchen activities, Achutan (2009) recommended that not stacking dishes will reduce clanging noises and that hearing protectors for dishwashing room staff should be adopted. Noise levels in kitchens generally range from 65 dBA to 85 dBA.

4.7 Noise reduction design options in kitchens

Eliminating noise in kitchens is beneficial for workers as it produces a peaceful, pleasant environment that makes employees more attentive and focused and improves working conditions. It facilitates communication, improving productivity and safety when critical messages must be received and comprehended (Ecophon 2010).

Alpert (2018) claimed that designers could strategise the exposed kitchen setting to reduce noise. Acoustic separations, floor treatments and perforated metal ceiling tiles are important, but they are rarely enough to cut down on all the noise produced during a busy rush. Preparation work and clean-up can be separated from the chef's area or open cook lines.

Kitchen noise can be minimised by utilising the right layout and design for the kitchen. For instance, Zhang et al. (2015) suggested that when the intelligibility of the dining hall is poor and the noise is mainly from the customers, a layout that shortens the distance between speaker and listener can improve speech intelligibility, as is possible in open-plan kitchens. Earlier, Yu (2009) recommended redesigning the kitchen and dining areas to reduce noise spillover.

There are several design possibilities to reduce noise, such as selecting equipment with lower sound-power levels:

- *Installing silencers for extractor fans*: Clements et al. (2019) observed that a high flow rate ventilation system might provide good air quality but can also lead to increased noise levels because of fan and duct noise.
- *Installing suitable mufflers on engine exhausts and compressor components*: Mufflers or silencers can be used on noisy, pressurised air equipment to reduce noise at the source (OSHA 2014). Generators during load-shedding in kitchens that run lights, fans and some appliances can be muffled to reduce noise.
- *Installing acoustic enclosures for equipment casing that radiate noise*: Refrigerators, ice machines and air coolers can be muffled to reduce noise in kitchens.
- *Improving the acoustic performance of constructed buildings by applying sound insulation*: Sound insulation during construction and finishing for ceilings and walls can be covered with acoustic tiles.
- *Installing vibration isolation for mechanical equipment*: Grinders and blenders, especially ice crushers, can be installed on tables with vibration pads to prevent noise transmission to the floor.
- *Installing acoustic barriers without fissures and with an uninterrupted lower surface density of 10 kg/m^2 to minimise the transmission of sound through the walls*: Barriers should be positioned close to the source to be effective. According to Noise Help (2019), acoustic doors can be installed between the kitchen and dining room, or a double door system or heavy fir door can be installed to prevent noise transmission from outside. Soundproof French doors or double-glazed windows can be installed.
- *Developing a mechanism to record and respond to complaints*: Complaints from staff, customers and neighbours about noise exposure should be attended to.

Behavioural guidelines proposed by the ACGIH (Spellman 2006) include additional guidelines that are pertinent to commercial kitchens envisaged in this study. Although hearing protection is preferred for any period of noise exposure > 85 dBA, the interval of noise exposure can be limited. For every 3 dBA increase in sound levels, the 'allowed' exposure extent should be decreased by 50%. Shift work scheduled in the rotation will reduce noise exposure, as some shifts are less busy and hence less noisy; split shifts can reduce noise exposure. Preceding the distribution of HPDs as the final control mechanism, the use of sound shielding materials, isolation of the noise source and additional engineering controls should be executed. Regular medical hearing testing should be completed on staff exposed to high noise levels. A change in management policy on hearing checks for kitchen workers will be useful. It seems regular maintenance of equipment will assist in lower noise levels in commercial kitchens.

■ 4.8 Hearing conservation programmes

Kitchen workers suffering from NIHL can be administered pharmacological intervention to prevent further hearing loss (Lynch & Kil 2005). There is a dearth of literature on HCP in kitchens. Nonetheless, Kerns et al. (2018) maintained that worksite health and wellness programmes should include screenings for hypertension and elevated cholesterol to target noise-exposed workers.

Many HCPs are limited in their ability to control exposure to high-level noise, partly because of inadequate sound attenuation by HPDs. According to Lynch and Kil (2005), there is an urgent need to enhance current levels of hearing protection. However, HPD is inadmissible in the food-service industry to avoid miscommunication, and hence, engineering design options during construction in kitchens are the solution.

If workers are exposed to noise levels at or above 85 dBA, an HCP should be established. The programme includes a policy and procedure. The Standards Council of Canada's (2011) Hearing Loss Prevention Program Management recommended that a hearing preservation programme include hazard identification and exposure supervision, regulating procedures, HPD, hearing analysis, awareness and training, and continuous monitoring and improvement.

Pimenta et al. (2019) recommended that an evaluation of the HCP's efficacy should be conducted as per the checklist proposed by the NIOSH. The HCP includes physical, human and organisational assets, which assist in the application of methods that lead to detecting, analysing, monitoring and regulating the exposure of workers to higher noise and other risk factors that may trigger the development of work-related NIHL.

Sound masking is another potential method to mask noise using other sounds to enhance emotional valence. Tong et al. (2021) used six natural sounds, flowing water and waterfall, robin and wood thrush, cicada and katydid, to mask the noise of a range hood, which is the predominant source of noise in an experimental kitchen. Yang et al. (2022) proved that acoustic metamaterials, based on the concept of the extended tube on a commercial kitchen hood, indicate superior noise reduction performance as per standard acoustic power measurement.

■ 4.9 Conclusion

To conclude, in Chapter 4, the sources of noise in kitchens, types of noise and adverse health effects of noise were discussed, as well as acoustic comfort, noise and productivity, and demographics. It further deliberated on noise classification, NIHL, strategies for noise prevention and noise reduction options in kitchens by a few engineering applications to kitchen appliances. It then urged for the implementation of HCP by employers for kitchen workers to minimise sound levels in the workplace.

Chapter 5

Lighting in kitchens

5.1 Lighting and quality of life

The previous chapter focused on a review of indoor environmental criteria for the design of restaurant kitchens in Durban with respect to acoustics. This chapter will present various aspects of light and its influence on human well-being. The discussions will show that VC is dependent on several parameters such as type of light, contrast, glare and flicker. The chapter will conclude with regulations in kitchens and safety in the workplace. Karyono et al (2022) emphasise that the industry 4.0 aim is to enhance a worker's life by providing a better work environment with lighting comfort.

Light is the essence of human life (Fedoronko 2020). Light is necessary for vision; it enables us to sense and perceive our surroundings and affects our physiological and psychological health (Knoop et al. 2020). Lighting conditions can create responses, or so-called non-image-forming effects, which can be either acute or circadian (Van Duijnhoven et al. 2019). Pachito et al. (2018), in a wider perspective, declared that exposure to light is crucial in a diversity of biological processes, as it is linked to the human biological clock (Melanson et al. 2018). Light has a massive effect on human physical and mental well-being, as it is encoded in human DNA to perform better under specific lighting (Felderman 2017).

How to cite: Gangiah, S 2022, 'Lighting in kitchens', in *Environmental ergonomics Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town, pp. 89–113. https://doi.org/10.4102/aosis.2022.BK346.05

Artificial light is a compulsory feature of many manufactured buildings and is required to extend daylight. However, artificial light can negatively affect human health, and this is reflected in how it affects sleep, alertness, moods, and biological and psychological processes (Morton 2016). In this regard, I have suggested that this sentiment is likely to be shared by kitchen workers in Durban; the kitchen workers in basement kitchens and those on shift work may experience the adverse effects of circadian disruption.

Van Duijnhoven et al. (2019) reviewed the literature on the association of light with human health in the workplace. Workplaces should receive natural light as the first choice and, if necessary, be complemented with appropriate electric lighting to support workers' safety and health and to enable safe equipment operation in commercial kitchens. Additional task-lighting may be required to meet specific visual alertness requirements.

Visual comfort is the absence of visual discomfort and is capable of bestowing contentment in a work environment. Kruisselbrink, Dangol and Rosemann (2018) declared that lighting quality is a concept that permits excellent vision while providing high comfort. The review by Van Duijnhoven et al. (2019), as illustrated in Table 5.1, could not prove the effect of lighting on all the variables measured but indicates the effect with respect to physical and physiological health, mental health, eye health, sleep parameters and VC. Lighting parameters such as illuminance, Correlated colour temperature (CCT), luminance, uniformity of light and sources of light could influence kitchen workers in their workplace.

Notwithstanding, no published work is available regarding lighting in kitchens or the effect of lighting on kitchen workers. The concentration and mental health of workers can affect work performance in the kitchen. Singh, Arora and Goyal (2020) found that classroom lighting between 250 lux and 500 lux correlates with increased concentration in students and improved performance. Tiredness and sleeplessness caused by a troubled sleep pattern frequently occur amongst shift workers and may lead to the so-called shift work disorder (Richter et al. 2016).

■ 5.2 Daylight and artificial light

The utilisation of light in architectural spaces has implications for comfort, behaviour, economics and the environment (Knoop et al. 2020). Many buildings lack sufficient daylight and rely almost solely on artificial lighting (Fedoronko 2020). A combination of daylight and artificial light is commonplace in the kitchen work environment. Hammer and Holzer (2020) urged the need to deliberately design indoor environments for sufficient daylight quality for all climates worldwide. In this regard, Jensen (2019) added that natural lighting renovations result in cheerful staff and reduced sickness, leading to improved output. The approval of the new European Standard EN 17 037 – Daylight of

TABLE 5.1: Summary of the relationship between lighting conditions and occupational health categories.

Physical and physiological health	Mental health	Eye health	Sleep parameters	Visual comfort
1. Light source – daylight or electric light does not influence feeling healthy nor physical well-being.	1. Light source – daylight or electric light does not influence mood.	1. Light source – daylight or electric light does not influence eyestrain.	1. Light source (daylight or electric light) does not influence alertness, a disrupted biological clock nor sleepiness during the day.	1. Light source – daylight or electric light influences glare, luminous perception of darkness and visual acceptance. It does not influence the luminous perception of brightness.
2. Correlated colour temperature influences fatigue, light-headedness and vitality, but does not influence headache.	2. Correlated colour temperature influences concentration, mental health, positive mood, social functioning, and thinking clearly. It does not influence negative mood and memory.	2. Correlated colour temperature influences blurred vision, difficulty focusing, eye discomfort, eye fatigue, eyestrain and irritability.	2. Correlated colour temperature influences alertness, daily sleep timing, daytime dysfunction, daytime performance, energy, evening fatigue, lethargy, sleep duration, sleep quality, self-reported activity, sleepiness, during the day and tiredness.	2. Correlated colour temperature influences the pleasantness of light.
3. Illuminance influences headache, malaise, physical well-being and skin dryness.	3. Illuminance influences mental effort and mood.	3. Illuminance influences eye pain.	3. Illuminance influences AIS-5 (Athens Insomnia Scale). It does not influence AIS-3 (sleepiness during the day).	3. Illuminance influences glare, the pleasantness of light.
-	-	-	-	4. Luminance influences glare.
-	-	-	-	5. Uniformity influences visual acceptance and visual comfort.

Source: Van Duijnhoven et al. (2019).

Buildings (European Standards 2021) deals exclusively with the design and provision of daylight.

The sun is the most important source of natural light, as the Earth receives light from the sun in the form of direct radiation and diffuse radiation from the sky (Medved 2022). Daylight is the optimal source of illumination, either through glass curtain walls, large windows or skylights. Mardaljevic (2008) lamented that natural light is a greatly under-exploited natural resource; daylight always has the potential to displace all or part of the artificial lighting and is valued by workers. The authors, however, caution that if the daylight illuminance goes below 100 lux, it may not be adequate for the visual environment and performing visual duties.

In the International System of Units (SI), 1 unit lumen per square metre is a lux (Sebitosi & Pillay 2007). I observed that all primary roles and functions of kitchen personnel involve visual tasks. The authors added that 86% of office workers in England and New Zealand considered natural lighting to be their favoured source of lighting, as natural light results in less stress and discomfort. Most indoor occupants state that natural light is better for emotional comfort, satisfaction, general well-being, visual health and the colour appearance of people and furnishings (Minnon 2019).

Daylight has a number of distinct advantages, including superior visual performance, healthy vision, successful entrainment of the circadian clock, a number of acute non-image generating impacts and the critical role of vitamin D generation (Knoop et al. 2020). Because of sunlight's potential to kill bacteria, Osibona, Solomon and Fecht (2021) highlighted the protective effects of natural light with respect to communicable diseases. Ultraviolet light can weaken and damage bacteria, and the disinfectant effect persists with indirect sunlight exposure through glass and windows.

While commenting on the role of light in maintaining health and well-being, Van Creveld and Mansfield (2020) felt that the impact of light on human emotions and well-being is least understood. Woo et al. (2021) demonstrated the importance of daylighting strategies in designing spaces that support the physical and mental health of occupants. Daylight and views through windows impart psychological and mental health benefits. Given the health implications of inadequate and uncontrolled daylight, building designers and engineers are confronted with creating indoor lighting conditions optimised for the occupant's circadian system, visual and thermal comfort, and mental health. This balance is created by providing sufficient windows to maximise daylight penetration and furnishing them with blinds. The authors concluded that when a person works with adequate daylighting, it has the same beneficial effect on emotions as active behavioural interventions such as yoga and meditation. Blitzer and Mackay (2015) posited that the daylight from windows and skylights be replaced at night by additional lighting.

Nisbets (2019) maintained that windows in the kitchen should preferably be less than 10% of the total floor area, looking out to the sky or open spaces. Workers favour working near windows or in workplaces with daylight, a claim confirmed by the investigation of Hedge and Nou (2018). Therefore, not surprisingly, Torresin et al. (2018) added that getting a seat by the office window is a coveted prize.

Fedoronko (2020) observed that humans are linked to the natural environment at a deeper level than the built environment; humans have a deep-seated need to connect with nature. According to Marcheso-Moreno (2019), windows offer sunlight that positively affects workers' subjective well-being; however, access to natural lighting is not always possible for many workers because of the nature of modern work with 24/7 work, shift work, nonroutine work and diverse topographical latitudes. Hence, deep rooms and workstations placed too far from a window could have negative health effects. Sonae Arauco (2020) added that possibilities for more natural light in an internal space include the installation of skylights and glass sliding doors.

One of the most positive aspects of having a skylight is that it brings extra daylight into a room, increases natural light from skylights, and reduces artificial lighting and electricity (Reggev 2017). The indisputable preference for windows is well-known. Lee and Lee (2021) showed that exposure to certain lighting colours enhanced the feeling of pleasure and reduced the soporific effect during light exposure. The depth of direct sunlight infiltration into the offices during summer, according to Hwang and Kim (2011), reduces the visual discomfort ratio to the lowest.

Apart from the advantages of health and well-being for the workers themselves, the overall effect of effective lighting is better productivity. However, Münch et al. (2020) found that subjects exposed to electric illumination are suggestively drowsier at sunset, whereas people with daylight activity are significantly more alert. Unlike natural lighting, which varies throughout the day because of the weather conditions and sun position, artificial lighting is constant in illuminance and colour temperature. Accordingly, preferences for artificial lighting vary with weather type, brightness and time of the day (De Kort & Smolders 2010). Illuminance levels outdoors and indoors vary with location.

Van Bommel's (2012) recommendation of at least 1 000 lux on the eye is for biological stimulation. Păsculescu et al. (2019) believed that the VC of workers could be ensured by inducing positive sensations during activity with artificial lightings such as fluorescent tubes and Light-emitting diodes (LEDs). Glickman (2019) developed new evidence-based LED technology that operates with blue-enriched (BE) architectural lighting to optimise circadian rhythm and light's acute arousal effects. In the absence of prior investigations on the commercial kitchen's use of artificial lighting, I advance a likelihood that all commercial kitchens use artificial lighting in the day, with or without the presence of daylight.

Fluorescent lighting has an adverse effect on workers, as it has been known to cause eyestrain and initiate headaches (Pochepan 2017), and it affects the well-being, performance and physiological arousal of workers. Harsh lighting also makes it difficult for the eye to focus. Most people cannot notice the flicker in tube lights with a flicker rate of 120 Hz. It is vital to realise the impact of artificial lighting on worker well-being and performance, directly or indirectly.

The preceding evidence raises a need to comprehend how the use of artificial lighting affects employee comfort. The need is further underlined in

Aries, Veitch and Newsham's (2010) report on the inverse correlation between light level and employees' level of fatigue and sleep quality. In contrast, Fostervold and Nersveen (2008) claimed that there is little evidence of direct or indirect light's direct impact on the health, well-being or cognitive performance of office workers. However, Gabel et al. (2013) proved that dawn-simulating light might provide an effective strategy for enhancing cognitive performance, well-being and mood.

The simulation of natural light is believed to attract some of the earlier mentioned benefits of natural light to the worker's well-being. Although compact fluorescent lamps (CFL) and incandescent bulbs remain the most widely used artificial lighting, LEDs have become more conspicuous in the field of lighting. Such LED lights are energy-efficient and consume very little power, with a full range in colour from warmer hues to white closer to daylight (Eartheasy 2020). The number of light sources, particularly artificial lighting, may be reduced using more efficient lighting fixtures and electronic ballasts, such as upgrading T12 and T8 fluorescent tubes with T5 tubes (Tassou et al. 2011). Notably, in this regard, Jiang et al. (2019) invented a wireless ballast-less lighting system for CFL that operates with remote lighting control via Bluetooth. It is too early for empirical discussion of health benefits or any disadvantages, as the product is still new.

Harsh lighting, along with dim lighting, is equally detrimental to the well-being and productivity of workers. Jensen (2019) contended that dim lights could be unfavourable to productivity for several reasons, such as causing eyestrain and migraines, as the eyes are required to exert much harder in poor light. Low lighting can also cause sleepiness and loss of concentration, which would affect worker productivity (Charlotte 2017). In the kitchen, the main workstations have their own light sources, as in the ventilation hoods with built-in lights (Ring 2018). Very bright indoor lights can be harmful to the eyes (Dunaief 2018).

Flickering lights are observably distracting and create unpleasant working conditions, as observed by Silvester and Konstantinou (2010), who claimed that the flicker produced by fluorescent lighting leads to visual discomfort, deteriorations in visual performance, stress and headaches. Flicker from LED lights may be more noticeable; therefore, from a worker's well-being perspective, fluorescent lights are not appropriate for commercial kitchens.

Disability glare arises from an extreme nonuniform distribution of light in the visual field, which impedes the visual system and thus reduces the scene's visibility (Fotios & Johansson 2019). I consider such impediments hazardous to workers in a commercial kitchen environment. In this regard, Hwang and Kim (2011) found that after improving the causes of visual annoyance and applying glare and shade control, the worker's visual annoyance ratio decreases tremendously. Therefore, individual light fittings are not favourable in kitchens, as several workers share different task stations.

Insufficient light or glare reduces the ability to see objects or details clearly (Al-horr et al. 2016). It seems that glare in the kitchen occurs because of bright, shiny work surfaces. Costanzo et al. (2018) posited that daylight illuminance higher than 2000 lux is known to be strongly associated with occupant discomfort and glare risks. Fostervold and Nersveen (2008) reported that lower glare and a decrease in flicker improved lighting quality and led to lower job stress severity; lighting from multiple sources also reduced glare.

Ring (2018) contended that strong lighting could create glare because the objects in the room have highly reflective surfaces, especially in kitchens, as the equipment is made of polished stainless steel. Strong glare can be distracting and may even have a blinding effect, which is dangerous in kitchens. Objective glare indexes are associated with subjective VC and non-visual functions such as subjective physical well-being and alertness (Borisuit et al. 2011).

Fostervold and Nersveen (2008) reported that glare control requires lighting installations that use unique combinations of indirect and direct lighting. I contend that such an optimal combination is necessary given a commercial kitchen's various tasks and work areas. Windows may induce daylight glare and decrease indoor VC. An associated implication is demonstrated by studies that find people closing their window blinds to control unwanted glare (Wang & Boubekri 2009). Yao (2014) revealed that new mechanical Venetian blinds could protect occupants from solar glare and can maximise light diffusion into buildings.

5.3 Colour of light

According to Boduch and Fincher (2009), colour relates to a specific frequency of light, and the colour of lighting can have an effect on a person's mood and work performance (Küller et al. 2006). Viola et al. (2008) found a positive effect of a high colour temperature of 17 000 K on workers.

Kitchen workers from different cultural backgrounds and ethnicity may associate with similar lighting colours differently. Common lighting, such as incandescent and fluorescent lighting, falls within the red to the green colour range, whereas daylight falls in the light blue to blue colour range (Lumens 2020). This means that the illumination presently used in interiors has a precise opposite warmth to natural sunlight and gives the eye a different range of colour. This is the reason why individuals often need to take a moment to let their eyes adjust when walking into a lighted interior from direct sunlight. Hence, dimly lit storage rooms leading from kitchens or gas cages in bright outdoor spaces create a temporary blinding effect that could cause accidents in kitchens.

Task-lighting is a common feature in commercial kitchens. Van Deusen (2018) reasoned that a neutral colour temperature, slightly towards the cooler side of 4 000 K, would be best for kitchen task-lighting. This should be augmented with fill light so that the work surface is well lit and difficulties with shadows are kept to a minimum. Lighting over 6 500 K gives a bright blue light hue and is used mostly for task-lighting to measure colour temperature (Lumens 2020). However, Morton (2016) claimed that inappropriate lighting could lead to poor colour rendering. Sethi and Malhan (2015) argued that commonly used fluorescent tubes do not give particularly good colour effects and are not recommended for kitchens as the colour of food is masked.

The Colour Rendering Index (CRI) is a measurement of the light's ability to show an object's colour naturally with a source like daylight (Zumtobel 2018). The CRI of modern kitchen lighting is important. The better the CRI value, the more realistic food colours will appear to kitchen workers (Houzz 2019). Warehouse Lighting (2020) observed that in kitchens, a higher CCT could help a chef arrange attractive artistic food on the plate. Another approach is to equal the CRI at the plating area to that of the CCT in the dining area, where it is perceived by the customer when receiving the plated food, in order to create consistency. CBMC Lighting Solutions (2017) reported that in higher-end restaurants, the CRI is particularly significant, as food presentation is an art. Higher CCT and CRI would help kitchen workers to have a comfortable atmosphere and clear vision for plating food (Die-Pat 2016b).

5.4 Lighting and health

The renewed interest is emerging in physical reactions to light, such as circadian health and alertness, as well as subjective responses, such as visual discomfort, satisfaction with access to daylight, and the relationship between contrast and emotive perception (Jakubiec et al. 2019). As alluded to in the prior section, kitchen lighting has definite implications for kitchen worker health. Kralikova and Wessely's (2017) review stated that good lighting in the workplace with well-lit task areas is essential for optimising visual performance, comfort, and ambience, especially with an ageing workforce.

Turning now to physiological and hormonal effects of light, alertness and sleep, as well as the cognitive and psychological effect of light, Viola et al. (2008) reported that subjective measurements of alertness, good mood, weariness, performance, irritation, attention and ocular discomfort were all enhanced by white light. This would assist with designing lighting strategies to ensure employee health, productivity and safety (Najjar et al. 2014). Aries, Aarts and Van Hoof (2015) accordingly claimed that daylight had been linked with higher attendance, reduced tiredness, a respite from seasonal affective disorder (SAD), diminished unhappiness and skin disorders, enhanced vision and beneficial effects on degenerative diseases of the brain. Pachito et al. (2018) concluded that cool white light might improve alertness and may cause less irritability, eye discomfort and headache.

Counteracting behaviour, such as moving closer to cope with vision difficulties, is clearly linked with dry eye symptoms (Lin et al. 2019). Employees with years of experience at work and shorter breaks are more likely to develop eye fatigue. This observation is very likely to impact on kitchen workers' extended work hours.

According to Van Bommel (2006), light mediates and controls several biochemical processes in the human body. These biological impacts are influenced by colour temperature, light level, exposure duration and timing, as well as the size and position of the light source, and they are likely to affect people's well-being, health and performance. Rossi (2019), nonetheless, argued that daylight provides better illumination for the synchronisation of the biological clock. Kumar, Jain and Mathur (2020) claimed that illuminance and circadian lighting design are interrelated with each other. A disturbed biological clock amongst kitchen workers because of shift work or harsh lighting can cause sleep disorders, reduced energy levels, tiredness and lethargy. Eyestrain, blurred vision and irritability can be caused by dim or harsh lighting in kitchens. In this regard, Rea and Figueiro (2018) adopted circadian stimulus (CS) as a metric for quantifying light in architectural spaces. This metric is not suitable for kitchen workers in Durban, as most restaurant kitchens do not operate from midnight hours until early morning.

Millett (2014) compared SAD with jetlag, as sufferers show symptoms because of the shifting of the circadian rhythm with respect to their daily routine. Seasonal affective disorder is present at a low level for many people working in poorly lit buildings. According to Parekh (2017), SAD is a form of winter depression. The symptoms can be distressing and overwhelming because of shorter daylight hours and less sunlight in winter. As seasons change, people experience a shift in their internal biological clocks that can cause them to be out of step with their daily schedules. I feel that kitchens with low lighting levels may affect workers' alertness and cause SAD, although bright sunlight is accessible once outside in the sunshine. Marć et al. (2018) reported that kitchens are usually located on the lowest floors of the building, which results in a very small number of windows.

The significance of lighting is inferred in treatment with light for patients having SAD (Lam 2009). Maierova et al. (2016) maintained that daily environmental light exposures provide the strongest influence on the circadian system to adjust the 24-h endogenous rhythm in humans to external clock time, and light has modulating effects on work performance and perception of well-being, mood and sleepiness. Acute reactions include changes in melatonin secretion, core body temperature, heart rate, brain blood flow and cognitive performance, whereas circadian reactions include changes in sleep patterns and circadian phase shifts, which can lead to particular behavioural disorders over time (Van Duijnhoven et al. 2019).

Lighting has an important influence on alertness and stress. For example, daytime workers may be exposed to insufficient or inappropriate light, leading to mood disturbances and decreases in levels of alertness (Pachito et al. 2018). British Columbia Campus (2020) warned that kitchen workers must stay completely alert on the job and when carrying chinaware and glassware from one place to another.

Bindu and Reddy (2013) reported that lower lighting levels during the daytime affected the sleep quality of cooks during the night, with disturbed sleep and alertness. Ruger et al. (2006) concluded that light levels have a positive effect on subjective alertness. The authors further postulated that light levels affected heart rate and core body temperature. Aries (2005) found a significant correlation between the vertical illuminance at eye level and the parameters 'fatigue' and 'sleep quality'.

Phipps-Nelson et al. (2003) found that bright light decreases sleepiness and improves psychomotor vigilance performance. Bright light increases heart rate and core body temperature only during night exposure. Blue-enriched white light can enhance attentiveness and avert fatigue-related behavioural decrements of vigilance, while accuracy in complex tasks necessitating precision may deteriorate (Rodríguez-Morilla et al. 2018). Paradoxically, Smolders and De Kort (2017) neither clear beneficial effects of exposure to white light with a higher colour temperature on mental well-being and performance nor activate effects on physiological arousal during regular daytime hours.

Choi et al. (2019) found that BE-LED light seems to be a simple yet effective potential countermeasure for morning drowsiness, and the decline of melatonin levels significantly improved the subjective perception of alertness. However, *The New York Times* (Parker-Pope 2010) reported that medical doctors caution against blue light that may be a greater trigger for migraines, and old fluorescent lights emit blue light.

According to Woofter (2020), lighting plays a huge factor in how a person perceives the workplace because of its psychological effect. The author added that the right fixtures could even foster creativity, boost morale and encourage communication. Black and Decker (2009) emphasised that the main objective should be comfortable and effective illumination by setting the right fixtures in the right places and maximising natural daylight. Hence, visual effects are perhaps the most phenomenological of all the comfort categories (Boduch & Fincher 2009). For example, lighting a ceiling can make a space feel brighter. As kitchens are not accessible to customers, I strongly feel that it is pointless to create themed lighting, which may cause eyestrain among workers.

Silvester and Konstantinou (2010) illustrated the effect of colour on the behaviour of children in Germany. Preteens (8–12-years-old) are more positively disposed toward a reddish light, which pacifies them with a decrease in hostile behaviour. An increase in prosocial behaviour by the participating students ensued in better reading and greater reading speed, and fewer errors. The psychological effects of lighting suggest that high illuminance and high colour temperature can have positive effects on students' well-being, health and performance (Yang & Jeon 2020). It appears that lighting above the specified minimum lighting requirements of various world standards in different kitchen areas can positively influence and reduce errors among kitchen workers. It seems that the more intense the task, the brighter the light required. This is the main reason surgical operating rooms with 1000 lux are much brighter than offices (Thuillier 2017).

5.5 Visual comfort and performance

Thuillier (2017) defined VC through a set of criteria based on the level of light in a room, the balance of contrasts, the colour 'temperature' and the absence or presence of glare. Designing VC in buildings is a process of optimising the illumination of the spaces as well as light perception in the way that building occupants are provided with a comfortable, highly productive and healthy living environment (Medved 2022). Lighting in kitchens should provide greater comfort to the eye (Simone et al. 2013). According to Laura Thuillier (2017), the:

> [*B*]est combination of factors to optimise well-being and the feeling of comfort includes the quantity and quality of light into a building, quality, and access to views from inside the building and the quality of the surrounding space. (n.p.)

Giarma et al. (2017) compared VC criteria by different standards and reviewed building environmental performance assessment tools and methods focusing on VC aspects – daylight, illuminance and lighting controllability.

As purported by Tekce, Artan and Ergen (2021) and supported in Table 5.1, VC defines lighting conditions and the views from the workspace of a worker. It is an important indicator of both occupant satisfaction and work performance. VC at work has an impact on comfort after work as well (Al-horr et al. 2016). Serghides, Chatzinikola and Katafygiotou (2015) showed that the impact of VC on sleep quality at home after work is influenced by gender, age and seasons. VC seems to include the optimal permutation of illuminance levels, luminance ratios and colour temperature. Buildings need to avoid excessive use of artificial lighting yet maintain some optimality (Yun et al. 2012). Therefore, daylight, artificial lighting, glare and VC should be structured and designed together to obtain a more holistic picture (Van Den & Inanici 2014).

Good lighting enhances people's sense of well-being, improving concentration, motivation and performance (Kralikova & Wessely 2017). Workplace illumination is an important parameter influencing the worker's productivity in terms of speed, quality of work, absenteeism, turnover, occupational diseases and accident (Pahari, Biswas & Pal 2020).

Also, a strong relationship exists between illuminance and task completion times (Sanjog, Patel & Karmakar 2013). Hence, it seems that additional lighting, such as improved general lighting, task-lighting and personal control of lighting to improve kitchens' lighting levels, would improve cooks' work performances. In this regard, Juslén et al. (2007) reported that production sped up in an environment having 1200 lux by 9% more when compared with 800 lux. Greenberg (2017) later confirmed that lighting plays a major role in employee productivity. Tetlow (2007) relevantly recommended individually controllable task lights that are critical for kitchen work.

High-intensity and high-quality lighting provide more adjustment between the person and their work environment (Newsham et al. 2009). Controversially, Akbari et al. (2013) reported that the amount of lighting did not have any influence on human productivity. Too much luminosity in working stations causes a decrease in human performance and productivity. Boyce et al. (2006), however, argued that while the goal of creating high-quality lighting to improve organisational productivity is more challenging, investments in lighting to create a productive workplace will pay off in the end.

On the effect of light on age and gender, the demographic characteristics of human beings (and therefore of kitchen workers) have a mutual relationship with their well-being. For instance, the age and gender of kitchen workers are impacted upon by the lighting conditions in the kitchens, as will be presented in the sections that follow.

As per the American Optometric Association (2020), eyes and vision change over time, and employees require more brightness to see. Nylen (2017) asserted that the prevalence of visual problems and eye diseases increases in the age group of 65 years and older; early diagnosis and treatment can reduce the risk of accidents and increase working capacity and well-being. Hence, workplace lighting plays a significant role in improving task performance amongst the elderly.

Higher lamp lumen levels are necessary for special age groups of occupants (Sebitosi & Pillay 2007); age-related increases in illuminance preference would be consistent with known age-related decrements in vision. Kunduraci (2017) posited that the eye of an average 60-year-old requires three times more illuminance than the eye of an average 20-year-old.

Studying gender differences, Lee, Park and Han (2013) revealed that women, when compared with men, are more likely to perceive lighting as an important factor in their everyday lives, showing a preference for incandescent lighting and perceiving fluorescent lighting as having adverse effects on human health. Hence, gender differences in light sensitivity might play a key role in ensuring the success of individually targeted light interventions in kitchens. Yang and Moon (2019) found that women have higher scores for VC with 500 lux than those of men.

Chellappa et al. (2017), however, reported that men have higher brightness perception and faster reaction times in a sustained attention task using BE light and improved sustained attention performance compared with women. The physiological reason for women's higher lighting requirements than men is that they are born with fewer cones and rods that are light receptors (Owen 2012).

Dry eye symptoms are common among women and are shown to increase with age (Nylen 2017; Jeng et al. 2018). Women have an increased risk of glare as the eye position is slightly further down. Visual impairment is also more common among women than men, which can have biological and socio-economic causes (Zetterberg 2016). This could be because of the longer lifespan of women and the increased risk of cataracts, and age-related macular degeneration also contributes to this condition.

Lee and Lee (2021) revealed that different lighting colours have varied levels of pleasure and arousal. The impact of lighting colour on pleasure was significantly influenced by ethnicity but not by arousal. The most pleasant lighting colour amongst participants was blue, which was preferred over red and purple. The least pleasant lighting colour was red, which had a lower level of satisfaction than all other lighting colours. Asian respondents considered red and purple lighting substantially less pleasant than other colours, and when exposed to red, orange and purple lighting, they felt more unpleasant than Caucasian respondents.

■ 5.6 Lighting in food-service kitchens

Ring (2018) claimed that effective natural or artificial lighting conditions should be provided in an area where food is being prepared. It is essential to have strong lighting of 350 lux, as the cooks continually rely on their vision to assess the quality of the food and the ingredients, steer through the kitchen, and use kitchen equipment and tools appropriately. Kitchens are often too large to be illuminated entirely by natural light, as glare and shadows are going to be a perpetual problem (Ring 2018). Moreover, commercial kitchens require direct lighting where preparation is going to take place, such as worktops, sinks and stoves that will ensure that all chopping and cooking are done safely, without shadows. Kitchen countertops in Turkey require a minimum of 500 lux (Kunduraci 2017). Colin (2011), however, recommended 750 lux. Lamps with high CRI are preferred in the kitchen area. Various tasks such as preparation, cooking, cutting, washing and eating are completed in kitchens. To fulfil the visual requirements for each task, layered lighting design can be applied. Each task can be well-lit by task-lighting that prevents glare or dark shadows. The author recommended maximising daylight in the kitchen area as much as possible to provide an adequate amount of light. However, if glare is a risk, shading can be used to prevent undesirable reflections.

Pimenta et al. (2019) found that urban Brazilian food services have lower compliance rates (2.7%) in municipal schools with lighting requirements. Interestingly, adequate lighting is reported in 44% of food establishments in Ethiopia (Kumie & Zeru 2007). Läikkö-Roto and Nevas (2014) in Finland revealed that restaurant business operators rated lighting in kitchen and storage areas as 8.4, whereas the food control officials rated it as 6.7 on a scale of 1–10. There appears to be no published study of kitchen lighting in South Africa.

Eagles and Stedmon (2004) found the need for extra lighting in food preparation areas where workers might be doing delicate tasks with sharp knives. Concerningly, Omidiandost et al. (2015) reported from Iran that the lighting in a hospital kitchen measured only 148 lux instead of the expected 250 lux in food services. I suggest that such inadequate lighting in kitchens is not conducive to the well-being of kitchen workers. Pompei et al. (2022) propose 500 lux for restaurant kitchens in cooking rooms, preparation, and plating rooms, washing rooms as well as pizzerias, but only 100 lux for food storage sections in Italian buildings based on standard EN 15193-1: 2017. Die-Pat (2016b) added that the safety of workers is enhanced if they can see every detail of their work while using sharp knives and other relatively dangerous cooking equipment. Gaydos et al. (2011) reported that 28% of 106 restaurant kitchens in San Francisco's Chinatown lacked adequate lighting. Any shortcoming in lighting adequacy has knock-on effects for well-being and, consequently, performance. Bindu and Reddy (2013) added that 62.2% of cooks in Indian commercial kitchens report that the workers often experience eyestrain and irritation. A well-lit workspace is uplifting, encouraging workers to see their work environment as positive and motivating them to do their very best (Die-Pat 2016b).

In general, there is migration from fluorescent and incandescent kitchen lighting. Instead, LED lighting in the open kitchen may be carefully tuned for optimal function while creating a warmer feel (Gordon & Zeigler 2017). As the kitchen is a very hot working environment, choosing a low-heat-emitting light such as an LED will produce little heat and is remarkably bright for the working area (Die-Pat 2016b). Yamaguchi et al. (2022) expected a substantial reduction in electricity demand for lighting and a decrease in the internal heat gain from the installation of LED lighting.

To design an effective lighting environment, the target lighting conditions must be considered from many dimensions, including light levels such as illuminance and luminance, control of glare, distribution, uniformity and light source cooler (Hwang & Kim 2011). Webstaurant Store (2018) stated that task-lighting allows staff members to perform functions that may need a more concentrated light source, like cooking. It can take the form of overhead lamps and bright fluorescent lights in a kitchen. Directional and accent lighting can reduce glare and increase contrast and is considered a good idea in modern kitchen lighting (CBMC Lighting Solutions 2017). Accent lighting has a dramatic effect on kitchen space and is generally not used in kitchens.

5.7 Lighting classification

A lighting classification for kitchens to address ergonomic needs appears not available in the literature. However, two related classifications are reflected in Table 5.2. These are drawn from the classification of artificial lighting and classifications of light fixtures according to lamp types, installation, percentage of light output above and below the horizontal.

It seems evident that the lighting variations (Table 5.2) in commercial kitchens must meet the requirements of the *Occupational Health and Safety Act No. 85 of 1993* (OHSA) as per the South African Legal Information Institute (1993). For example, all food-grade lighting should be shatterproof and protected. Die-Pat (2016b) recommended that extremely high temperatures found in many kitchen areas, such as near ovens and stoves, can often result in bulb shattering. Installing shatterproof bulbs protects employees from injury when shattered glass could either cut them or get into their eyes.

Commercial kitchen lighting belongs to the ambient or general, accent and task-lighting classifications (Levison 2019). Ambient lighting is a necessary part of any good lighting plan because it provides an overall brightness to a room and creates enough light to see and move around comfortably and safely. The purpose of general lighting is to illuminate the entire kitchen and offer appropriate visual conditions for users to manoeuvre the space and see the contents of any shelves, cupboards or drawers (Ring 2018). The problem with general lighting is that kitchen workers must accomplish several tasks with their backs to the light source, which casts a shadow on the workstation; hence, functional lighting is needed. The author added that functional lights provide light for individual workstations where the strength of the general light is insufficient, as kitchen work requires excellent lighting.

TABLE 5.2: Summary of classification of lighting and lighting fixtures.

Basic types of lighting	Artificial light sources	Types of lighting lamps	Determinants of indoor lighting fixtures
Levison (2019)	Electrical Knowhow (2013)	US Department of Energy (n.d.)	US Department of Energy (n.d.)
1. Ambient	1. Incandescent lamp	1. Fluorescent-industrial linear	1. Light function
2. Task	2. Compact fluorescent lamp	2. Incandescent – cool white light bulb	2. Lamp type
3. Accent	3. Fluorescent tube	3. Outdoor solar – not suitable for kitchen	3. Installation method
	4. Discharge lamps 5. LED	4. LED – ingress LED panel or LED downlights	4. The percentage of light output above and below the horizontal

Key: US, United States; LED, light-emitting diode.

Task-lighting focuses on a specific area to provide targeted illumination for accomplishing tasks (Lightology 2018), allowing the option to adjust the lighting for a workspace or chosen area. Black and Decker (2009) claimed that task-lighting provides focused light in specific work areas, such as the cooktop, sink and countertops. Ambient and task-lighting together make up the core of a kitchen plan. Los Alamos National Laboratory Sustainable Design Guide (2018) recommended that to help maintain VC, task illumination must not be more than three times that of ambient illumination. Effective task-lighting should reduce glare and be bright enough to prevent eyestrain, making it ideal for activities like cooking, studying and work (Levison 2019). Accent lighting creates a focal point and appears pointless in commercial kitchens. Jakubiec et al. (2019) preferred that climate-based daylight metrics are used to identify when kitchens may be classified as typically bright and comfortable or gloomy and dim.

5.8 Lighting standards for kitchens

Mikulka (2018) claimed that one of the main elements in lighting lies in generating a sufficient level of illuminance. Table 5.3 illustrates the various standards for illuminances for the range of kitchen tasks as given in lighting at work (Health and Safety Executive 1997) and Chartered Institution of Building Services Engineers (CIBSE). Comparisons can be drawn with respect to variations in lighting levels in different areas of kitchens and whether the lighting levels meet the minimum requirements. Table 5.3 indicates the minimum standards. CIBSE has specified categorical lighting levels for every station in the kitchen. The WHO also mentions the acceptable range of lighting levels. Other standards indicate lighting levels that pertain to certain kitchen tasks. An observable gap exists in standards for specific commercial kitchen areas such as salad preparation, the sushi and meat section or the seafood section. Table 5.3 illustrates that OHSA (South Africa) has the lowest lighting requirements compared to international standards. The Occupational Health and Safety Brief declares that poor lighting at work can lead to eyestrain, fatigue, headaches, stress and accidents (International Labour

TABLE 5.3: Comparative illustration of international standards for lighting.

Activity level of illuminance (lux)	OHSA (RSA)	SANAS	CIBSE	BOSH	IES	OSHA (USA)	WHO	Australian standards
Food preparation and cooking	150	500	500	500	300–750	500	300–500	500
Bakeries – preparation and baking	100	-	300	-	-	-	-	-
Finishing, glazing and decorating cakes	200	-	500	-	300–750	-	-	-
Dishwashing	-	300	300	-	-	-	-	-
Storage	-	150	150	-	50–200	-	-	110–150

Key: OHSA, *Occupational Health and Safety Act*; SANAS, South African National Accreditation System; BOSH, British Occupational Safety and Health; CIBSE, Chartered Institution of Building Services Engineers; IES, Illuminating Engineering Society; OSHA, Occupational Safety and Health Administration; WHO, World Health Organization.

Organisation [ILO] 2017). As mentioned earlier, too much light can also cause safety and health problems such as glare, headaches and stress, and these could lead to mistakes at work, poor quality and low productivity.

Glamox (2017) stated that a kitchen is a workplace for chefs and cleaners, and the illuminance and uniformity levels are, therefore quite high. Importantly for the commercial kitchen environment, the ingress protection rating is an international method used to describe the protection of a fitting to stop the penetration of solid objects or water entering the light fitting. Electrical Encounter (2019) notably recommended ingress protection 20-rated products in the kitchen to avoid steam-generated moisture and condensation or water drips.

According to the *Environmental Regulation Act of 1987* and the *Occupational Health and Safety Act of 1993*, food preparation areas in the kitchen need to have an illumination of 150 lux only in total contrast, significantly below the South African National Accreditation System (SANAS) that endorses 300 lux.

This inconsistency can be perplexing to food preparation establishments, and this could lead to the increased possibility of wide deviations from recommended lighting standards in lighting in kitchens. The SANAS minimum standard is aligned to the other international standards such as WHO, Australian Standards 1 680, ANSI and CIBSE.

In South Africa, a code of practice – South African Bureau of Standards (SABS) 0114-1:1996 (SABS 2019) – offers the minimum lux for a range of workstations and activities. Kitchens are allocated 200 lux. In significant contrast, Eagles and Stedmon (2004:442) recommended that the standard illuminance should be 500 lux for food preparation and cooking, 300 lux for serveries, vegetable preparation and washing up areas, and 150 lux for food stores. Like other standards, there are similar country-to-country variations (Sebitosi & Pillay 2007). As per Archtoolbox (2021), the Illuminating Engineering Society recommends lighting levels from 300 lux to 750 lux in kitchens. Further to preparation, cooking and dishwashing, intricate decoration of cakes, pastry work, desserts, confectionery, sugar and chocolate art in bakeries and cake shops also require appropriate lighting.

■ 5.9 Lighting and safety in the kitchen

There is an obvious link between lighting and workplace safety; namely, insufficient lighting leads to increased error rates and, in many cases, to small or significant injuries (Silvester & Konstantinou 2010). Poor illumination detracts from workplace safety in kitchens. If staff are unable to see the tasks performed properly, accidents and mistakes are more likely to occur. For example, sufficient lighting should be provided so that a kitchen worker can see water spilt on the floor in order to avoid a slip. If workers are unable to distinguish, for instance, the faces of approaching personnel, it could cause a security risk as their ability to recognise threatening behaviour is delayed (Morton 2016). This implies that kitchen workers' safety and well-being are in jeopardy. Karyono et al. (2022) demonstrate the necessity of an adaptive lighting system to maximize productivity and ensure human comfort.

This section on the literature review attempted to present a commercial kitchen discussion of how kitchen workers are affected by light and the significance of daylight. In doing so, it debated the need for artificial light, different types of lighting and the health effects of lighting. It then proceeded to deliberate on how lighting requirements vary with age and gender. It further discusses lighting source suitability, the differences in kitchen lighting guidelines and safety from glare. Lighting, in conjunction with the parameters discussed in the preceding chapters, determines the extent of kitchen workers' well-being in the commercial kitchen environment. Section 5.10 will focus on the interrelationship between the various parameters and is often referred to as indoor environmental quality (IEQ) in contemporary literature.

5.10 Interrelationships between the indoor environmental parameters

Indoor environmental quality is increasingly recognised as a significant factor influencing the overall level of building occupants' health, comfort and, consequently, productivity. Currently, there is no available broad statement on kitchen IEQ as no research in this area has been conducted. An in-depth survey of the literature has not revealed any evidence of a similar study. This book considers five IEQ parameters that influence worker well-being in commercial kitchens.

This study attempts to improve the well-being of kitchen workers in commercial kitchens by recommending improvements in environmental variables to enhance comfort in workspaces. Unlike the focus of this study on six parameters, there is empirical evidence of work in fewer IEQ parameters. Several studies on commercial kitchens discuss thermal comfort and noise only in separate studies as bivariate models and not as multivariate deliberations.

Rupp, Toftum and Ghisi (2020) found that men tend to perceive themselves as more sensitive to heat; therefore, it may not be gender-related but a psychological variable that should be considered when addressing individual differences in thermal comfort. Montazami and Lunn (2020) reported on the influence of IEQ, the control aspect and individual influences on mounting stress symptoms amongst employees. The sensitivity of occupants towards thermal comfort, lighting comfort, acoustic comfort and air quality is evaluated with an environmental stress score that represents stress symptoms from IEQ.

Gauthier and Bourikas (2020) studied environmental discomfort, but the results showed no relationship between the parameters, although associations are drawn between physical environmental parameters and the stated comfort levels. Barthelmes et al. (2020) studied the combined effect of IEQ, interfaces between IEQ, and behavioural actions – occupants' characteristics, inclinations for adaptive actions and the impact of behavioural actions on indoor settings. However, the results obtained are not discussed but provide a planned outline of a monitoring framework for open-plan offices.

The mention of prior studies indicates that similar interrelationships could be occurring in commercial kitchen environments. Many indoor environmental stressors can cause effects additively or through complex interactions. These can be synergistic or antagonistic, namely draught and temperature, view and luminance ratios, odours, humidity, mould, radiation, chemical compounds, particulates, and noise and vibration (Torresin et al. 2018). Kim and Haberl (2018) critiqued ASHRAE's (PMP) model and reported that it does not provide guidance on the inconsistencies in the results between the IEQ survey and spot evaluation of the same space when they arise.

Clements et al. (2019) theorised that the building system design contributes significantly to spatial variability in air temperature, lighting and sound masking exposures. Environmental psychologists have documented that many design characteristics positively impact the well-being and functioning of building users, such as reduced noise, enhanced lighting and ventilation, better ergonomic designs, supportive workplaces, the provision of personal control and improved layouts (Steg & De Groot 2019). However, Altomonte et al. (2020) critiqued that as the response to environmental stimuli is subjective, performance standards contemplated by guidelines and protocols cannot necessarily ensure the well-being of every person.

A summary of Frontczak and Wargocki (2011) inferred that workers placed relatively high importance on contributions coming from light, sun, temperature, fresh air and smell. The results showed that satisfaction with all 15 environmental parameters and building features listed in the Center for the Built Environment (CBE) occupant satisfaction survey contributed significantly to overall satisfaction with personal workspace.

Kim and De Dear (2012) examined relationships between IEQ categories and overall workspace satisfaction. The authors used Kano's model of customer satisfaction to analyse IEQ category performance into more detailed relationships with satisfaction, such as basic factors, bonus factors and proportional factors. The basic factors in the Kano Model of satisfaction include temperature, noise level, amount of space, visual privacy, adjustability of furniture, colours and textures, and workspace cleanliness. Sethi and Malhan (2015) endorsed that workplace comfort is a basic need of kitchen staff in the kitchen and involves factors such as temperature and humidity, layout features, safety, hygiene and sanitation. In kitchens, providing adequate basic environmental factors, including the amount of space and workspace cleanliness, is essential. Simone et al. (2013) emphasised that an acceptable thermal environment is provided for kitchen occupants.

Some proportional factors, such as IAQ, amount of light, VC and ease of interaction should be the purview of basic factors in kitchens. Sound privacy, the comfort of furnishings, building sanitation and building maintenance are other proportional factors, according to Kim and De Dear (2012).

Kim's (2012) field-test set out to evaluate the ASHRAE, CIBSE and US Green Building Council's (USGBC's) performance measurement protocols (PMP) for commercial buildings in Texas; ASHRAE PMP accomplished its goal of providing the standardised procedures for evaluating and comparing the overall performance of a building, including energy, water and IEQ. The author added that several areas for improvement are identified, such as conflicting results from different procedures and limited guidelines for performing the measurements, as well as a lack of graphical indices and clear benchmarks (Kim 2012).

Park, Loftness and Aziz (2018) stated that post-occupancy evaluation (POE) IEQ measurements of office buildings comprised objective IEQ measurements along with subjective surveys with a significant analysis of thermal satisfaction. The level of thermostat control is related significantly to occupant satisfaction in both open-plan offices and closed offices. Although bivariate analysis reveals the relationship between measured and perceived IEQ indices, interdependencies between IEQ indices and other satisfaction variables of significance, it failed to perform multivariate analysis between IEQ parameters. The study also claims to explore correlations between occupant satisfaction and measured data with an integrated survey method. In parallel, this study will also explore interdependencies between IEQ parameters, with the addition of multivariate analysis between the IEQ indices to establish a correlation between the parameters and discomfort amongst food-service workers.

In another multivariate study, Jimoh (2017) created a mathematical model based on objective data with IEQ sub-divided into its constituent parts. I have created a model based on objective data with IEQ as a composite. Treating IEQ as a single unit of analysis, which consists of five parameters, seems accurate. The effect of covariates is accepted, as in the lecturers' characteristics, such as age and gender, on IEQ parameters. Statistically significant differences in satisfaction with IEQ are revealed regarding gender differences. However, on the age factor, a significant difference in satisfaction with acoustics is achieved. This study advances the well-being of occupants and interrelationships assessment to improve work performance.

There is a dearth of research on such combined studies. Jimoh (2017) lamented that Nigeria's lack of thresholds or standards on IEQ parameters could be responsible for this outcome. However, a study by Yang and

Moon (2019) found that an illuminance level of 500 lux is preferred for VC, thermal comfort and indoor environmental comfort; however, their statistical significance is not confirmed except for thermal comfort. In this regard, I also observed that there are no IEQ parameters for commercial kitchens in South Africa.

Heinzerling et al.'s (2013) evaluation of the PMP provides an accurate comparison of IEQ performance of commercial buildings. The authors' allocation of the weighting of the IEQ categories when determining overall IEQ quality provides a factor of relative importance based on an occupant survey. The results are determined through regression coefficients. I will also perform a similar statistical analysis to establish relationships amongst various elements across different data-gathering tools. The Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) Indoor Climate Quality Assessment guidebook represents a good first attempt at outlining the issues of IEQ evaluation. Such measurements implemented in a standardised fashion can transform the measurements of IEQ models into scores that can be used in ratings and standards.

Dawe's (2019) post-occupancy assessment on IEQ with occupant surveys in eight LEED-certified buildings found that none of the buildings achieved an 80% thermal satisfaction rate, which is defined as people expressing satisfaction from +1 to +3 with the heat. The author also added that acoustics have low satisfaction across all eight buildings, and most concerns arise from sound privacy in open-plan offices.

Designing buildings can help to best serve human needs and wants; for example, restaurants and coffee shops have social designs typical for their functional use. A gap often exists between building designers and building users; favouring a human-oriented, democratic approach within the local context can help ensure that the design will enhance well-being and health-promoting behaviour.

Jimoh (2017) investigated IEQ variables such as temperature, RH, ventilation, noise, lighting and workspace utilisation in university buildings. The investigation revealed that gender and age of lecturers affect their satisfaction with IEQ parameters such as acoustics, while workspace characteristics such as type of building, floor level, direction faced by the window and type of office affect their satisfaction with IEQ parameters like the size of workspace, ventilation and VC. Park et al. (2018) concurred in a study of office buildings and reported that there is a significant difference between men and women in thermal dissatisfaction. This difference between the genders may be because of clothing insulation and metabolic differences. This study explores the significance of gender and age on the different IEQ factors amongst kitchen workers.

Dawe (2019) reported that the primary factor leading to heat discomfort in these buildings is a lack of control over the thermal environment, both for heat and airflow. The adjustability of furniture and airflow control amongst university lecturers affect their contentment with IEQ parameters (Jimoh 2017).

Frontczak et al. (2012) added that the indoor environment is to a large extent controlled manually by the building users, for example, by opening the windows to regulate ventilation or setting the thermostat levels to regulate heating. This study explores the element of control in kitchens, where access to switches on light bulbs and adjusting thermostatic controls, ventilating equipment and fans provide satisfaction to kitchen workers.

I propose features to resolve the comfort issues and fast-response behavioural changes, such as opening windows and operating fans that allow for individual control of environmental conditions. To monitor and measure combined IEQ, a low-cost suite of integrated sensors and data-processing capabilities autonomously measure key IEQ indicators (Parkinson, Raftery & Present 2020). These measures can improve building performance and IEQ and occupant satisfaction, health, well-being and performance.

5.11 Limitation of prior indoor environmental quality investigations

Bluyssen (2019) criticised the assessment of dose-related indicators of IEQ, based on single dose-response relationships as developed for the average occupant. Such measures ignore the fact that individuals are in different scenarios such as homes, offices and schools, and different situations such as washing and cooking. It seems that dosage exposure and response may depend on time and other variables such as physical, physiological, personal, psychological and social needs that are all considered – not per variable, but integrated. Methodological protocols are consequently raised. The selected approach must be suitable for determining patterns of stressors and interactions and take account of dynamic behaviour over time per scenario.

The relationship between IEQ and well-being is complicated. Table 5.4 lists the studies on kitchens and the IEQ parameters measured across different geographical areas with dissimilar climatic conditions. Only two studies measured acoustics and lighting along with other IEQ; however, no relationships are correlated.

Being already under significant stress because of peak periods, food-service workers are likely to be more affected by indoor environmental design flaws, and in addition, each worker may have different environmental needs because of variations in ethnicity and adaptation, which has received very little attention in environmental design research.

TABLE 5.4: Summary of studies on indoor environmental quality in kitchens.

Source	Location of kitchens	Temperature	RH	Air flow	CO_2	Noise	Light	Work-space	Type of kitchen or equipment	Architectural features	Personal factors*	Secondary factors**	Phenotype and genotype***	Comfort/ discomfort
		Thermal comfort												
Heinonen (1997)	Various food services	√	√	√					√					
Akbar-Khanzadeh *et al*. (2002)	Restaurants	√	√	√	√									
Eagles and Stedmon (2004)	UK restaurant	√	√	√		√	√	√						
Kajtar et al. (2005)	Building	√	√	√	√				√					√
Haruyama et al. (2010)	Various food services	√	√	√					√	√	√	√		√
Matsuzuki et al. (2011)	Various food services	√	√	√				√	√		√			
Saha, Guha and Roy (2012)	Student hostels	√	√	√	√				√					
Zhao et al. (2013)	Chinese Restaurant	√	√	√	√									
Simone et al. (2013)	US restaurants	√	√	√	√			√		√	√	√		√
Zhao et al. (2014)	Chinese kitchen	√	√	√	√									
Bindu and Reddy (2016)	Various food services	√	√	√	√	√	√							√

Table 5.4 continues on the next page→

TABLE 5.4 (cont.): Summary of studies on indoor environmental quality in kitchens.

Source	Location of kitchens	Temperature	RH	Air flow	CO_2	Noise	Light	Work-space	Type of kitchen or equipment	Architectural features	Personal factors*	Secondary factors**	Phenotype and genotype***	Comfort/ discomfort
	Thermal comfort													
Singh et al. (2016)	Commercial kitchen	√	√	√	√						√	√		√
Beheshti et al. (2015)	Bakeries	√	√	√										
Rahmillah, Tumanggor and Sari (2017)	Domestic kitchens	√	√	√										√
Sajedifar et al. (2017)	Hospital kitchen	√	√	√							√			√
Logeswari and Mrunalini (2017)	Student hostel	√	√								√			
Alam and Salve (2021)	Railway pantry cars	√	√	√							√	√		√

Key: CO_2, carbon dioxide; RH, relative humidity; UK, United Kingdom; US, United States.
Personal factors*-age, gender, race, height, weight, BMI; Secondary factors**- work experience, work shift, job position, work activity, physical fitness, and health status; Phenotype and genotype***- hair, skin colour, type of nose, body type.

5.12 Conclusion

In conclusion, Chapter 5 has discussed that lighting levels vary widely across kitchens, and the lighting standards also differ broadly across different countries. The interrelationship between various parameters is shown in this chapter to vary widely, depending upon several factors such as geographic location, climate, type of building and presence of fenestrations. The influence of five parameters of environmental quality is not necessarily clear-cut. Although all the parameters are significant, this discussion does find that for the well-being of kitchen workers in commercial kitchens, heat plays a significant role. The next chapter discusses the methodology of the study. Table 5.4 compares the various studies on kitchen IEQ and indicates that various primary and secondary variables are excluded and not discussed.

Chapter 6

Research methodology

6.1 Introduction

This chapter offers a detailed explanation of the research strategy employed to meet the aims and objectives of this study. The initial sections of this chapter will outline the research questions of the study and then proceed to discuss the selected case studies.

The following research questions have been set to help address the aim of this study:

1. What is the level of indoor airflow, humidity, thermal environment, lighting and acoustics in restaurant kitchens?
2. How does heat stress affect food production workers who use gas and electrical kitchen appliances?
3. What are the perceptions of the adaptability of food production workers to selected indoor environmental conditions?
4. What are the indoor environmental criteria required to design restaurant kitchens in Durban?

6.2 Research design

Flick (2019) asserted that research design is a plan to answer a research question. The research design utilised in this study incorporated a

How to cite: Gangiah, S 2022, 'Research methodology', in *Environmental ergonomics Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town, pp. 115–161. https://doi.org/10.4102/aosis.2022.BK346.06

nonexperimental, exploratory case study design. This study followed a systematic and scientific approach to extend available knowledge in IEQ and embarked on exploratory research with the objective of exploring an area where little is known. This type of design is often used to establish an understanding of how best to proceed in studying an issue or what methodology would effectively apply to gather information about an issue. Kapur (2018) claimed that exploratory studies focus on the subject matter with no hypothesis being formulated. Against this backdrop, this study used an exploratory research design to examine IEQ in commercial kitchens.

A mixed methods approach is considered appropriate for this study. Bryman (2006) stated that the criterion for qualitative and quantitative components of mixed methods comprise 'mutually illuminating' and collaborative effects of eliciting facts. Mixed methodology approaches are interesting for their value in combining qualitative and quantitative research (Flick 2019). Quantitative data collection is combined with some qualitative techniques. The purpose of the quantitative data is to evaluate objective data, while the qualitative data, per Creswell (2013), are obtained from respondents.

The research instruments used in this study comprised a questionnaire, interview schedule and structured observations. The instrument design, population size, sample techniques and instrument distribution are explained in detail in Section 6.2 and are summarised in Table 6.1.

A research strategy is a step-by-step plan of action that gives direction to the researcher's opinions and determinations, facilitating researchers to conduct investigation scientifically and on schedule to produce quality results and detailed reporting (Dinnen 2014). Research strategy, according to Bryman and Bell (2011), is a general orientation to conduct research. Of relevance to this study, the research strategy is based on a mixed approach that includes a case study. It may involve a single study or multiple studies (Creswell 2013). This study is a multiple-case or collective case study.

Flick (2019) added that a case study aims to precisely describe cases; the main problem is to identify a case that is significant for the research question and what methodological approaches its reconstruction requires. A case study is often used to narrow down a very broad field of research into one

TABLE 6.1: Summary of methodological choice for the study.

Unit of analysis	Instrument	Population size (eThekwini Municipality)	Sample technique	Sample size	Instrument and administration
Commercial kitchens	Observation checklist	1 563	Purposive sampling	33	Gauge
Head chefs and kitchen managers	Self-administered questionnaire	40	Purposive sampling	33	Self-administered
Food-service workers	Interview schedule	510	Purposive sampling	170	Face-to-face

or a few easily researchable examples (USC Libraries 2019). According to Yin (2014), the case study method is relevant when research requires an extensive and 'in-depth' description of phenomena. Multiple-case designs have distinct advantages and disadvantages in contrast to single-case designs.

Casteel and Bridier (2021) claimed that the population of interest for a study is comprised of the individuals, dyads, groups or organisations that are potential units of analysis and to which the study results may be generalised or transferred. The population here includes all the food-service establishment kitchens in Durban. The target population is the specific, conceptually bounded group of potential participants that represents the nature of the population of interest. The population frame for the study comprised Durban municipality-licensed restaurant kitchens. A list of restaurants currently operating in eThekwini Municipality (2015b) was compiled from the Tourism Board South Africa after cross-referencing against the list of licensed restaurants. Only food-service operations with a minimum of 10 staff were considered restaurants and included in the study.

The sampling frame is an operationalised representation of the target population and is the group of units from which the sample is recruited (Casteel & Bridier 2021). This sample frame consisted of kitchens serving different cuisines with different styles of service. The sampling frame for this study consisted of 33 restaurant kitchens in the Durban area. It comprised some food production workers and kitchen managers from the selected restaurant kitchens. The population consisted of 170 food production workers on duty for that specific shift on that day in restaurant kitchens and 33 kitchen managers or head chefs. The unit of analysis is the selected commercial kitchens.

■ 6.3 Development of instruments

According to Kumar (2015), the first step in tool development is a careful examination of the extant theory, which is current or existing theory relating to the construct the researcher decides to measure. In social research, there are three main forms of data collection, namely questionnaires, interviews and observation or study documents. As every method has its limitation, it is useful to combine methods (Flick 2015). Multiple forms of data collection were undertaken. I developed the instruments from the construct, and latent variables were formulated. I revisited the research questions frequently to ensure that the generated items reflected the dimensions and elements of interest and remained relevant. These dimensions were heat, ventilation and humidity, noise and lighting. At this stage, the proposed subscales of the tool were identified, and verification of the representativeness of items was undertaken. The item and factor analysis stages of the tool development process are used to establish whether such items are representative of the expected factor. Test equipment was selected based on its ability to observe and measure variables.

6.3.1 Self-administered questionnaire

A questionnaire is commonly a set of printed or written questions with a choice of answers and is devised for a survey or statistical study. A questionnaire is used to gather qualitative as well as quantitative data by the inclusion of open-ended questions.

The questionnaire intended for the head chefs or kitchen managers consisted of 43 main questions. The first section comprised basic demographic information on the food-service workers and background information about their experience, current position, the type of enterprise, cuisine, menu, covers, occupancy, number of meals cooked and busy periods. The second part elicited data on their perceptions about the various parameters such as heat, humidity, air velocity, lighting and noise that were later measured with test equipment. The questions also prompted information on their insights about staff responses to the kitchen environment on heat, humidity, airflow or ventilation, noise and light. The Likert scale was used for 25 closed-ended questions requiring quantitative responses. The measurement scale for data was ordinal, but the variable was treated as continuous. Figure 6A-1 indicates the questionnaire prepared by the author. Zhang et al. (2020) acquired chefs' perceptions of the indoor environment with a questionnaire with three sections:

1. A basic information section, including gender, age and height.
2. A thermal comfort section, where respondents estimated their annual satisfaction level with temperature, humidity, air velocity and overall thermal comfort in the kitchen, which was measured using a seven-level scale, the levels being 'very uncomfortable', 'uncomfortable', 'just uncomfortable', 'general', 'just comfortable', 'comfortable' and 'very comfortable'.
3. In the IAQ section, respondents evaluated the COF overflow frequency (four-level scale: 'no', 'rarely', 'sometimes' and 'often'), the spill-over concentration of COF (four-level scale: 'no', 'light', 'thick' and 'heavy') and noise intensity (four-level scale: 'no', 'weak', 'moderate', 'strong').

6.3.2 Interview schedule

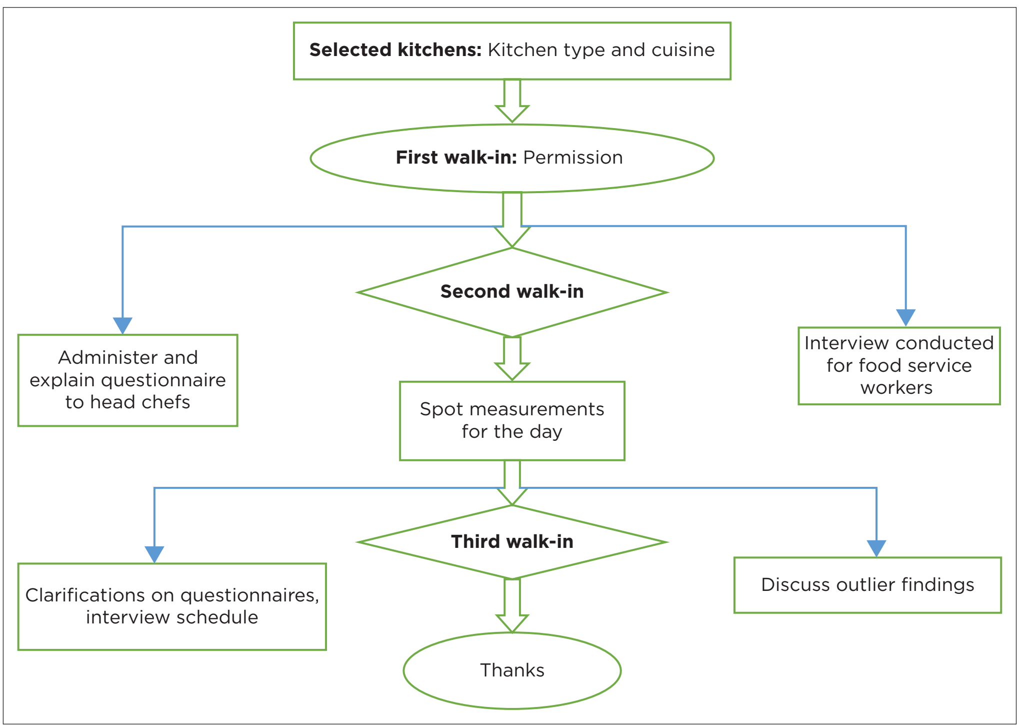
The use of this instrument is necessary to elicit information on the reactions of food-service workers to the kitchen environment. Semistructured interviews prompt the interviewed subjects' perceptions expressed in an openly designed interview situation compared to a standardised interview (Flick 2019).

The first section comprises 39 questions on basic demographic information on the food-service workers and background information about their age, gender, race, experience, shift, current position, comfort with the uniform, make-up, hairstyles, fitness levels, personal habits, weather, skin colour and type of nose.

The second part is adapted from the work of Kim et al. (2013) and focuses on respondents' opinions on heat, ventilation, humidity, lighting, noise and space design. The interview schedule comprised a series of open-ended questions according to themes. I retrieved information on the socio-economic background of workers, adaptability and the specific tasks performed. I prepared an IS as given in Figure 6A-2.

6.3.3 Observation schedule

Naturalistic observation is a method of research that is often used by social scientists and is a technique involving the observation of subjects while they remain in their natural environment. Observation can be so valuable that taking photographs increases the reliability of observation. The layout of kitchens is captured by still photography. The research instrument consisted of 103 items, with nominal and ordinal measurements. Figure 6.1 presents the observation checklist that I conjured up.



Source: Author's own work.

FIGURE 6.1: Scheme of instrument administration for data.

6.3.4 Test equipment for measurement

Clements et al. (2019) measured flow rates through spot checks of air velocity to evaluate IEQ. Park, Loftness and Aziz (2018) evaluated the IEQ of offices by spot measurements (SM) of thermal, air, visual and acoustic conditions. Krishnamurthy et al. (2017) used spot readings of WBGT for a steel factory at Salem in India. Tartarini, Cooper and Fleming (2018) assessed the thermal environment of a nursing home by SM of indoor air temperatures. Simone et al. (2013) adopted short-term or SM for globe temperature, air temperature, operative and radiant temperatures, as well as air velocity and RH in commercial kitchens. Similar processes were followed by Simone et al. (2013) when measuring and recording thermal parameters in different types of kitchens. The selected equipment accords with the SABS, which provides a range of standards covering the demands of the calibration industry and helps the organisation enhance customer satisfaction and meet regulatory, safety and reliability requirements to ensure consistency of quality throughout the supply chain. According to the National Regulator for Compulsory Specifications (2018), all laboratories are accredited by SANS 17 025, which provides the requirements for the competence for testing and calibration in laboratories by the SANAS. Calibration is performed on-site or under controlled laboratory conditions. Calibrated gauges for measurement of parameters assure the validity and reliability of data collected.

6.4 Data collection

6.4.1 Sampling method

Flick (2019) claimed that in the case of studies, sampling is purposive, focusing on concrete cases that can contribute to the knowledge in the study. Trochim, Donnelly and Arora (2016) also argued that in purposive sampling, the researcher samples with a purpose related to the kind of participant they need, usually seeking one or more specific kinds of people or groups. According to Creswell and Clark (2011), these perspectives are simplified as an intentional selection of participants who have experienced the key concept explored. The purposive sampling of restaurants for this study is accordingly informed.

Kitchens were selected with due consideration to the type of cuisine to include diversity in cooking methods and a minimum of 10 employees. The respondents were key informers as they experienced the IEQ in kitchens during work. All the restaurants in the sample frame that was convenient in terms of operating hours and distance were requested to participate in the study. Purposive sampling was adopted to maximise what could be researched in the time available.

BOX 6.1: Types of quantitative and qualitative data sources.

Quantitative	Qualitative
• Quantitative data collection: • scientific equipment • observational checklists • questionnaire. • Quantitative data analysis uses numeric data for: • description • comparing groups • relating variables.	• Qualitative data collection: • semistructured interviews • observations • documents • audio-visual materials such as photographs. • Qualitative data analysis uses text and image data for: • coding • theme development • relating themes.

Charan and Biswas (2013) contended that the method of sample size calculation is different for different study designs, and one blanket formula for sample size calculations cannot be used for all studies. Any application of sampling logic to case studies would therefore be misplaced. Yin (2003) posited that because of the nature of the case study approach, 'the typical criteria regarding sample size are irrelevant'. When cases are studied, a small number such as four to ten is used. The sample size must, however, relate to the question and the type of qualitative research. Kumar (2015) accordingly claimed that it is an approach in which a few carefully selected cases are intensively studied. Bearing this in mind, the sample size selected is given in Table 6.1.

The extensive use of screening criteria in replication sampling logic, according to Swisher (2017), reduces the variance in the sample on purpose and hence is superior to sampling logic. Multiple cases resemble multiple experiments, and the need is for replication logic, not sampling logic, for multiple-case studies. That means that each case must be selected carefully so that it forecasts a comparable or accurate replication, or it predicts dissimilar results but for anticipatable reasons or a hypothetical replication. The author added that the capacity to conduct six or ten case studies, arranged effectively within a multiple-case design is equivalent to the ability to conduct six to ten experiments on related topics. A few cases (two or three) would be literal replications, whereas a few other cases (four to six) might be designed to pursue two different patterns of theoretical replications. For this study, a nonprobability census sample was drawn from food-service establishment workers who reported for duty during the data collection period. A census sample minimises sample bias.

All the restaurants in the sample frame that are convenient in terms of operating hours and distance are requested to participate in the study. Purposive sampling is adopted to maximise what could be researched in the time available. A nonprobability census sample is drawn from food-service establishment workers who reported for duty during the data collection period.

6.4.2 Instrument administration

This study followed the criteria per Kim and Haberl (2018) that included a data collection protocol during walk-in measurements at peak times of business on-site for a day. The first step in conducting the field study was to approach each restaurant individually and recruit the owner or manager to participate in the research study. Next, 'gatekeeper' letters were obtained to conduct the study and dates were confirmed for evaluation of IEQ in the commercial kitchens.

Questionnaire administration involved early notice to the restaurants about the researcher's arrival. The managers or owners informed kitchen workers about the research two days prior to data collection. Head chefs filled in questionnaires in their kitchens or offices. The study setting was non-contrived, as it was conducted in a natural setting. Sekaran and Bougie (2016) stated that the extent of interference by the researcher has a direct bearing on whether the study undertaken is correlational or causal.

According to Haberl et al. (2008), Level 1 information about the thermal comfort of buildings relies on occupant surveys and SM of ambient temperature (Ta), RH, mean radiant temperature (MRT) and air velocity (V air) that can then be compared to benchmarks such as those published by the CBE. As recommended, protocols for measuring IAQ at Level 1 require a hand-held meter to capture SM – Ta, RH, CO_2 (Kim & Haberl 2018) and CO. A HI or WBGT meter was used to measure Ta, RH, WBGT and black globe temperature (BGT). A hygrometer was used to cross-check Ta and RH. An air quality monitor was used to measure CO_2 and O_2 levels. Air velocity was measured by an anemometer or a velocity meter. Air velocity, RH and CO_2 levels indicate ventilation in kitchens. The performance metrics required of selected IEQ parameters included temperature, humidity, MRT, airspeed, CO_2, and measurements of illuminance and background noise (Kim & Haberl 2018). However, the author critiqued ASHRAE's PMP because they lack specific step-by-step measurement protocols that can be used for IEQ SM.

Protocols for the performance measurement of lighting and daylighting rely heavily on standards published by the Illuminating Engineering Society (IES) (Haberl et al. 2008). In Level 1, the basic method, occupant surveys and spot illuminance are made and compared to published illumination levels in the IES Standards. Protocols for the performance measurement of indoor acoustics for Level 1, the basic method, include indoor and outdoor decibel

SM, which are compared to the appropriate noise criteria for the space being measured. Kim and Haberl (2018) were of the opinion that in addition to instrumental measurements, an occupant 'right-now' survey of thermal sensation, comfort, acceptability and preference should be conducted concurrently.

Kumar, Jain and Mathur (2020) recommended that the collection of occupant satisfaction surveys along with physical parameter measurements is the most effective way for IEQ assessment. As per the above recommendations, Level 1 measurements were taken in commercial kitchens; however, the criteria in kitchens are different from office requirements (Table 6.2).

Table 6.4 provides a detailed list of equipment that is selected, what each measured and the contribution of each measure to the study objectives. Berquist et al. (2019) recommended that to investigate the relationship between IEQ and occupant comfort in commercial buildings, longitudinal and simultaneous evaluations of both aspects should be conducted to ensure the variations in indoor conditions and occupant demographics.

Saha, Guha and Roy (2012), Li et al. (2012), Simone et al. (2013) and Logeswari and Mrinalini (2017) conducted thermal studies in kitchens. However, these studies did not include noise and lighting. As the commercial kitchen environment in Durban presents different conditions from the studies mentioned, a measuring procedure was established, focusing on the processes characterising the kitchen space. Employees facing high-energy appliances, such as grillers, tunnel pizza ovens and deep-fat fryers are exposed to higher radiant temperatures than employees working in preparation areas a few feet from the appliances (Simone et al. 2013).

A dishwasher in India works in hot, wet, humid and noisy environments for long periods. Workers in dishwashing areas are subject to very humid hot air and, therefore, to higher discomfort levels (Johnson et al. 2019). Matsuzuki et al. (2013) claimed that the thermal conditions of the working environment in commercial kitchens are primarily driven by radiant heat, humidity levels and airflow that directly impact the employees. Rusnock and Bush (2012)

TABLE 6.2: Scheme for instrument administration of data.

Level	Thermal comfort	Indoor air quality	Lighting	Acoustics
Basic	Spot measurements of temperature, RH, MRT, airspeed	Outside airflow rates at each outside air intake Spot measurements of temperature and humidity to characterise occupant perceptions of IAQ	Spot measurements of illuminance in selected spaces	Spot measurements of A-weighted sound pressure level (dBA) in occupied spaces

Source: Adapted from Kumar et al. (2020).
Key: RH, relative humidity; MRT, mean radiant temperature; IAQ, indoor air quality; dBA, decibels.

reported that the activities in the kitchen influence the noise levels. Jobtips (2020) claimed that noise varies from moderate to noisy as noise levels might change during the day in a restaurant business. Tasks in kitchens influence the amount of lighting utilised (Yazıcıoğlu & Kanoğlu 2016). Moreover, appliances, size and arrangement of the kitchen zones, number of employees and variable environmental conditions during business hours such as occupancy and type of meals ordered complicate the further evaluation of the indoor thermal environment in kitchens (Simone et al. 2013). Based on standardised methods as discussed above, a procedure for collecting data for the physical environment and subjective reactions obtained through interviews in commercial kitchens is presented in this study.

The classification of kitchens is based on an IMC that uses kitchen load as a basis for categorisation. This will assist in comparing the IEQ in different types of kitchens.

The researcher postulates that as there is insufficient cataloguing of classification of kitchens, the International Code Council (2018) IMC ergonomic system of organisation of kitchens can be adapted to establishments based on the type of equipment. Currently, it seems that the clear-cut demarcation of service methods or types of service styles in food and beverage operations is not strictly followed, as most establishments are embracing the concept of customer orientation and making changes gradually in their operations to encompass a pleasant meal experience.

6.4.3 Self-administered questionnaires

The briefings to food-service managers and head chefs were conducted a day or two prior to the fieldwork. Participants were informed that the study could improve their kitchen environment and that their contribution was very important. A three-day lag time helped the researcher to follow up on unfilled questionnaire items and seek clarification. Unresponsiveness of respondents was absent, as total participation was noted.

6.4.4 Interviews

An interview schedule was administered to food production workers. Chan, Yi and Wong (2016) reported that workers in a hot environment such as catering need to be interviewed individually to elicit responses free from any group

TABLE 6.3: Classification of sampled kitchens based on equipment and fuel.

Light-duty equipment	Medium-duty equipment	Heavy-duty equipment	Extra-heavy-duty equipment using solid fuels
Kitchen 1, 2	Kitchen 3, 4, 5, 6, 7	Kitchen 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28	Kitchen 29, 30, 31, 32, 33

bias and to be more comfortable, regardless of heat stress, so that they can respond to their environment.

The food-service and kitchen managers briefed the staff on the research to obtain a high response rate. A follow-up personal visit by the researcher ensured better cooperation amongst the participants. Each worker was approached individually while performing their work, and a request was made for 10 min–15 min of their time to be interviewed at their convenience. The researcher then sat with them in the kitchen during their break time or sometimes in the restaurant for the interview. The workers were generally shy to express themselves at first but slowly talked confidently about their experience of working in the kitchen. The semistructured interview, as scheduled, lasted between 10 min and 15 min, depending on the respondent's delay in answering the questions. All the workers were approached or interviewed during the day shift at breakfast, brunch or lunch. In one restaurant, the data were collected during the evening as the business only opened from 12:00. Various areas within the kitchen workspace served as venues to record worker perception of the work environment; removing the worker to a more comfortable atmosphere for interviewing could have introduced biased responses.

6.4.5 Structured observation

The third data collection tool with respect to kitchen layout and ergonomic design for all kitchens was evaluated by nonparticipant observation. The observation checklist was completed in two phases: Phase I and Phase II. In Phase I, the observation checklist was filled in by the researcher by observing the facilities, layout and equipment present. Questions AA 1 to CB 90 were direct observations by the researcher, which also included reactions of food-service workers in the kitchens. Photographs were taken to record the facilities in the commercial kitchens, as it helps overcome the typically fleeting nature of observation (Figure A12).

Phase II involved scientific testing equipment for the completion of the structured observation checklist from questions DA 91 to DA 103 using gauges intended to provide objective measures of environmental ergonomic design data. Spot measurement was followed by several prior studies, namely Clements et al. (2019), Park et al. (2018), Krishnamurthy et al. (2017), Tartarini et al. (2018) and Simone et al. (2013) for IEQ parameter measurements in commercial kitchens.

A strategy adopted by the South African Mines Occupational Hygiene Programme in their code of practice on thermal stress details the mandatory requirements for an occupational health program specific to thermal stress. Adapting this code of practice, the researcher categorised the thermal environment and practised the following steps in relation to heat stress. The observation process in each sampled kitchen was implemented as follows:

Step 1: The kitchen was subdivided into eight activity zones (receiving area, preparation area, stove, oven, holding area, dishwashing area, corridor, entrance to the kitchen) and other (griller and or fryer).

Step 2: Measurements were taken of the IEQ parameters that affected heat, such as assessment of ambient air temperature, WBGT, BGT, air velocity and humidity, followed by noise and lighting levels.

The measuring equipment yielded several types of measurement: external temperature, humidity, noise, indoor ambient temperature, operating temperature, RH, noise and lighting. Six different kitchen zones, namely receiving areas, food preparation, cooking equipment (such as stoves, ovens, fryers, grillers), holding areas, dishwashing areas and corridors were considered to have different thermal, humidity, ventilation, noise and light conditions in the commercial kitchen.

The researcher recorded kitchen temperatures and RH at time intervals of 15 min. The heat stress meter was used for SM of thermal parameters – air temperatures, wet-bulb globe temperatures and black globe temperatures at 0.30 m (1 ft) off the working station where kitchen workers were working at a height of 1.5 m. It was not conducive to measure these parameters at different heights during the peak operating hours of one working day, as the kitchen was busy, and the researcher was requested to refrain from undertaking this exercise. This restriction made the collection of detailed data more difficult.

The air velocity meter was used to measure the airflow and RH in different areas of the kitchen. The air quality monitor measured the CO_2 levels (ppm) and O_2 levels in percentage. The light meter was used to measure lighting levels in lux at a height of 1.5 m. Sound levels were measured by a noise level meter in dBA at 3-s intervals. The kitchen area was calculated from measured length and width with a laser measure (m). Hubbard (2020) claimed that architects measure distance with laser tools that are typically accurate to 1.58 mm (0.062 in) and give an instant measurement with the touch of a button.

Table 6.4 provides a detailed list of equipment that was used, why it was selected, what each measured and the contribution of each measure to the study objectives.

TABLE 6.4: Test equipment list.

Serial no.	Variable of interest	Research objective	Gauges	Social research instruments			Accuracy of the instrument
				Interview schedule	**Questionnaire**	**Structured observation**	**From equipment manuals**
1.	Ambient temperature in the kitchen	1, 2, 3	Thermohygrometer	B 1–4	24	BC 41	± 1°C
2.	Outside temperature	1, 2, 3	Heat index WBGT meter	A 15		DA 94, 95, 96, 97	± 1°C
3.	Wet-bulb globe temperature	1, 2, 3	Heat index WBGT meter	B 1–4		DA 98	± 1°C
4.	Temperature in different areas in kitchen	2, 3	Heat index WBGT meter	B 1–4		DA 97	± 1°C
6.	Humidity	1, 2, 3	Air temperature-humidity meter or hygrometer	B 7–10	34	BD 53–59, 62–63, DA 91	± 3 %
7.	Relative humidity	1, 2, 3	Air velocity meter	B 7–10	36, 37	DA 91	± 3 %
8.	Air velocity	1, 2, 3	Anemometer (air velocity meter)	B 5, 6	40	DA 101	± 2 %
9.	CO_2 in air	2, 3	Air quality monitor	B 5	40	DA 102	± 30 ppm + 5% of reading
10.	Oxygen	2, 3	Air quality monitor			DA 103	± 1 %
11.	Light	1, 3	Light meter (lux)	B 11–16	29	AB 13–15, 17–18, 25, 26, DA 93	± 3 %
12.	Acoustics	1, 3	Noise level meter	B 21–25	32, 35	BC 39–40, 41, DA 92	± 1.4 dB
13.	Kitchen area	1, 4	Laser measure	B 27–32	6	AA 8, BD 42, 47	

Key: CO_2, carbon dioxide; DA, displaced aggression; WBGT, wet-bulb globe temperature.

6.5 Data analysis

Quantitative data are collected through a questionnaire survey, and qualitative data are collected through in-depth interviews to identify kitchen workers' approaches to IEQ in kitchens. Indoor environmental quality is measured with test equipment. The use of multiple data collection instruments permitted cross-referencing or triangulation of the results towards defensible assessments of IEQ in sampled commercial kitchens.

Roomaney and Coetzee (2018) stated that triangulation is an important justification for adopting a mixed methods approach and is used when researchers test the validity of the results from combining various methods to study the same phenomenon. Using triangulation allows for the systematic extension of possible knowledge creation by using the second set of methodological proceedings and placing findings on more solid ground (Flick 2019). The type of triangulation chosen depends on the purpose of a study, and more than one type can be used in the same study. In this study, the focus was on method triangulation. The data collected with three different instruments, such as questionnaires, interview schedules and observation checklists, were combined with direct observation techniques and direct measurement techniques. Method triangulation is commonly known as multimethod triangulation, which also refers to the combination of qualitative and quantitative data.

The quantitative data collected from the responses to the instruments were analysed using the SPSS version 25.0. It is used by various researchers for complex statistical data analysis (Foley 2018).

The data from interviews and questionnaires were thematically analysed. Themes were developed to accord with the variables of interest. Retrieving qualitative data from respondents requires the researcher to do a write-up on the information received. Many qualitative statistics are available in the form of narrative (text) writings that are derived from a variety of sources, including interviews, survey questions, papers, published findings and current documents. Words combine into meanings, but meanings must be sorted, interpretations deliberated and inferences drawn.

Following Welman, Kruger and Mitchell (2005), these themes were identified before, during and after data collection by means of word counting, pattern recognition, descriptive and interpretative codes. Also, data collection and data analysis were found by David and Sutton (2011) to often fold into each other in the exploratory form of qualitative research. For example, measurement of CO levels in the kitchen and comparison with permissible levels could indicate inadequate ventilation without any further analysis of this data.

Correlation was used to assess reliability; the closer the correlation is to 1.0, the more reliable the scores are. McLeod (2013) posited that if findings from the research are replicated consistently, they are reliable. A correlation coefficient can assess the degree of reliability. A reliable test should show a high positive correlation. Multiple logistic regression models were used to define the relationship between multiple variables to analyse the association between variables.

Multiple regression is used to predict the value of a variable based on the value of two or more other variables. The variable to be predicted is called the dependent variable or criterion variable, and the variables used for predicting the value of the dependent variable are called the independent variables.

The next section discusses data preparation and coding, data capturing and pretesting of instruments, which are required to improve the validity and reliability of the data collection procedure.

6.6 Data preparation and coding

Import.io (2018)[2] appropriately defined data preparation as a preprocessing step in which data from one or more sources are cleaned and transformed to improve their quality before their use in business analytics. It is often used to merge different data sources with different structures and different levels of data quality into a clean, consistent format. Castle (2018) stated that:

> [*D*]ata preparation refers to any activity designed to improve the quality, usability, accessibility, or portability of data. The goal of data preparation is to empower people and analytical systems with clean and consumable data to be converted into actionable insights. (n.p.)

Flick (2015) claimed coding means allocating numerical values to answers. Prior to coding, data cleaning is necessary. For this study, the first step in data cleaning was removing unwanted observations from the data set. This included duplicated or irrelevant observations. All three instruments' measurements were cleaned while coding and then input into SPSS. The act of representing data leads to the achievement of analysis. Content analysis was done in terms of units where the work was broken down into its component elements. Structural errors arise during measurement, data transfer or other types of 'poor housekeeping', where the researcher checked for typos or inconsistent capitalisation. Unwanted outliers, especially with humidity measurements, were filtered as they could cause problems. Moreover, linear regression models are less robust to outliers (Ben-Gal 2005). Missing data are a deceptively tricky issue because the missing value may be informative that particular equipment does not exist in certain kitchens. However, crediting the missing values based on other observations was useful in a few cases.

2. See Modern Data Management (2018).

After data preparation, the qualitative data's common themes – words, phrases and meanings within the data – were analysed. The questionnaires with closed-ended questions and structured observations were precoded. The interview schedule was coded after the collection of data, as it was unstructured. Here, the answers were allocated to categories and then labelled with numerical values (Flick 2015). Structural coding generally identifies large segments of text on broad topics, which form the basis for in-depth analysis within or across topics. A greater understanding of data was acquired by 'coding up', which raised the validity of the codes chosen.

6.6.1 Data capturing

A technique that translates the information provided by a respondent into an electronic format is referred to as data capture. This conversion is either automated or done by a staff member manually entering the data. The coded data were sent to an approved statistician to be captured for this study.

6.6.2 Pretesting

Initially, an expert's comment on the representativeness and suitability of the questions was obtained. Allowing suggestions to be made on the structure of the questionnaire helped establish content validity and enabled the researcher to make amendments prior to pilot testing. The generation of items during tool development required considerable face and content validity, resulting in refined wording and inclusive content. Prior to using tools, questionnaires were pilot-tested. The purpose of the pilot test was to refine the instruments so that respondents had no problem answering the questions and there was no problem in recording data (Saunders, Thornbill & Lewis 2009). In addition, it enabled the researcher to obtain some assessment of the questions' validity and the likely reliability of the data collected.

Preliminary analysis using the pilot test data was undertaken to ensure that the data collected enabled investigative questions to be answered. Ten per cent of the convenience sample frame was chosen randomly for pretesting the three tools. The trial run was established to indicate whether the questionnaire would succeed. Pretesting was conducted on 15 food-service workers from three different restaurants to strengthen reliability. The pretesting sample did not form a part of the study sample.

6.6.3 Descriptive statistics

The analyses will present the descriptive statistics in the form of frequencies, percentages, graphs and cross-tabulations. Descriptive statistics, according to Sharma (2019), are a representation of the entire population or a sample and provide a summary of the samples and measures done on a study. All descriptive statistics represent the measure of a central tendency to help understand the meaning of analysed data. The two main purposes include highlighting the potential relationship between variables and the basic features of variables in a data set. Descriptive statistics explain a simple summary of various samples, data sets, etc. and include their measures. The findings derived from the qualitative data obtained from the interviews with food-service workers are based on themes identified and presented graphically. Quantitative questionnaire data were analysed using descriptive and inferential statistics. Discussion of the latter follows.

6.6.4 Inferential statistics

According to Kothari (2009), quantitative data analysis is helpful because the results are easy to understand as it is quantifiable. Inferential techniques include the use of correlations and chi-square test values and factor analysis, which are interpreted using the *p*-values. Consistent with Field (2013), correlational analyses were conducted to determine the implication of the predictor variables in contributing to the dependent variable.

The exploratory factor analysis (EFA) conducted on the responses formed the sample of 170 workers and maintained a ratio of 5 in the number of observations to the number of variables. Comrey and Lee (2013) proposed that each variable that was subjected to factor analysis had at least 5 to 10 observations. Larger sample size can reduce the errors in one's data, and so EFA generally works better with larger sample sizes. However, earlier, Guadagnoli and Velicer (1988) proposed that if the data set has several high factor loading scores (> 0.80), then a smaller small size ($n > 150$) should be sufficient. A factor loading for a variable is a measure of how much the variable contributes to the factor (Yong & Pearce 2013). The types of factors are represented graphically; for example, numerical ability is a common factor, and communication ability is a specific factor. Moreover, the factor loading scores indicate that the dimensions of the factors are better accounted for by the variables. Next, the correlation *r* must be 0.30 or greater, as anything lower would suggest a weak relationship between the variables (Tabachnick, Fidell & Ullman 2007).

The results of the primary study in Chapters 7, 8, 9 and 10 are presented both as brief discussions and in table form. The study calculated predictions between variables within research instruments as well as across the three different instruments in the food-service establishments, namely the structured observational schedule, the questionnaire for food-service managers and head chefs, and the interview schedule for kitchen workers.

The next step in data mining was sorting through the large data sets to identify patterns and establish relationships to solve problems by data analysis.

Factor analysis as the data mining tool allowed for the prediction of future trends. Factor analysis as a statistical technique was used in this study for data reduction (Costello & Osborne 2005).

6.6.5 Exploratory factor analysis

Factor analysis is a correlation method used to combine several variables into a limited number of factors that hypothetically represent real-world constructs. According to Widaman (2012), this technique may be considered the most popular and useful method for identifying underlying dimensions that can mathematically account for behaviour. The basic theory of factor analysis is that for a collection of observed variables, there are a set of underlying variables called factors, which are smaller than the observed variables that can explain the interrelationships amongst those variables (University of California, Los Angeles [UCLA]: Statistical Consulting Group 2016).

Porritt (2015) argued that recent studies have indicated that under the proper circumstances, factor analysis may be accurately performed in samples as small as $n = 9$. A small sample size of 170 food-service workers and a sample frame of 33 restaurants provided reliable data. Winter, Dodou and Wieringa (2009) stated that when EFA is well conditioned, it can yield reliable solutions for sample sizes well below 50 with high λ, low f, high p. In some conditions, sample sizes even smaller than 10, beyond the smallest sample size of previous simulation studies, were found to be sufficient.

Adonis (2016) added that the typical use of factor analysis is in survey research, where a researcher wishes to represent a few questions with a small number of hypothetical factors. Factor analysis was used to establish whether the three instruments in this study measured the same construct. Several questions in the questionnaire and observation schedule in this study seemed to reflect this trend and were combined to create a new variable. This, according to DiStefano, Zhu and Mindrila (2009), was a factor score variable that contained a score for each respondent on the factor. When applied to this study, the factors were interpreted, given names and considered real things.

Field (2013) declared that the KMO measures should be greater than 0.50 and Bartlett's test of sphericity less than 0.05. In all instances, the conditions were satisfied, and this allowed for the factor analysis procedure to be applied to the Likert-scale items. Certain components were divided into finer components, and this is explained in the rotated component matrix.

Association is more specific to dependently linked variables that are highly correlated with another attribute, and regression is a commonly used technique (Ray 2015). The author added that multivariate linear regression is one of the most widely known modelling techniques.

6.6.6 Regression analysis

Given the largely quantitative research design, simultaneous backward multiple regression analysis was appropriate to measure the relationship of the predictive variables to the dependent variable. Regression analysis enables the prediction of future outcomes based on the predictor variables. Regression analysis is also a powerful statistical method that allows one to examine the relationship between two or more variables of interest (Foley 2018).

The backward method of multiple regression calculates the contributions of each predictive variable by looking at the significance value of the *t*-test for each predictor (Field 2013). According to the author, if the predictor meets the deletion criterion or not, making a statistically significant contribution to how well the model predicts the outcome variable, it is eliminated from the model. The remaining values are examined to evaluate and define their contribution to the outcome of the dependent variable.

Multicollinearity is a statistical phenomenon in which two or more predictor variables in a multiple regression model are highly correlated (Akinwande, Dikko & Samson 2015). The level of multicollinearity can be measured by considering the predictor variables. The predictor variables should not have a strong relationship with each other. The stronger the relationship between the predictors, the higher the degree of multicollinearity of the betas (Walker 2011).

Specifically, this study examined the multicollinearity of the predictive variables per Maher et al. (2013) by checking the Pearson's correlation coefficient between the predictive variables. Moreover, the process involved focusing on the model summary of the backward multiple regression analysis of the data and how it was produced, as well as the standardised coefficient beta weights of the predictive variables. Before commencing with regression analysis, analysis of variance (ANOVA) was performed to confirm that the model was correct to permit regression analysis. An alpha of 0.05 was used for all statistical tests. The regression types included are partial eta-squared (η^2), general linear model effect size and logistic regression.

There are a variety of regression techniques available in SPSS. It can range from simple linear regression, multiple linear regression and more advanced analyses such as logistic regression (Field 2013). Even though there are many types of regression analysis, at their core they all examine the influence of one or more independent variables on a dependent variable (Foley 2018). The different components of regression, namely partial eta square, general linear model effect size and logistic regression, determine the magnitude of the effect of one or more variables over the other variables, as the elements of different IEQ parameters can influence each other in the commercial kitchen environment.

6.6.6.1 Partial eta-squared

The partial eta-squared (η^2) is an estimate of effect size reported by SPSS, in conjunction with ANOVA and generalised linear model analyses. Many social scientific journals require reporting estimates of effect size to supplement tests of statistical significance, which is good practice (Field 2013). Effect size-statistical tests such as a *t*-test tell what degree of certainty to attribute to the possibility that a difference is not an accident but an effect; another important concern is how important the difference is (Draper 2019). Partial eta-squared (η^2) was calculated as the ratio of the between-groups sum of squares to the sum of the between-groups sum of squares and the error sum of squares. Wherever the *p*-value was not significant, partial eta-squared (η^2) was used in this study to establish to what extent a dependent variable was affected by several independent variables.

6.6.6.2 General linear model effect size

P-values alone do not indicate the size of an effect between variables (Field 2013). Suppose one variable is a dependent scale (number) variable and the other an independent nominal variable. In that case, the interpretation of the relationship is given by the effect size as measured by partial eta-squared (η^2) value (Maher et al. 2013). The logical reasons to choose an alpha level other than $p = 0.05$ with which to interpret the statistical significance and the interpretation of practical relationships based on effect size may be conservative, depending on the context. Association between related and dissimilar elements can be established to highlight the implication between elements of IEQ parameters.

6.6.6.3 Logistic regression

Logistic regression is a statistical method for analysing a data set comprising one or more independent variables that determine an outcome. The outcome is measured with a dichotomous variable – two possible outcomes (MedCalc 2020). Logistic regression is used to obtain the odds ratio in the presence of more than one explanatory variable. The procedure is quite like multiple linear regression, with the exception that the response variable is binomial (Sperandei 2014). The result is the impact of each variable on the odds ratio of the observed event of interest. According to the author, the main advantage is avoiding confounding effects by analysing the association of all variables together. The researcher used the backward method of simultaneous multiple regression to complete the elements of data analysis.

6.7 Validity and reliability

Reliability means consistency and validity means accuracy, which are critical factors in research and the foundations of good research (Adams &

Lawrence 2018). Mohajan (2017) stated that validity and reliability increase transparency and decrease opportunities to insert researcher bias in qualitative research and added that it is judged for rigour and strength based on the validity and reliability of research. Heale and Twycross (2015) claimed that rigour refers to the extent to which the researcher worked to enhance the quality of the study, which can be achieved through the measurement of validity and reliability. The quantitative and qualitative measures have been met to validate the quality of the study with rigour. Qualitative rigour is discussed in Section 6.7.2.

Reliability refers to an instrument's ability, consistency or dependability that is reliable and accurately measures accurately, reflecting the time score of the attributes under investigation (David & Sutton 2011). Mohajan (2017) posited that in quantitative research, reliability refers to the consistency, stability and repeatability of results. However, in qualitative research, reliability refers to when a researcher's approach is consistent across research and projects. The appropriateness and reliability of information gathered in an evaluation must be high-quality data that comes from well-defined indicators. Other factors that affect data quality may include instrument design, data collection procedures, training of those involved in data collection, source selection, coding, data management and routine error-checking (Community Toolbox 2019).

Accurate instrument calibration was vital for this study. Calibration is necessary to ensure that the instruments and devices used to measure parameters are accurate (Amsbary 2012). The most competitive offer from the supply and calibration was chosen. A designated instrumentation engineer from the manufacturing company demonstrated by prior appointment the procedure to measure all variables of interest.

Trial measurements were taken in an operating kitchen to authenticate each of the instrument readings from test equipment. One of the principal characteristics of an outcome measure in a trial, and any measurement in general, is its reliability (Lachin 2004). Measurement reliability concerns the consistency of measurement, also known as internal consistency reliability (David & Sutton 2011).

According to Yin (2013), observation is one of the best ways to enhance reliability; however, it requires multiple observations at different times. Ambient temperatures and airflow in the kitchen were measured at different intervals. The reliability of the instrument can be judged by estimating how well the items that reflect the same construct yield similar results; the consistency can be checked. For example, higher values of ambient temperature, WBGT and humidity mean higher thermal stress for workers. Reliability is a prerequisite for validity, but reliability alone is not sufficient to demonstrate validity. Hayashi et al. (2019) stated that the validity and reliability of research and its results are important elements to provide evidence of the quality of research in the organisational field.

There is greater evidence of validity in quantitative studies than in qualitative research studies (Hayashi et al. 2019). Flick (2019) commented that validity typically receives more attention than reliability in qualitative research. There is diversity within qualitative research methods and techniques, so there are no universally accepted criteria to assess validity in qualitative studies.

Face-to-face interviews, test equipment measures and self-administered questionnaires are valid instruments for collecting data. The interviewees were briefed on the subject matter prior to interviews, facilitating validity and reliability by enabling them to understand the requested information (Saunders et al. 2009). Once the researcher generated the initial pool of items, the next step involved rigorous discussions (Kumar 2011) between the researcher and field experts to review the items in terms of content adequacy. Content validity is the extent to which a research instrument accurately measures all aspects of a construct (Mohajan 2017). To assure content validity, items for each construct were generated from a review of associated literature.

Cronbach's alpha is the most used test to determine the internal consistency of an instrument (Heale & Twycross 2015). Internal consistency of the questionnaire and structured observation were estimated by Cronbach's alpha. An alpha of 0.70 or higher is desired, and values up to 0.899 are derived as given in Table A7 and Table A8 on correlations. The validity of a study refers to how accurately the instruments measure what they are supposed to measure (Adams & Lawrence 2018). Amongst other things, this was achieved by calibration of test equipment. According to Veal (2011), multiple methodologies and data sources used by the typical case study method offer the possibility of achieving a high level of internal validity. Multiple methods in the study consisted of instruments, namely the observation checklist, questionnaire and interview schedule. Data were sourced from a range of food-service workers. Furthermore, in-depth interviewing and long-term observation allow for greater internal validity (David & Sutton 2011).

Pilot testing or pretesting adds to the validity of the instrument. Trochim et al. (2016) stated that internal validity refers to the degree to which conclusions are made about causal relationships. However, the author added that one important feature of internal validity is that it is only relevant to the specific study in question; it has zero generalisability. Good experimental techniques, in which the effect of an independent variable on a dependent variable is established, can prove internal validity (Abowitz & Toole 2010). Airflow is an independent variable that affects humidity, which in turn affects thermal stress. It seems the higher the airflow, the lower the humidity and thermal stress.

Table 6.5 summarises the measures followed to enhance the quality of the study by means of the various quantitative and qualitative measures to ensure validity and reliability.

TABLE 6.5: Enhancing quality of study.

Qualitative data	Demonstrated in	Quantitative data	Demonstrated in
Researcher bias, objectivity, honesty	Section 6.7	Appropriate statistical analysis of the data	Section 6.5
Design of research tools	Section 6.3	Design of research tools	Section 6.3
Sample selection	Appropriate sample selection Interview schedule of 170 food-service workers	Sample selection	Appropriate sample selection Observation checklist of 33 food service establishments 33 questionnaires of head chefs and kitchen managers
The use of triangulation	Section 6.7.2	Sample size	Section 6.4.1
Rigour	Section 6.7.2	Rigour	Section 6.7.2

Source: Adapted from MESHGuides (2021).

Trochim et al*.* (2016) categorised validity according to the quality of measurement. The author pointed out that face validity means a good translation of the construct. Construct validity is the extent to which a research instrument or tool measures the intended construct. Construct validity was improved in the study by assuring face validity from consulting industry experts to assess that the instruments measure what it claims to measure. According to Bryman (2011), face validity reflects the content of the concept. The interview schedule and questionnaire were shown to the experts in the field for approval. Participants' consent was obtained prior to the interview.

After the interview, a summary of the responses was reviewed with the respondent to ensure content validity. The more the scale items represent the domain of the concept being measured, the greater the content validity (Sekaran & Bougie 2016). The authors added that convergent validity is a type of construct validity that is estimated using correlation coefficients. The thermal stress faced by food-service workers and observed by head chefs and kitchen managers elicited by the questionnaires was correlated by observation checklist and gauges in this study to satisfy convergent validity as tabled in Table A7.

6.7.1 Triangulation

Beyond the validity measures in the prior section, the application of triangulation raised the internal validity, especially of the qualitative data. Flick (2019) claimed that triangulation refers to the combination of different methods, study groups, local and temporal settings, and different theoretical perspectives in dealing with a phenomenon. A prior study by Miles and Huberman (1994) disclosed that triangulation in social science research refers to a practice by which a researcher wants to confirm an outcome by showing that independent measures of it agree with or at least do not contradict it. The type of triangulation chosen depends on the purpose of a study, and more than one type of triangulation can be used in the same study.

In this study, the focus was on methodological triangulation by developing a strategy for combining the data collected from all three instruments, namely questionnaires, the interview schedule and direct observation and physical measurement techniques. Triangulation by this method is commonly known as multimethod triangulation, which can be within a method or between methods (Yeasmin & Rahman 2012).

Method triangulation was applied with the quantitative data from the observation schedule and qualitative data obtained from the interview schedules, as well as the questionnaires and compared. All the IEQ parameters in the commercial kitchen environments were recorded with testing equipment and noted for physical observation to compare with the opinions of food-service workers and head chefs.

6.7.2 Qualitative rigour

Cypress (2017) claimed that rigour is defined as the strength of a research design, and the trend is to use the term rigour instead of trustworthiness. The author further added that to ensure reliability and validity in qualitative research, strategies for ensuring rigour must be built into the research process. Attending to rigour throughout the research process will have important ramifications for qualitative inquiry.

Riege (2003) argued that the validity and reliability of case study research is a key issue. The author introduced the notion of different ways of judging the quality of case study research, including credibility, trustworthiness or transferability, replicability or confirmability, and dependability. According to Denscombe (2014), credibility is the extent to which qualitative researchers can demonstrate that their data are accurate and appropriate using a technique like respondent validation, asking respondents to comment on and confirm the findings. The credibility criterion involves establishing that the results of qualitative research are believable from the perspective of the respondents in the research; the respondents are the only ones who can rightfully judge the credibility of the outcome (Trochim et al. 2016). Flick (2019) argued that credible results would be produced by an extended arrangement and persistent observation in the field and the triangulation of different methods, researchers and data.

Dependability involves the researcher demonstrating that their research reflects processes and results that other researchers can see and weigh in terms of how far they establish reputable techniques and rational decisions (Denscombe 2014). Dependability emphasises the researcher's obligation to describe the ever-changing research context. Flick (2019) emphasised that dependability is checked through a process of auditing data.

According to Denscombe (2014), transferability is the information needed to infer the relevance and applicability of the findings to other people, settings, case studies and organisations. Trochim et al. (2016), however, mention that transferability refers to the degree to which the results of qualitative research can be generalised or transferred to other contexts or settings. This is like external validity. Transferability is primarily the responsibility of the researcher doing the generalising. The judgement of how sensible the transfer of the results to another context is achieved in the case study context through the choice of cases included in the research.

Confirmability involves recognising the role of the self in qualitative research and keeping an open mind by not neglecting the data that do not fit the preferred analysis and checking rival explanations (Denscombe 2014). Trochim et al. (2016) stated that qualitative study tends to assume that each researcher brings a distinct viewpoint to the research. Confirmability refers to the degree to which the findings could be corroborated by others. The researcher can conduct a data audit that examines the data-gathering and evaluation procedures and makes judgements about the potential for prejudice or misrepresentation. Additionally, triangulation of data, as adopted in this study, can be a useful tool to demonstrate confirmability.

■ 6.8 Anonymity and confidentiality

Trochim et al. (2016) and David (2019) asserted that anonymity means that there is no way for anyone, including the researcher, to recognise participants in the study directly. The latter author added that it also means that any investigation conducted face-to-face or telephonically cannot be considered anonymous, which rules out practically all qualitative research that includes interviews.

Confidentiality, on the other hand, means that the respondents can be identified but that their identities are not revealed to anyone outside of the study; only the researcher is aware of the participants' identities, and safeguards are in place to ensure that the identities of the participants are not revealed to anyone else. Data management and security are used to ensure confidentiality. Trochim et al. (2016) claimed that confidentiality means that the researcher makes a promise that identifying information will be known only to the researcher unless circumstances dictate exceptions to maintain the well-being of the participants.

Flick (2019) argued that anonymisation in data collection is a challenge to deal with. This is prevalent during data management when participants' personal identifying information can be linked to their data using identity numbers or pseudonyms. Hence, personally identifying information needs to be stored separately from the data. However, Surmiak (2018) claimed that revealing the identity of specific vulnerable study participants based on their request may empower them in certain circumstances because their voices can finally be heard.

Case studies are about human affairs, and hence it is important to protect human subjects. The researcher should take special care and be sensitive to the participants by maintaining their privacy and confidentiality (Yin 2013). Responses and results from research are to be kept confidential always to respect participants' dignity and right to privacy. The purpose of the research was explained to all respondents in the form of a cover letter. The participation was voluntary, and the researcher was available on-site to answer any questions.

Whether the study is anonymous or confidential, it is important to inform participants about what information the researcher will collect from them and how their identities will be protected. An informed consent form is the best way to explain the nature of the data collection and to assure participants that their privacy will be protected (complete dissertation by Statistics Solution 2022).

Confidentiality versus anonymity – in the data collection process, when researchers are trying to obtain information from survey participants, they frequently indicate that the survey will be conducted anonymously or confidentially. There are distinct differences between the two terms, and the researcher should be clear on the meaning of each, as they are very important for the protection of the participant. It is also important to remember that a study with only one data collection method cannot be both confidential and anonymous. Research participants should be informed beforehand of the type of data collection that will take place. They should also be informed of how long the data will be stored, where the data will be stored and how it will be destroyed after an appropriate amount of time.

The restaurant kitchens, managers and head chefs, as well as the identities of kitchen workers, were coded during the data entry process to maintain anonymity and confidentiality. In terms of data security, researchers should follow all security measures their institutional review board requires, such as keeping paper-and-pencil data in locked file cabinets, password-protecting electronic data and securely destroying the data after the research is completed.

In this field study, the participating organisation consented to the research based on confidentiality and so afforded an opportunity to understand the environmental ergonomics of commercial kitchens.

6.9 Ethical considerations

Conducting ethical research is more than simply doing the right thing (Mandal, Acharya & Parija 2011). Ethical principles are moral values and ideals. The researcher built a position of trust and treated respondents with respect, indicating that the interviewer was interested in them as individuals and accepted their uniqueness. The potential participants were informed of the topic, procedures, risks and benefits of participation prior to consenting to the study. The significance of the study and their role in contributing to the betterment of their work environment by concerned parties was explained to all food-service workers. Protecting research participants from unethical treatment and infringement of rights is an assigned responsibility of all researchers conducting a study on human subjects (Kue et al. 2018). As the study traverses cultures, the researcher acknowledges the sensitivity of matters relating to culturally specific behaviour. Ethical clearance was obtained from the University Research and Ethics Committee, which issued an ethical clearance (level 1) for this study in 2015.

6.10 Conclusion

In conclusion, Chapter 6 began with a methodology discussion and the justification for methodological choices. Details of the instruments and triangulation to substantiate findings were presented with statistical analysis undertaken.

Chapter 7 is an analytical chapter which will focus on the critical evidence acquired. In addition, data from the questionnaires, interview schedules and test instruments will be analysed and discussed.

Questionnaire for food-service managers and head chefs

Demographics

1. Gender ____________________
2. Designation __________________________
3. Age ___________________
4. No. of staff on shift ______________________________
5. Which of the following best describes the ethnicities of the staff:

Ethnic background	SA white	SA Indian	SA mixed (coloured)	SA African	SA other mixed-race	European white	Other, non-African	Other Africans
No. of staff								
Other, please specify:								

6. What is the area of the kitchen?

20 ≤ 100 sqm	101 ≤ 200 sqm	≥ 200 sqm	≥ 300 sqm

7. What is the output in number of meals per day?

500 ≤ 750	250 ≤ 500	100 ≤ 250	10 ≤ 100

8. What is the average output in number of plated meals per shift?

≤ 250	≤ 150	≤ 100	≤ 50

9. How many workers are in the kitchen?

≤ 25	≤ 20	≤ 10	≤ 15

10. What is the seating capacity of the restaurant?

≤ 40	41 ≤ 80	80 ≤ 150	150 ≥ 200	≥ 250

11. What are the different types of food-service offered from your kitchen?

No. of meals	**Plated meals**	**Room service**	**Buffet no. of portions**	**Take-away**
0–20				
21–40				
41–60				
61–80				
81–100				
101–120				
121–140				

Figure 6A-1 continues on the next page→

12. What is the dominant cuisine?

Continental	Contemporary	Indian	East Asian	Italian	Portuguese	Fusion

Other, please specify: ____

13. What restaurant service style does the kitchen serve?

Family restaurant	Casual	Pub	Coffee shop	Cafeteria-style	Quick-service	Fine dining

Other, please specify: ____

14. What is the average numbers of diners at mealtimes?

Covers	**Breakfast**	**Lunch**	**Dinner**
0–20			
21–40			
41–60			
61–80			
81–100			
101–120			
121–140			
141–160			
161–200			
201–250			

15. How often do you filter oil in a fryer or frying pan?

Daily	Alternate days	Thrice weekly	Twice weekly	Fortnightly	Monthly

Other, please specify: ____

16. How often do you change the oil in the fryer and/or frying pan?

Daily	Alternate days	Twice a week	Once a week	Once in 15 days	Once a month

17. How often is the electrical and mechanical equipment serviced?

Weekly	Monthly	Biannually	When the equipment breaks down

Other, please specify: ____

Figure 6A-1 continues on the next page→

18. What is the waiting period to repair or replace any malfunctioning equipment?

24 hours	One week	Fortnight	One month	Three months	One year

Other, please specify: ____

19. Please state the number of cooling devices in the kitchen.

Type of cooling device	**Air conditioner**	**Domestic fans**	**Industrial fans**
No. of cooling devices			

Other, please specify: ____

20. Have staff shown any of the following symptoms that you attribute to heat?

Tiredness	Increase in blood pressure	Decrease in blood pressure	Headache	Muscle cramps
Feeling and being sick	Heavy sweating	Intense thirst	Fast pulse	N/A

Other, please specify: ____

21. Please tick the appropriate boxes for symptoms shown by staff because of excessive heat.

Personality	Confusion	Irrational behaviour	Any other	N/A
Behavioural	Irritability	Use foul language	Walking away	N/A
Mental fatigue	Losing concentration	Anger	Foul language	N/A

22. Which of the following, on average, best describes the kitchen during peak hours?

Very hot	Hot	Warm	Slightly warm	Slightly cool	Cool

23. How do the staff cope with the heat?

Drink cold liquids	Step outside	Take short breaks	Sit under a fan

Other, please specify____

24. Please indicate your opinion on the highest level of influence of the following on coping with kitchen heat.

Age	**≤ 20-years -old**	**≤ 30-years -old**	**≤ 40-years -old**	**≤ 50-years -old**	**Over 50-years -old**	**N/A**
Work experience	Strongly agree	Agree	Not sure	Disagree	Strongly disagree	N/A
Correct body weight	Strongly agree	Agree	Not sure	Disagree	Strongly disagree	N/A
Gender – men cope better than women	Strongly agree	Agree	Not sure	Disagree	Strongly disagree	N/A
Race	African	Indian	Mixed (coloured)	Caucasian (white)	Other (please state)	N/A
Fitness	Strongly agree	agree	Not sure	Disagree	Strongly disagree	N/A

Figure 6A-1 continues on the next page→

25. Indicate the number of staff wearing the following head gear in the space provided.

Classic chef hat	Toque	Disposable chef hat	Sailor or skull cap	Café style cap	Cap	Driver cap	Head wrap	Hair net	Mop cap

26. How long does it take to replace burnt out bulbs or flickering lights?

Immediately	One day	Two days	Three days	One week	One month	Never

27. To what extent do you feel that staff suffer from the following because of inadequate light?

Condition	**With certainty**	**Belief**	**Reservation or wariness**	**Doubtful**	**N/A**
Headaches					
Visual problems					
Too much bending					

28. What intervention has been taken to solve problems of lighting?

No problem with lighting	Lower the height of light	Change globes	Clean globes and fixtures	Provide extra lighting

Please elaborate: ____

29. Which of the following factors affect adaptation to light amongst your staff?

Age	Gender	Race	Work experience in kitchen	Work activity	Physical fitness	Health status

30. What has been done to reduce noise in the kitchen?

No problem with noise	Switch the equipment off	Lubricate the equipment	Send equipment for repair	Place rubber mats to absorb noise

Please elaborate: ____

31. Which of the following factors affect adaptation to noise amongst your staff?

Age	Gender	Race	Work experience in kitchen	Work activity	Physical fitness	Health status

Please elaborate: ____

32. What intervention has been taken to reduce humidity in the kitchen?

No problem with humidity	Clean extractor	Open windows and doors	Install fan

Please describe: ____

Figure 6A-1 continues on the next page→

Equipment	Rank from loudest (1) to lowest noise (11)
Ovens	
Grillers	
Gas stoves	
Fryers	
Grinders and blenders	
HVAC and fans	
Dishwasher	
Swivelling doors	
Trolleys	
Air conditioner	
Refrigeration	

33. Which of the following words best describe the humidity in your kitchen?

Low	Optimal	High	Excessive

34. The nature of staff complaints regarding kitchen humidity are:

No complaints	Sweat not drying	Uniform is wet	Stickiness

35. How often is the kitchen ventilation system cleaned?

Daily	Weekly	Monthly	Quarterly	Bi-annual	Yearly	When extractor breaks down

36. Which of the following factors affect adaptation to humidity amongst your staff?

Age	Gender	Race	Work experience in kitchen	Work activity	Physical fitness	Health status

37. Which of the words best describe the air quality in your workplace?

Stuffy	Stale air	Bad odours	Clean

38. Which of the words best describe ventilation in your kitchen?

Poor	Inadequate	Satisfactory	Good

39. Please indicate below: Have the staff undergone **formal** or **informal training** or **no training** to use gas appliances safely?

40. Kitchen air filters are cleaned at least:

Once a week	Once a month	Once in six months	Once a year	Once in two years	Never

Figure 6A-1 continues on the next page→

41. Please read the following statement and tick the appropriate boxes:

No.	Question	Yes	No
1.	Does the kitchen have adequate cooling sources?		
2.	Has any staff shifted from kitchen to other departments because they were unable to cope with heat?		
3.	Are the staff comfortable in their uniforms?		
4.	Are the staff comfortable in their head gear or chef's hats?		
5.	Are work areas free from shadows?		
6.	Can employees comfortably see their work without straining?		
7.	Is mobile task-lighting provided?		
8.	Are there very loud impact noises heard in the kitchen?		
9.	Do people need to raise voices to speak with someone one metre away?		
10.	Was a measurement program carried out for the following? Please tick.		
	10.1 Heat		
	10.2 Light		
	10.2 Noise		
11.	Have you ever seen mould growth under the sink?		
12.	Have you seen mould growth on the kitchen walls or tiles?		
13.	Does sweeping and dusting in kitchen increase dust and particulate matter in the air?		
14.	Does the amount of fumes, mist and smoke vary during the day?		
15.	Do you have adequate measures to extract particulate matter during repairs, installation or construction in kitchen?		
16.	Do your staff smoke in the kitchen?		
17.	Does contaminated outdoor air leak into your kitchens through your doors or windows?		
18.	Does the kitchen have any room temperature control? If yes, please elaborate. ______________________		
19.	Are there deliberate measures to prevent excessive noise? If so, please elaborate. ______________________		

Figure 6A-1 continues on the next page→

42. Please tick the boxes and elaborate wherever necessary:

No.	Question	0 = Never;	1 = Rarely;	2 = Sometimes;	3 = Fairly often	4 = Very often
1	All the kitchen equipment is in good repair.	0	1	2	3	4
2	The amount of light in your kitchen is adequate.	0	1	2	3	4
3	The staff are happy about adequate lighting in kitchen.	0	1	2	3	4
4	The staff complain about glare (difficulty seeing in the presence of bright light such as direct or reflected sunlight) in the kitchen.	0	1	2	3	4
5	The staff complain about contrast (the difference in brightness or colour that makes an object clear) in kitchen.	0	1	2	3	4
6	Given the noise level, can you talk to your colleague or neighbour in your kitchen without shouting?	0	1	2	3	4
7	The staff complain frequently regarding noise in the kitchen.	0	1	2	3	4
8	The staff complain that they are unable to communicate with co-workers because of noise in the kitchen.	0	1	2	3	4
9	The staff complain about blenders, grinders and/or food processor making too much noise.	0	1	2	3	4
10	The staff complain about the extractor making too much noise.	0	1	2	3	4
11	The staff complained about stoves and/or ovens making too much noise.	0	1	2	3	4
12	The staff complained about fans making too much noise.	0	1	2	3	4
13	The staff complained about humidity in the kitchen.	0	1	2	3	4
14	The staff are content with airflow in the kitchen.	0	1	2	3	4
15	The staff complain of hot or cold draught in the kitchen.	0	1	2	3	4
16	Staff complain about difficulty in breathing.	0	1	2	3	4
17	All kitchen equipment is installed as per specifications.	0	1	2	3	4
18	Staff complain that it is too hot in the kitchen.	0	1	2	3	4

Key: N/A, not applicable; SA, South African.

FIGURE 6A-1: Questionnaire for food-service managers and head chefs.

INTERVIEW SCHEDULE FOR FOOD-SERVICE WORKERS

A. **Personal information** (Demographics)

1. Name ___________________
2. Age _____________
3. Gender _____________
4. Race _____________
5. Height ______________ cm
6. Weight _______________ kg
7. BMI _____________ kg/m^2
8. Job position _______________________
9. Type of main job
10. Years of employment
11. Working hours
12. Tenure: full-time – part-time
13. Shift: day shift – split shift – evening shift – any other
14. Tasks ____
15. How would you describe the weather today?
16. What type of weather were you expecting today (outside)?
17. Are you comfortable with the weather in Durban?
18. Do you like Durban weather?
19. Do you maintain a comfortable lifestyle?
20. Do you use an air conditioner in your residence?
21. Do you drive a car to work?
22. How many years have you spent in the kitchen cooking?
23. How many meals are prepared in a single shift?
24. Are there adequate cooling sources in your kitchen?
25. Do you wear make-up while working in the kitchen?

    Observation_________________________________
26. Do you feel comfortable working in your chef's uniform?

    Observation _________________________________
27. Do you feel comfortable working in the kitchen with make-up or foundation?

    Observation _________________________________
28. Do you wear an elaborate synthetic wig or wool on your head?

    Observation _________________________________
29. Do you feel comfortable working in the kitchen with excess hair?
30. Do you think less hair or a clean-shaven head would be comfortable for work in the kitchen?

Figure 6A-2 continues on the next page→

31. What is your ethnicity or cultural background?
32. Nose shape ________________________________
33. Skin tone ________________________________
34. Are you suffering from any chronic disease or illness?
35. What physical activity are you involved with and how often do you indulge in these activities?

Activity	**Frequency**				
	Every day	**Three to four times per week**	**Twice a week**	**Once a week**	**Never**
Walking					
Jogging					
Running					
Cycling					
Swimming					
Physical exercise – gym					
Swimming					
Any other					

36. Do you think you possess physical fitness?
37. Did you expect today to be a hot day?
38. Why did you expect today to be a hot day (or not)?
39. From your past experience, do you expect summer months to be hot like this?

B. **Indoor environmental quality**

Variables	**Factors**	**Questions**
Thermal comfort	Temperature	1. How is the heat at your workplace? 2. How would you describe the heat during peak periods? 3. Do you feel comfortable cooking with gas stoves or with electric stoves? Why? 4. Do you experience radiant heat when cooking with traditional clay ovens?
Ventilation	Air quality Air movement Humidity	5. How is the air quality in your workplace (i.e. stuffy, stale air, cleanliness, odours)? 6. How is the ventilation in your kitchen (i.e. inadequate, satisfactory)? 7. How is the humidity in your kitchen (i.e. dry, comfortable, very humid)? 8. Are there more smoke and fumes during the rush or peak period in the kitchen? 9. Do you feel any change in ventilation in the kitchen while cooking with gas stove or electric stove? 10. Have you seen any mould growth on kitchen walls or floors?

Figure 6A-2 continues on the next page→

Lighting	Amount of light Visual comfort	11. What do you feel about the amount of light at your workplace? 12. How is visual comfort at your workplace (i.e. glare, reflections, contrast)? 13. Have lighting adjustments been made for people with visual limitations? 14. Is there local lighting for close work to reduce eye strain and fatigue? 15. Are the lighting needs of older workers met? 16. Is there good general illumination throughout the kitchen? 17. Do you have any lights in the kitchen that flicker? 18. Does the flicker disturb you? 19. Is there regular cleaning and maintenance of lights and windows?
Acoustic quality	Noise level Sound level	20. Was a noise measurement programme of exposure carried out? 21. How is the sound level at your workplace (i.e. ability to talk to your colleague or neighbour without shouting)? 22. Do you think that the noise levels in your workplace may affect your hearing? 23. Do people need to raise their voices to speak with someone 1m away? 24. Do you have to speak lourder to older staff because they have difficulty hearing? 25. Besides cooking activities, what are the other sources of noise in the kitchen? 26. What measures were taken to prevent noise exposure?
Kitchen layout	Amount of space	27. How is the amount of space available for individual work?
	Storage	28. Is the amount of space available adequate for storage of equipment or ingredients?
	Ease of interaction	29. How difficult is it to interact with co-workers in the kitchen?
Kitchen design	Equipment	30. How comfortable and adjustable is the placement of operating equipment? Can you reach easily or must you stand on your toes or stretch awkwardly?
	Plan	31. What do you think about the workplace design?
Overall satisfaction	Workplace satisfaction	32. How comfortable are you with your personal workstation?

Adapted from CBE occupant survey database (Kim et al. 2009).

FIGURE 6A-2: Interview schedule for food-service workers.

Food-service establishment structured observation

1. Name of the establishment ___________________________
2. Date __________________________________
3. Location ______________________________
4. Type of kitchen load __________________________________
5. Owner _______________________________
6. Address __________________________________
7. Seating capacity ______________________
8. Number of employees ____________________
9. Type of organisation: proprietorship/partnership/independent owner/chain/franchise/corporation/other

AA. Structural design and material	**Floor (width)**	**Wall (length)**	**Ceiling (height)**
AA. Construction			
1. Kitchen – preparation area			
2. Cooking area			
3. Dining area			
4. Refrigeration area			
5. Wash area – utensils			
6. Dry food storage			
7. Garbage area			
8. Kitchen			
9. No. of staff on duty: Staff–space ratio =			

10. Staff uniform – jacket	
11. Staff hairstyles	
12. Staff chef's hat	

AB. Facility design and layout: Lighting				
13. Is there adequate lighting on food preparation areas?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
14. Is there adequate lighting on cooking areas?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
15. Is there adequate lighting on dishwashing areas?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5

Figure 6A-3 continues on the next page→

16. Are all lights protected from breakage?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
17. Is there adequate artificial light in the evening shift?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
18. Is there adequate light during load-shedding in the evening?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
19. Is task-lighting present?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
20. Is infrared light present?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
21. Is there UV light for keeping food hot?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
22. What type of lighting is used?				
23. What types of lamps are used?				
24. What types of luminaires are used?				
25. Is there natural light?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
26. Are there skylights?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5

Figure 6A-3 continues on the next page→

27. Are there sufficient shielded lights to prevent shadows or dark areas?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
28. Is there any direct glare?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
29. Is there any indirect glare?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
30. Are there any flickering lights?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
31. Is there sufficient contrast in the kitchen?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
32. Is there any local light?				
33. Have windows and skylights been whitewashed or shaded to avoid glare? ____________				
34. Are dangerous pieces of equipment and areas well-lit to alert employees to the hazards? ____________				
35. Describe the architectural features of the light:____________ ____________				
36. Are light switches easy to reach?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5

Figure 6A-3 continues on the next page→

BB. Thermal environment

37a. Sources of heat:

Equipment	Number	Size or capacity
1. Electic ovens		
2. Gas ovens		
3. Clay ovens		
4. Electic stove		
5. Gas stoves		
6. Pressure fryers		
7. Grillers		
8. Kettles		
9. Fryers		
10. Hot plates		
11. Steamers		
12. Boilers		
13. Hot holding		
14. Others		

37b. Indirect sources of heat:

Equipment	Number	Size
1. Refrigerators – domestic		
2. Freezers – domestic		
3. Grinders		
4. Crushers		
5. Wet grinders or stone grinders		
6. Blenders		
7. Food processors		

38. Symptoms of thermal strain amongst staff:

Workers	Red face	Sweating	Wet uniform – excessive sweating	Swearing	Panting

Figure 6A-3 continues on the next page→

BC. Noise in kitchen				
39. Sources of noise:				
Equipment	**Type**	**Continuous**	**Intermittent**	**Fluctuating**
1. Ovens – gas, electric				
2. Ovens – tandoor, pizza				
3. Pressure stove				
4. Stoves				
5. Fryers				
6. Sizzlers				
7. Grillers				
8. Refrigerators				
9. Freezers				
10. Steamers				
11. Boilers				
12. Food processors				
13. Others				
14. Fans				
15. Exhaust				
16. Head				
17. Suppliers				
18. Workers				
19. Visitors				
20. Vacuum-cleaning				
21. Polishing floor				
22. Moving equipment or doors				
23. Miscellaneous				

BC. Dishwashing				
40. Does the dishwashing machine produce noise?				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5

Figure 6A-3 continues on the next page→

41. Does the dishwashing machine produce heat?				
BD. Ventilation				
42. Canopy: Length ________ m Width ________ m				
43. Number of enclosed sides				
44. Total exhaust				
45. Number and size of grease filters or extractors				
46. Adequate duct sizes and numbers				
47. Canopy overhang				
48. Dishwashing machine exhaust system				
49. Cooking bank hood				
50. Pizza hood or tandoor hood or low-side wall hood				
51. Make-up air system				
52. Interlocked with exhaust system				
53. Mixed-mode ventilation				
54. Fresh air supply through HVAC				
55. Make-up diffusers area and velocity				
56. Number of fans: ___________ Type:				
57. No. of cooling sources				
58. Type of cooling sources				
59. Natural ventilation				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
60. Number and size of windows				
61. Number and size of doors				
62. Air leakage into the kitchen from closed doors				
63. Air leakage from closed windows				
64. Floor is dry, semi-wet or wet				
65. Chemicals stored separately – fumes causing ventilation problems				
BE. Water supply				
66. Number of taps				

Figure 6A-3 continues on the next page→

67. Leaking taps – add to humidity				
BF. Facilities – adjustment and cleaning				
68. Adjustment of thermostatic controls				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
69. Adjustment of ventilating equipment				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
70. Adjustment of fans				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
71. Clean air ducts				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
72. Clean fans				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
73. Clean light bulbs				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
74. Clean light fixtures				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
75. Clean floors (mopped floors)				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5

Figure 6A-3 continues on the next page→

76. Gas cylinders stored away from kitchen				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
77. Gas stoves in good repair				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
78. Ovens, cookers in good repair				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
79. Any equipment producing too much soot				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5
80. Frequency of filtering oil				
81. Frequency of changing oil in fryer				
CA. Food-service system				
82. Conventional – cook-chill – ready-prepared – commissary				
83. Type of menu				
84. Cuisine				
85. Number of meals per day				
86. Size of ovens				
87. Size of burners on gas stove				
88. Presence of pressure burners				
CB. Pest control				
89. Presence of mesh or screens at doors				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5

Figure 6A-3 continues on the next page→

90. Windows are screened to protect from dust and insects				
Very unsatisfactory	Unsatisfactory	Acceptable	Satisfactory	Very satisfactory
1	2	3	4	5

DA. Environmental measures ergonomics

91. Humidity levels

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

92. Noise levels – different areas

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Outside

93. Light levels – different areas

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

94. Air temperature (°C) – outside: ____________________

95. Ambient temperature (°C) – before starting shift

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

96. Ambient temperature (°C) – peak period

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

97. Operative temperatures (°C) – 1.2 m height

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

98. Wet-bulb globe temperature

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

99. Black globe temperature

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

100. Air velocity m/s

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

Figure 6A-3 continues on the next page→

101. Carbon dioxide levels ppm

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

102. Oxygen levels %

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

103. Discomfort index

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

Source: Author's own work.

FIGURE 6A-3: Food-service establishment structured observation.

Chapter 7

Data presentation, analysis and discussion: Heat and thermal comfort

7.1 Adaptation to heat in the kitchen

The previous chapter examined the methodological choices for this investigation. This chapter deliberates on data collected on heat and thermal comfort variables. Firstly, thermal stress based on individual factors of food production workers is discussed, followed by kitchen activities, type of equipment and design elements. Study variables are examined by way of correlation, factor analysis and regression models. The findings are presented according to the emerging themes.

Human thermoregulation and acclimatisation are fundamental constituents of the human coping mechanism for environmental heat exposure (Hanna & Tait 2015). Variations in thermal tolerance can be intensified by ethnicity and cultural differences, for example, individual genotypes that include skin colour and type of nose. Ethnic differences in thermoregulatory responses in exposure to heat by Qiu, Hodder and Havenith (2020) indicate that Chinese men preferred higher comfort temperatures than British men. Moreover, it includes individual factors that determine physiological adaptation, comprising age, gender, fitness, body fat and physical activity.

How to cite: Gangiah, S 2022, 'Data presentation, analysis and discussion: Heat and thermal comfort', in *Environmental ergonomics Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town, pp. 163–184. https://doi.org/10.4102/aosis.2022.BK346.07

The effect of tolerance to heat is affected by demographic factors such as age, race and comfortable lifestyle, gender, height, weight, body mass index, fitness and physical activity, years of employment and work experience, job position and worker shift (Hanna & Tait 2015). The average age of respondents was 31.28 years, with a standard deviation of 8.56 years. This study indicates that 3.5% fall in the category of an older population. A high factor loading of 0.801 for age with other individual factors demonstrates that age plays a major role in coping with heat.

An important factor in the context of human heat adaptation relates to individual genotypes, although the role of ethnicity appears debatable. Most food production workers were black Africans (90%), followed by Indians (7.6%). However, the ratio between the Africans and Caucasians was much higher for head chefs and kitchen managers, even though Africans still dominate employment in commercial kitchens in the sample investigated. This trend is in line with the demographic figures of South Africa (Statistics 2017). There are significantly more African employees than the other race groups (89.5%). A notable variation is observable in the nationwide South African race profiles (Index Mundi 2020), described as black African (80.9%), 'coloured' (mixed-race, 8.8%), white (7.8%) and Indian (2.5%).

An important cross-tabulation indicates that the kitchen worker's ethnicity and cultural background are related to their comfortable lifestyle, driving a car to work and physical fitness. A high factor loading of 0.850 for race, along with other individual factors, infers that race or ethnicity is a key factor in coping with heat.

The ratio of men to women was approximately 1:2 (36.3%:63.7%), respectively, in this study. The role of gender was further amplified in cross-tabulation between the kitchen worker's gender and BMI, which was statistically significant. The weight of South African kitchen workers was notably higher, in the range from 42 kg to 157 kg, with a standard deviation (SD) of 15.46 kg. Sixty-four per cent of kitchen workers were female, and 50% of them were overweight. Thirty-six per cent of kitchen workers were men, and 71% of them were of normal weight. The BMI amongst the kitchen workers varied from 18.70 (underweight) to 47.90 (severely obese) with a mean of 28.57, which indicates normal weight.

A factor loading of 0.780 for men who cope with the heat better than women with other individual factors demonstrates that gender plays a vital role in coping with the heat. The logistic regression reveals that gender with a β coefficient of 3.257 and VIF = 1.209 are factors affecting the BMI of a kitchen worker. The association between variables across instruments indicates that gender is closely associated with other individual factors, years of employment and type of kitchen.

There is a close association between gender, height and BMI. The height of kitchen workers varied from 1.45 m to 1.83 m, with an average of 1.59 m. The weight of kitchen workers in this study in Table 7.1 varied in the range of 42 kg to 157 kg, with a SD of 15.46 kg.

Weight has a moderate factor loading of 0.672 into the socio-economic index, along with other individual factors. Given the lower-income country status of South Africa, people with higher socio-economic status are more likely to be obese.

This study finds that a minority of 29.8% of kitchen workers have normal BMI, with the remaining workers being overweight to obese. It seems BMI in the range of 20–25 is considered normal range, which is important to endure physically strenuous kitchen work, which affects acclimatisation.

Almost 86% of the kitchen workers believed that they possessed fitness. Nearly 30% of head chefs or managers felt that fitness did not affect coping with heat in the kitchen; 70% felt that it played an important role. Almost 42% of the workers engaged in some physical activity, with walking being the most prevalent activity (46%) on different occasions. Football seemed to be the most popular sport amongst the staff. Only cycling seemed to be noteworthy, besides walking. More than a third of the respondents walked every day (35.1%), and very few cycled regularly. There was no major difference in terms of frequency regarding the other activities.

The cross-tabulation between the kitchen workers' possessing physical fitness and BMI was found to be statistically significant. The association between physical activity (PA) and BMI was weak in non-obese individuals. Consequently, these individuals had lower heat adaptation.

All Asian populations studied had a higher body fat (BF) at a lower BMI compared with Caucasians. The high BF% at low BMI can be partially explained by variances in body build, trunk-to-leg-length ratio, slimness and muscularity. Hence, the association between BF% and BMI is ethnicity-specific. Fitness has a moderate factor loading of 0.554 into demographics along with other individual factors, which means that fitness is a player factor in coping with the heat.

Regarding acclimatisation, 47% (f = 16) of head chefs strongly agreed that work experience played a substantial role in coping with heat; also, years of employment contributed to work experience and acclimation to heat. Kitchen workers revealed that work experience varied from three months for a trainee chef to 35 years for a 60-year-old chef. Acclimation amongst experienced chefs and kitchen workers helped them to cope better with heat stress in kitchens compared with newer staff. The relationship with years of employment indicated that the greater the number of years worked, the lower the heat experienced near stoves because of thermal adaptation until ageing set in from 50 years onwards.

The collective data indicated that the higher the position, the lower the heat experienced near stoves. There is strong evidence to conclude that the variables are negatively associated.

Food preparation is an essential task before cooking. Almost 18% of kitchen workers from 33 restaurant kitchens were tasked with food preparation and supply to the chef for further cooking. Almost 49% of staff were directly involved in cooking activities, whereas 34.3% were involved in other related activities. Kitchens offering Italian cuisine had chefs (18.8%) preparing pizza dough, pizzas and pasta. It seems that these variations could be because of the various cuisines noted in this study.

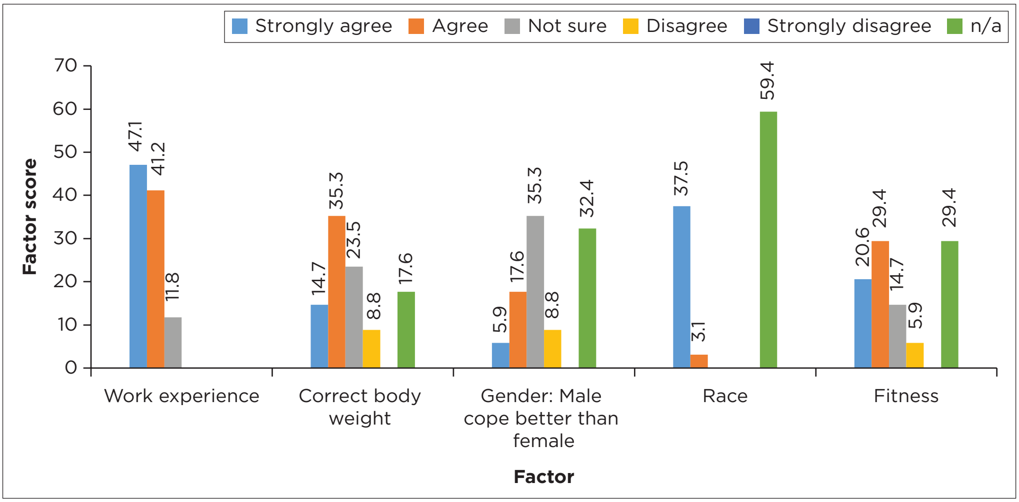
Cooks' jobs at hotels occurred in shifts that usually began early in the morning, although the split shift was not a common occurrence. Almost 66% of the kitchen workers had day shifts and worked full-time. The work hours of workers varied from 5 h per day for part-time workers to a maximum 13-h shift, sometimes daily, in this study. Logistic regression showed that heat experienced by chefs near stoves was affected by shift work, along with other variables. The shift work of kitchen workers influences their ability to cope with the heat in the kitchen. The cross-tabulation between the kitchen worker's shift and BMI in this study was significant. Seventy per cent of the workers had higher weight than was considered normal; 35% were overweight, and another 35% were obese.

7.2 Factors affecting coping with thermal strain

Beyond their individual influences, multiple personal factors, that is, a combined influence of age, gender, race, body weight, fitness and work experience, affect the kitchen worker's ability to cope with thermal strain. The association between these personal factors will be discussed in the sections that follow.

Further to individual factors presented earlier, the combined effects of these factors exist, comprising work experience, body weight, gender, race and fitness. Head chefs believed that age (59%), task experience (47%), fitness (20.6%) and body weight (14.7%) were recognised as important in coping with the heat, as given in Figure 7.1.

It seems that when multiple personal factors are given together, the final effect is much more than the simple algebraic sum of the magnitude of individual factors. A factor may decrease, oppose, reverse or counter the effect of a group of other factors or another factor. For instance, superb fitness



Source: Author's own work.

FIGURE 7.1: Factors affecting coping with kitchen heat.

may overcome the combined negative heat effects of no task experience, high body weight and gender.

The following findings were noted: some statements show significantly higher levels of agreement; for example, 47.1% of head chefs and kitchen managers strongly agreed that work experience affects coping with the heat, whereas levels of disagreement seem to be zero. Similarly, 37.5% strongly agreed that the race of a worker influenced coping with heat in the kitchen, while the level of disagreement amongst head chefs seemed to be zero. There were no statements indicating higher levels of disagreement; for example, only 8.8% of head chefs and kitchen workers disagreed that body weight and gender influence coping with heat.

Individual personal factors will be examined next, followed by a discussion of the associations between personal factors. Exploratory factor analysis obtains deeper insight into the individual factors that impact heat stress. Acceptable loadings are revealed along two components with subthemes of socio-economic index and demographics in the rotated component matrix in Table 7.8.

Using EFA, the questionnaire revealed a factor loading of 0.801, 0.400 and 0.672 for age, work experience and correct body weight with factors influencing coping with kitchen heat, and this was categorised into Component 2, socio-economic index. Here, 35% (f = 12) of the head chefs strongly agreed that age had the highest level of influence on coping with kitchen heat; more than 47% (f = 16) strongly agreed that work experience had the highest level of influence, and only 14.7% (f = 5) strongly agreed that correct body weight has the highest level of influence on coping with kitchen heat.

TABLE 7.1: Rotated component matrix: Influence of factors on coping with heat.

Personal factors	Component	
	1 Demographics	2 Socio-economic index
Age	−0.007	0.801
Longer work experience	−0.352	0.400
Correct body weight	0.328	0.672
Gender (male workers cope better than female workers)	0.780	0.158
Race	0.850	−0.088
Fitness	0.554	0.426

Note: Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalisation. Rotation converged in three iterations.

Exploratory factor analysis further revealed a factor loading of 0.780, 0.850 and 0.554 for gender, race and fitness with factors influencing coping with kitchen heat and was categorised into Component 1, demographics. Consistent with EFA, 37.5% (f = 12) strongly agreed that race has the highest level of influence on coping with kitchen heat, and 20.6% (f = 7) strongly agreed that fitness has the highest level of influence on coping with kitchen heat.

Predicted probability was of membership for women. The odds ratio was almost 1.5 and, therefore, positive. Each female worker assumed she was 1.45 times physically fitter than she actually was, which helped the female worker to cope with heat better, as this had a positive psychological effect.

Regarding physical fitness, 57%, 50%, 49% and 39% of the black, Asian, mixed-race and white respondents, respectively, show low physical fitness levels, indicating lower tolerance to heat. However, 10%, 6% and 5% of the white, Asian and black, and mixed-race respondents, respectively, indicated a higher level of physical fitness, indicating higher tolerance to heat. The association between BMI and fitness helped to determine the adaptability of local food production worker genotypes and phenotypes.

Physical fitness had a medium to large effect on BMI with p = 0.075, a moderate effect from 0.06 as per partial eta-squared (η2). Concerning kitchen worker BMI, strong links were found to exist between gender, height and BMI; as p = 0.046, less than the significance level of 0.05, there was strong evidence to conclude that the variables were associated. For gender and years of employment, as p = 0.046, less than the significance level of 0.05, there was strong evidence to conclude that the variables were associated. For gender and type of kitchen, as p = 0.046, less than the significance level of 0.05, there was strong evidence to conclude that the variables were associated.

It is therefore necessary that BMI determination is further explored [Y = b0 + b1x1 + b2x2 + b3x3]. Hence, BMI = 3.475 + (0.584 × type of kitchen) + (3.257 × gender) + (0.296 × weight of the staff). The analysis is likely to reveal measures that may be undertaken to manage heat stress in commercial kitchens better.

TABLE 7.2: Factors affecting BMI of a kitchen worker.

Model	Unstandardised coefficients		Standardised coefficients	*t*	Sig.	Collinearity statistics	
	b	**Std. error**	**Beta**			**Tolerance**	**VIF**
(Constant)	3.475	2.288	-	1.518	0.131	-	-
Type of kitchen A4	0.584	0.287	0.082	2.034	0.044	0.832	1.202
Gender of staff A3	3.257	0.470	0.279	6.938	0.000	0.827	1.209
Weight of worker A6	0.296	0.013	0.817	21.948	0.000	0.966	1.035
Race A4	0.655	0.364	0.068	1.801	0.074	0.953	1.050
Working hours A11	−0.167	0.108	−0.059	−1.548	0.124	0.918	1.090
Tenure A10	−2.232	1.221	−0.069	−1.828	0.070	0.927	1.079
Shift A13	−0.282	0.173	−0.061	−1.633	0.105	0.948	1.055

Key: Sig., significance; VIF, variance inflation factors.
Note: (1) Dependent variable: BMI (kg/m^2) of kitchen worker A7. (2) Predictors: (Constant), shift, gender, weight, working hours, race, tenure, type of kitchen.

The best-fitting model for predicting the BMI of the kitchen staff is a linear combination of the type of kitchen, gender of staff and weight of the worker. The preceding section of this chapter has presented the role of gender and weight in the perception of heat stress and discomfort.

7.3 Heat production in the kitchen

The kitchen activities, as well as cuisine, affect the kitchen equipment utilised and subsequent heat production. Every active zone in the kitchen workspace holds a subset of equipment appropriate for the associated activity for that work area. The presence of a large number of appliances for meal preparation, such as grills, ovens, hot plates, fryers, kettles and pasta boilers in commercial kitchens causes a significant increase in temperature (Marć et al. 2018).

Next, food production systems will be discussed, followed by how kitchen output affects heat production, diversity in cuisine and increased heat from extra-heavy-duty load in kitchens. The cook-serve method is found to be very popular in the sampled kitchens; the conventional food-service system is the most common production method. Eighty-eight per cent of kitchens prepared main courses on customers' orders.

The cook-chill system was observed in three commissary kitchens in this study. When the cook-chill system is followed instead of cook-serve, the two variables (namely 'number of meals per day' and 'heat near stoves') are negatively associated. The food is cooked in advance of service and kept frozen or chilled until service. The variables 'number of meals' and 'heat experienced near stoves' are closely associated. Most preparation work involves cooking in advance or using semi-prepared meals for quicker service.

The number of meals cooked per day indirectly alludes to the equipment heat generation, which indicates the heat produced in the kitchen. The larger the volume of food cooked, the greater the amount of heat produced in cook-serve. However, no absolute value of temperatures across the spectrum was measured.

There were significantly more respondents who indicated that they served less than 250 meals per day (76.5%). Large kitchens 6, 7 and 14 prepared meals ranging from 50 meals an hour to 400 meals a shift, including sit-down, room service and takeaway.

Seventy per cent of the kitchen workers claimed that food preparation produces heat and kitchens are hot, and 75% claimed that the kitchens were extremely hot during maximum kitchen capacity utilisation where volume was highest.

More than 80% of the respondents indicated that it was hot during peak hours. Only 3% indicated that the kitchen was slightly warm, as they adopted a ready-prepared system.

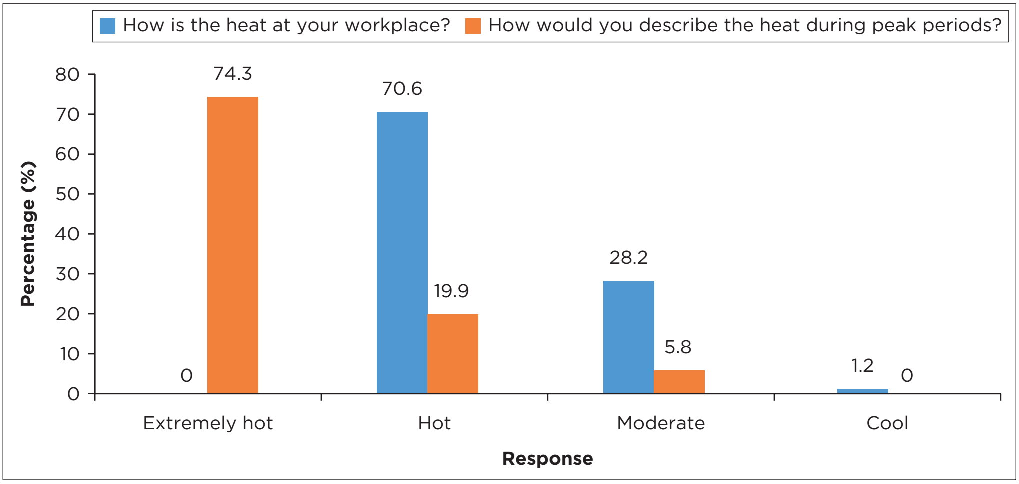
A diverse range of cuisine was offered in the sampled kitchens, from Indian to Mexican, especially Italian. Two restaurants served seafood and authentic Indian; South African Indian cuisine was observed in three kitchens. Indian cuisine kitchens have higher temperatures in receiving areas (29.82 °C) because of the lack of back doors. In Indian cuisine, the greater the extent of the cooking process, the higher the heat generated. Heavy preparation activities also lead to excessive dishes being washed, which increases humidity.

Different styles of cooking operations make a significant contribution to heat in commercial kitchens. Italian food was served at more establishments in the sample frame than any other (23.5%), ranging from pizzas only to a wide variety of pasta and antipasti. Italian cuisine kitchens have brick kilns that increase operative temperature near ovens (31.4 °C). Cooking areas in an East Asian kitchen have a high temperature from wok cooking (315 °C) and hence are considered to be extra-heavy-duty with higher CO_2 emissions (1000 ppm), similar to pizza ovens in Italian kitchens. Kosonen (2014) claimed that European cooking is medium load, whereas Asian cooking is extra-heavy load. Zhang et al. (2020) reported from their investigation that a stir-frying stove is a heavy-load appliance that can produce a large amount of COF.

Extra-heavy-duty equipment cooks at higher temperatures and produces radiant heat, as experienced by workers near traditional kilns and tandoors. Extra-heavy-duty kitchens operate at higher temperatures with higher extraction capacity because of solid fuels. Nearly 55% of kitchen workers experienced radiant heat from old-style ovens such as wood-fired pizza kilns (371 °C) and tandoors (480 °C), and heat is high in kitchens using gas and solid fuels compared with electricity. Grillers experienced higher mean temperatures of 33.75 °C.

TABLE 7.3: Mean temperatures of kitchens, as per ASHRAE classification.

Operative temperature in °C	Light-duty	Medium-duty	Heavy-duty	Extra-heavy-duty
Stove	0	26.44	26.54	30.66
Oven – electric, gas, kiln and tandoor	30.75	28.03	30.28	31.15
Griller	0	32.11	33.75	32.25
Fryer	0	30.07	30.92	32.20



Source: Author's own work.

FIGURE 7.2: Food-service workers' opinion on heat in kitchens.

The sampled kitchens indicated that frying cooks were also heat exposed, with temperatures of 32.2 °C. Exposure to the stove or heat was much higher for workers responsible for cooking and food preparation than for auxiliary staff. Significantly, more kitchen workers experienced heat.

What are the features of a design element of a kitchen? The plurality of kitchen activities comprises baking, preparation, cooking and clean-up. The sections that follow will encompass the type of fuel and classification of kitchens.

A discussion follows on fuels in the kitchen, the effects of cooking equipment and how heat near stoves is affected by other appliances. This study surveyed light-duty (2), medium-duty (5), heavy-duty (20) and extra-heavy-duty (6) kitchens. Amongst the 33 kitchens, 31 kitchens had both electrical equipment and gas appliances. Twelve per cent of kitchens used firewood, in addition to LPG and electricity, and 6% used charcoal for baking and grilling. Two kitchens producing authentic Indian cuisine had tandoor ovens that used LPG and charcoal. Five of the seven kitchens that cooked Italian cuisine had wood-fired kilns; one used an LPG-fired kiln or tunnel oven, and two restaurants used electric ovens as well.

I suggest that these instances may be associated with a comfortable lifestyle (gas heats up immediately). Notably, the cross-tabulation between a kitchen worker's preference for an LPG stove or electric stove and maintaining a comfortable lifestyle was momentous. Just over 58.5% and 41.0% of the workers felt comfortable cooking with LPG and electric stoves, respectively. Liquefied petroleum gas beats electric if one wants searing heat and exact temperatures immediately.

A comparison of gas and electrically fuelled cooking equipment reveals that the experience of heat is higher in kitchens using gas fuels compared with electricity (Table 7.4). The adoption of gas and electrically fuelled cooking equipment were 28% and 54%, respectively, in 31 kitchens. Grillers experienced high temperatures of 33.75 °C. To a lesser extent, the fry cooks using electricity were also heat exposed to mean temperatures of 32.2 °C. Sweating and red-faced pointers to heat stress were generally observed in gas-fuelled kitchens, especially at the teppanyaki and pressure stove ranges.

The type and size of cooking equipment affect the heat generated in the kitchen. Two pizzerias cooked exclusively on a conveyor oven and did not produce high heat and were accordingly classified as light duty.

Per Table 7.3, the heavy-duty kitchen mean temperatures near grillers were higher than in medium-duty and extra-heavy-duty kitchens, possibly because of the substantial use of LPG appliances contributing to expected higher values. The finding of this study concurs that equipment classified as extra-heavy load because of the use of solid fuels such as charcoal in tandoors has an operative temperature of 32 °C compared with wood-fired pizza kilns, with

TABLE 7.4: Heat stress experienced by chefs using gas and electricity.

Kitchen no.	Kitchen worker or chef	Frequency	Electric equipment	Gas equipment	Sweating	Red face	Heavy sweating
5, 9, 26	Grill chef	3	Griller	-	✓	-	-
1, 3, 8, 22, 27	Grill chef	6	-	Griller	✓	-	-
21	Teppanyaki chef	1	-	Teppanyaki	✓	✓	-
16	Roti chef	1	-	Griddle	✓	-	-
23	Curry chef	1	-	Stove	✓	✓	-
16	Curry chef	1	-	Pressure stove	-	-	✓
16	Tandoori chef	1	-	Tandoor	✓	-	-
17	Head chef	1	-	Wok	✓	-	-
28	Pizza chef	1	-	Pizza oven	✓	-	-
15, 31	Pizza chef	2	Pizza oven	-	✓	-	-
13, 26	Fry chef	2	Fryer	-	✓	-	-
6	Fry chef	1	Pressure fryer	-	✓	-	-
20	Chef de partie	1	-	Stove	✓	-	-
14	Breakfast chef	1	Toaster	-	✓	-	-
-	**Total**	**23 (70%)**	**8 (28%)**	**15 (54%)**	**23 (84%)**	**2 (67%)**	**1 (100%)**

TABLE 7.5: Operative temperatures and cuisines.

Kitchen areas	Fusion	European (continental)	Contemporary	Fast-food	East Asian	Indian	Italian
Receiving	25.14	25.8	27.85	29.38	27.3	29.82	28.21
Preparation area	27.56	25.8	30	30.08	30.85	29.22	29.7
Stove	29.18	27.6	26.76	29	30.85	30.82	30.08
Oven	27.85	27.15	28.05	30.75	–	31.03	31.41
Dish-washing	26.62	29.7	28.4	29.3	28.8	29.68	30.31
Griller	31.8	31	31.86	33.86	–	–	28
Fryer	27.7	–	30.6	31.2	31.1	26.8	–

TABLE 7.6: Mean temperatures in kitchen areas.

Areas	Mean	Median	*n*	Std. deviation	Minimum	Maximum	Range
Receiving	27.78	27.80	30	2.55	21.90	31.90	10.00
Preparation	28.97	29.40	32	2.52	23.10	33.70	10.60
Stove	30.71	30.80	31	3.19	23.20	38.00	14.80
Oven	30.81	30.90	30	2.69	24.80	38.20	13.40
Holding	29.73	29.70	33	2.41	23.10	34.40	11.30
Dish-washing	28.96	29.00	33	1.86	24.90	33.60	8.70

a temperature range from 29 °C to 34 °C. The temperature range of electric conveyor ovens, however, was from 28 °C to 33 °C.

The factors affecting the heat experienced by kitchen workers near stoves varied. Primary factors revealed in statistical analysis were the kitchen height, symptoms of red face, sweating, discomfort index, staff–space ratio and state of the uniform.

The regression Y = b0 + b1x1 + b2x2 reveals heat near stove = −6.795 + (−2.162 × symptoms red face) + (0.446 × discomfort index), as per Table 7.8.

The best-fitting model for predicting heat near the stove is a linear combination of symptoms of red face amongst kitchen workers and discomfort index (because of heat from stove or oven). Other predictors were not significant in the mathematical model given above.

Other equipment, in addition to stoves, also contributes to heat in the kitchen, such as ovens and dishwashers. The equation Y = b0 + b1x1 indicated that Heat = 17.078 + (0.312 × oven heat). As the variable 'heat from dishwashing unit' is not significant, it cannot be a part of the mathematical model here.

As per Section 3.8, Type II hoods are installed above dishwashers, as they are light-duty appliances because of lower heat loads.

The best-fitting model for predicting heat from ovens is a linear combination of heat from the oven (Table 7.8).

TABLE 7.7: Factors affecting heat near cooking stoves.

Model	Unstandardised coefficients		Standardised coefficients	*t*	Sig.	Collinearity statistics	
	b	**Std. error**	**Beta**			**Tolerance**	**VIF**
(Constant)	−6.795	5.720	-	−1.188	0.250	-	-
Height of kitchens (m)	−0.429	0.518	−0.077	−0.828	0.418	0.784	1.276
Face appears red	−2.162	0.773	−0.246	−2.796	0.012	0.877	1.141
Sweating	−0.515	0.520	−0.089	−0.991	0.334	0.837	1.195
Discomfort index (stove, oven)	0.446	0.041	0.955	10.920	0.000	0.887	1.127
Staff–space ratio (workspace ratio)	0.016	0.052	0.026	0.300	0.767	0.872	1.146
Uniform wet – excessive sweating	−1.424	1.299	−0.097	−1.096	0.287	0.857	1.167

Key: Sig., significance; VIF, variance inflation factors.
Note: (1) Dependent variable: heat near stoves. (2) Predictors: (Constant), width, length, height of kitchens, staff–space ratio; symptoms, face red, sweating, uniform is wet – excessive sweating, number of fans; discomfort index (stove, oven).

TABLE 7.8: Heat near stoves affected by ovens and dishwashers.

Model	Unstandardised coefficients		Standardised coefficients	*t*	Sig.	Collinearity statistics	
	b	**Std. error**	**Beta**			**Tolerance**	**VIF**
(Constant)	0.235	6.757	-	0.035	0.973	-	-
Heat from oven DA 97.4	0.882	0.133	0.774	6.651	**0.000**	0.993	1.007
Dishwashing heat DA 97.6	0.108	0.197	0.063	0.545	0.590	0.993	1.007

Key: Sig., significance; VIF, variance inflation factors.
Note: (1) Dependent variable: heat near stoves DA 97.3.

7.4 Heat stress

The temperature near stoves at the height of 1 m varied from 23 °C to 34.6 °C, while the temperature near ovens ranged from 24.8 °C to 33.8 °C. Griller areas recorded the highest temperatures, from 30.1 °C to 34 °C. Areas near fryers logged operative temperatures from 26.6 °C to 32 °C. Such detailed measures of temperatures in kitchens have not been documented in similar studies. However, it is essential to note that all kitchens sampled did not all use the same equipment.

Heat stress will be considered under the following themes – heat experienced by chefs at stoves and the effect of humidity on kitchen temperatures. Kitchen heat experienced by chefs was found to be associated with job position, work shift, type of kitchen load, years of employment and race. Except for grillers and bakers, the other chefs and kitchen workers were not stove exposed or heat exposed.

The adoption of the equation Y = b0 + (−b1) x1 + (−b2) x2 + (−b3) x3 + (− b4) x4 indicates secondary factors affecting heat perception near stove = 35.341 + (−0.103 × job position) + (−0.091 × years of employment) + (−0.403 × worker shift) + (−0.722 × type of kitchen).

The best-fitting model for predicting heat near stoves is a linear combination of the type of kitchen, job position, years of employment and worker shift. The relationship with job position indicates that the higher the position, the lower the heat experienced near stoves. There is strong evidence to conclude that the variables are negatively associated.

Higher levels of humidity during peak periods steered kitchens to being extremely hot. Thirty-nine per cent of the kitchen managers responded that humidity was high, and more than 48% indicated that staff complained about humidity.

The WBGT in the kitchens varied closely, as indicated in Table 7.10. Institutional kitchens recorded the lowest mean WBGT near ovens (25.76 °C) and stoves (25.76 °C), which were slightly higher. The author observed that the kitchen temperature ranged from 38 °C to 45 °C in the food parlours in India, with humidity levels between 70% and 80%.

TABLE 7.9: Secondary factors affecting heat near the stove.

Model	Unstandardised coefficients		Standardised coefficients	*t*	Sig.	Collinearity statistics	
	b	Std. error	Beta			Tolerance	VIF
(Constant)	35.341	1.069	-	33.046	0.000	-	-
Job position A8	−0.103	0.049	−0.153	−2.077	0.039	0.978	1.022
Years of employment A10	−0.091	0.045	−0.148	−2.016	0.045	0.995	1.005
Worker shift A13	−0.403	0.177	−0.170	−2.276	0.024	0.956	1.046
Type of kitchen A4	−0.722	0.283	−0.189	−2.548	0.012	0.968	1.033
Race A4	−0.588	0.383	−0.113	−1.537	0.126	0.988	1.013

Key: Sig., significance; VIF, variance inflation factors

Note: (1) Dependent variable: heat near stoves. (2) Predictors: (Constant), shift, race, years of employment, job position, type of kitchen.

TABLE 7.10: WBGT values in sampled kitchens.

Kitchen zones (°C)	Casual	Institutional	QSR
Preparation area	24.91	22.74	25.55
Stove	26.94	25.81	26.17
Oven	27.28	25.76	27.35
Griller	26.77	30.4	28.37
Fryer	26.11	28.4	30.16

Key: QSR, quick-service restaurant.

TABLE 7.11: Discomfort index near stoves.

Model	Unstandardised coefficients		Standardised coefficients	*t*	Sig.	Collinearity statistics	
	b	Std. error	Beta			Tolerance	VIF
(Constant)	49.152	10.718	-	4.586	0.000	-	-
Heat near stove DA 97.3	2.013	0.397	0.686	5.074	0.000	1.000	1.000

Key: Sig., significance; VIF, variance inflation factors.

a. Dependent variable: discomfort index (stove, oven) DA 105.3.

Next, DI near stoves will be discussed. Measurements indicate that only the cooking area presented dissatisfaction with thermal conditions, whereas 50% of employees were dissatisfied with the cooking and food preparation areas.

The discomfort index near the stove in this study was modelled on the equation Y = b0 + b1x1, which indicates that the discomfort index near the stove = 49.152 + (2.013 × heat near stoves). Thus, for every unit increase in heat near stoves, a 2.013 unit increase in discomfort index value is predicted, holding all other variables constant. The best-fitting model for predicting discomfort index near stoves is a linear combination of heat near stoves.

Looking at the discomfort index near humid areas, humid area measures were taken at positions near the minimum value > 85, indicating that the index was uncomfortable near stoves and dishwashers. The maximum value > 100 indicates extreme discomfort, and value > 110 indicates a hazardous to health index for dishwashers and cooks, respectively.

The minimum and maximum DI indicate that staff in Durban kitchens were uncomfortable during peak periods of business (Table 7.12 and Table 7.13). The DI values for dishwashing areas were lower than for cooking areas because of the absence of radiant heat. The heavy-duty load kitchens had higher discomfort values than other kitchens being conducted to gather information for this study.

The heavy-duty kitchens used LPG equipment extensively, increasing the heat stress of the kitchen workers, whereas in medium-duty kitchens only electric equipment was universally operated.

Focusing now on symptoms of flushing, flushing is commonly known as a biological reaction to heat. Flushing may be expressed in the equation Y = b0 + b1x1, namely, heat = 32.907 + (10.152 × symptoms: red face).

Thus, for every unit increase in red-faced chefs (BB38.2) as symptoms of heat stress, a 10.152 unit increase in heat near stove area value is predicted, holding all other variables constant. This equation for dependent variable heat near stoves helps to compose indoor environmental criteria for the design of restaurant kitchens in Durban in respect of heat strain in thermal environments.

This equation indicates that 15.2% of chefs on duty are observed to be red-faced. While only 15.2% of workers (Table 7.15) are red in the face from the heat in cooking areas, the statistic could be misleading as 78% of African workers are dark in complexion because of ethnicity, and hence it is not apparent; some Indian chefs are also darker in complexion.

TABLE 7.12: Discomfort index near humid zones.

Kitchen zones	*n*	Minimum	Maximum	Mean	Std. deviation
Discomfort index (stove, oven)	32	85.22	119.67	103.1350	6.75482
Discomfort index (dishwasher)	32	85.83	104.18	98.2101	4.80063

TABLE 7.13: Type of kitchen loads observed and discomfort index.

Type of kitchen	Variable	Discomfort index (stove, oven)	Discomfort index (dishwasher)
Light-duty equipment	*n*	2	2
	Mean	100.5277	100.4859
	Std. deviation	5.36786	2.66629
	Minimum	96.73	98.60
	Maximum	104.32	102.37
	Range	7.59	3.77
Medium-duty equipment	*n*	5	5
	Mean	102.6762	96.9789
	Std. deviation	5.04509	4.99766
	Minimum	93.79	85.83
	Maximum	112.29	104.18
	Range	18.49	18.36
Heavy-duty equipment	*n*	19	19
	Mean	105.2534	97.2802
	Std. deviation	14.43691	5.28164
	Minimum	85.22	90.18
	Maximum	119.67	102.37
	Range	34.45	12.20
Extra-heavy-duty equipment using solid fuels	*n*	6	6
	Mean	103.6918	102.1251
	Median	105.1586	102.4424
	Std. deviation	3.22164	1.46356
	Minimum	97.96	100.39
	Maximum	106.24	104.00
	Range	8.29	3.62

Moving on to the symptoms of heat stress and heat strain in the kitchens, heat strain is the physical response of the body to a heat stress environment. If a worker is frequently exposed to hot conditions and internal heat generated through physical work, it can lead to the development of adverse health outcomes. As per Table 7.15, 57% of kitchen workers in this study reported that they sweat in the work environment. Sweating was obvious amongst 11.1% of staff. Heavy sweating, along with headaches, was also reported by 3% of workers.

Almost 3% of the chefs in this study reported high blood pressure and feelings of sickness in Table 7.14. The most prevalent symptom of heat stress was tiredness and intense thirst amongst kitchen workers, which was concurred by 35% and refuted by 41% of head chefs.

Even though more than 50% of head chefs denied any psychological symptoms shown by kitchen workers because of excessive heat, several kitchen workers (23.5%) from other kitchens were observed to suffer from a decrease in attention and/or irritability. Confusion (14.7%) and loss of

TABLE 7.14: Physiological and psychological symptoms amongst food-service workers.

Physiological symptoms	**Percentage (%)**
Tiredness	35.3
Increase in blood pressure	2.9
Headache	14.7
Muscle cramps	2.9
Feeling and being sick	2.9
Heavy sweating	23.5
Intense thirst	35.3
A fast pulse	2.9
Other symptoms	8.7
Not applicable	41.2
Psychological symptoms	**Percentage (%)**
Decrease of attention	23.5
Decrease of performance for physical activities	14.7
Slowed and impaired perception	2.9
Decrease of motivation	8.8
Irritability	23.5
Using foul language	5.9
Impairment of thinking	2.9
Losing concentration	8.8
Anger	8.8
Confusion	14.7
Not applicable	52.9

concentration (8.8%) were also observed. One kitchen reported impaired perception and impaired thinking (2.9%). Obvious heat strain was observed amongst 14.7% of staff.

Engineering controls like forced-air ventilation or capturing heat from the kitchen cooktops or stoves can also reduce heat illness. Further, administrative controls can be used to limit a worker's exposure time through rest and work cycles, as well as to reduce the metabolic workload.

Moving on to factors affecting heat (°C) near stoves, the equation Y = b0 + b1x1 + b2x2 + b3x3 + b4x4 + b5x5 represents factors that affect awareness of heat, while near the stove is used to ascertain the kitchen worker perceptions of heat. Accordingly, heat near stove = 54.547 + (0.982 × South African Indian) + (−0.154 × South African African) + (−0.829 × number of meals per day) + (−7.334 × other) + (−1.3 × area of the kitchen); 'other' refers to QSR serving a seafood-based menu exclusively or fried chicken and/or burgers only.

The variables 'area of the kitchen' and 'heat experienced near stoves' are closely associated. The smaller the area, the greater the heat. So for every unit increase in area, a 1.3 unit decrease in 'heat experience near stoves' area value is predicted, holding all other variables constant, provided this increase in space is not occupied and permits air movement to dissipate heat (Table 7.16).

TABLE 7.15: Heat stress symptoms amongst kitchen workers.

Symptoms of heat strain	Percentage (%)
Face appears red	15.2%
Sweating	57.6%
Uniform is wet – excessive sweating	3.0%

TABLE 7.16: Factors affecting heat near stoves.

Model	Unstandardised coefficients		Standardised coefficients	*t*	Sig.	Collinearity statistics	
	b	Std. error	Beta			Tolerance	VIF
(Constant)	57.557	6.644	-	8.662	0.000	-	-
South African white Q5.1	0.122	0.131	0.115	0.926	0.368	0.813	1.230
South African Indian Q5.2	0.983	0.275	0.552	3.569	0.003	0.522	1.915
South African mixed-race Q5.3	0.094	0.948	0.013	0.099	0.922	0.744	1.343
South African African Q5.4	−0.163	0.059	−0.390	−2.752	0.014	0.622	1.608
South African other mixed-race Q5.5	1.964	1.432	0.203	1.372	0.189	0.569	1.759
European, white Q5.6	−0.251	0.317	−0.133	−0.792	0.440	0.446	2.241
Other, non-African Q5.7	0.492	0.762	0.099	0.646	0.528	0.533	1.875
Area of the kitchen Q6	−1.238	0.523	−0.285	−2.368	0.031	0.862	1.160
Number of meals per day Q7	−0.819	0.379	−0.271	−2.162	0.046	0.797	1.255
East Asian Q12.4	−2.407	1.927	−0.207	−1.249	0.230	0.453	2.206
Italian Q12.5	−2.139	1.355	−0.311	−1.578	0.134	0.322	3.108
Other Q12.8	−7.836	1.269	−1.006	−6.176	0.000	0.471	2.124

Key: Sig., significance; VIF, variance inflation factors.
Note: (1) Dependent variable: heat near stoves. (2) Heat near the stove experienced by kitchen workers is affected by race (Indian or African), output in number of meals per day and other factors, as well as area of the kitchen.

Beta coefficients for three predictors are South African Indian, $\beta = 0.983$, $t = 3.569$, $p < 0.003$; South African African $\beta = -0.163$, $t = -2.752$, $p < 0.014$; area of the kitchen, $\beta = -1.238$, $t = -2.368$, $p < 0.031$; output in number of meals per day, $\beta = -0.819$, $t = -2.162$, $p < 0.046$ and other cuisines – seafood, fried chicken, $\beta = -7.836$, $t = -6.176$, $p < 0.000$. The best-fitting model for predicting heat near the stove is a linear combination of South African Indian, South African African, area of the kitchen, output in the number of meals per day and other cuisines.

7.5 Genotype and phenotype effect on thermal adaptation

Examples of genotypes are the genes responsible for eye colour, hair colour, height, nose shape and skin colour. Examples of phenotypes are visible characteristics, including eye colour, hair colour and type, height, nose shape and skin colour. Sociocultural aspects or race influence heat stress perception in the workplace, according to Messeri et al. (2019). The following will be discussed under this topic: adaptation to Durban weather, kitchen worker's uniform, hairstyles and head coverings, body shape, skin colour and type of nose.

7.5.1 Adaptation to Durban weather

Over 98.8% of the sample (Figure 7.3) liked Durban weather, an indicator that they were acclimatised to the warm and sunny weather of the subtropical coastal climate. Only 5.8% of staff used an air conditioner at home, even though 19.6% claimed to maintain a comfortable lifestyle. It seems that a comfortable lifestyle after work is likely to help staff to cool off and come to work well-rested. Almost 91% of staff travelled by public transport or walked to work, while 9.3% drove to work by car.

Hot weather conditions have the potential to exacerbate already high heat conditions and therefore heat stress inside commercial kitchens as well. The mean temperature indicated in Table 7.17 can be comfortable for heat-adapted residents such as Indians, Africans, and people from tropical countries and semi-tropical countries, which may provide needed space for the raised commercial kitchen temperatures in Durban.

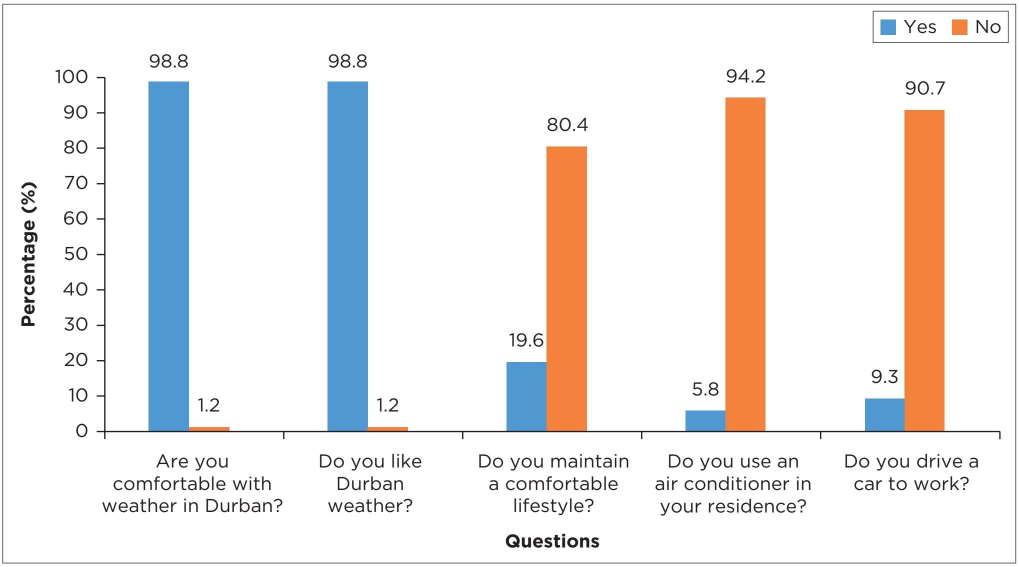
This study recorded outside temperatures ranging from 24 °C to 30.8 °C during the fieldwork. The cross-tabulation between kitchen workers being comfortable with Durban weather and tenure was substantial. Employment tenure was shorter for kitchen workers, with a mean tenure being 4.4 years only.

The cross-tabulation between kitchen workers who had past experience to expect summer months to be hot while maintaining a comfortable lifestyle was significant; 49.1% of workers expected the day of field study to be hot, while 37.5% of workers from their experience expected summer months to be warm like that of the field study day.

The cross-tabulation between the kitchen workers' comfort in the heat during peak periods and maintaining a comfortable lifestyle was found to be statistically proven. Unison supports the Trades Union Congress's call for a specific permissible maximum temperature for indoor work of 30 °C or 27 °C where the work is strenuous. At present, there is officially no clear maximum. However, the recommended maximum would be intended to be the absolute maximum, so regular indoor work at or just below 30 °C would not be acceptable, and managers should endeavour to reduce temperatures if they

TABLE 7.17: Mean values of outdoor temperature and humidity levels during field study.

Weather parameters	Mean	Median	*n*	Std. deviation	Minimum	Maximum	Range
Temperature (°C)	27.01	27.40	27	2.71	21.60	31.90	10.30
Relative humidity (%)	63.20	63.25	30	4.44	55.00	79.00	24.00



Source: Author's own work.

FIGURE 7.3: Kitchen workers' opinions on Durban weather.

go above 24 °C or workers feel uncomfortable. The WHO recommends 24 °C as the maximum temperature for working in comfort (Unison 2014).

Kitchen workers maintained a comfortable lifestyle and used make-up at work, and the variables were associated. The cross-tabulation between kitchen workers' perceptions of feeling comfortable working in the kitchen with make-up or foundation and BMI is important.

7.5.2 Kitchen worker's uniform

Eighty-one per cent of the workers were comfortable in their uniforms. However, at the time of the survey, not all kitchen staff wore a chef's jacket. Almost 39% of the kitchen workers in this study were wearing regulation t-shirts or even a housecoat for female chefs (Table A1).

Half (50%) of the kitchen managers (Table 8.13) claimed that staff complained about humidity such as sweat not drying, wet uniforms and stickiness. In very hot periods, the human organism makes use of perspiration to maintain its temperature within proper physiological limits.

It was observed that 96.5% of the food-service workers in the sampled kitchens wore long pants, except for 3.5%. Golf shirts and formal shirts in kitchens were observed amongst 12% and 3.5% of kitchen workers, respectively. The cross-tabulation between kitchen workers feeling comfortable working in chef's uniforms and the number of meals prepared in a single shift was significant. Only one chef had a wet uniform because of excessive sweating.

A significant correlation between the kitchen worker's uniform and the number of meals cooked per shift was established. Parameswarappa and Narayana (2014) reported that steelworkers wore a heavy PPE ensemble. As per OSHA Fact Sheet (2014), the use of bulky protective clothing and equipment may contribute to heat illness. Indoor workers also face risks for developing HRI when compared to outdoor workers; interior workers also face heat-related workload concerns during the summer months, especially if they are wearing semi-permeable or impermeable PPE (Venugopal et al. 2022b). As explained earlier in this section, a chef's uniform can prevent heat dissipation. The greater the meal output, the greater the discomfort from workers' uniforms.

7.5.3 Hairstyles and head coverings

In an experimentation of the influence of head hair on heat removal, Shin, Park and Lee (2015) found that the optimal temperature for head cooling under heat stress is 10 °C to relieve physiological heat strain; subjects, however, reported to prefer 15 °C. Heat removal from the normal hair condition, namely 100 mm to 130 mm length and cropped hair with 5 mm length, is not meaningfully different. However, Jacoby (2018) claimed that long hair has a similar effect to hats, which induce sweat and cool down the body. Hence, short hair will be cooler for the head. Cross-tabulation between 'less hair or a clean-shaven head will be comfortable for work in the kitchen and the heat at the workplace indicates that the variables are associated. Commercial kitchens in Durban do not specify the length of hair amongst kitchen workers, as a hairnet or a cap or a chef's hat covers the hair based on uniform regulations for staff.

The cross-tabulation between kitchen workers' perceptions of feeling comfortable with excess hair to work in the kitchen and BMI is major. Almost 48% of African workers have dreadlocks, hair extensions, and hair weaves (Table A3). Almost 70% of them are female workers, and 29% are male workers. Even though artificial hair is not preferred in kitchens, once covered, it is acceptable. The female workers voiced their opinion that hairstyles are part of grooming, and hence they indulged in hair extensions and weaves. About 28.2% have elaborate synthetic hair on their heads. There is a scarcity of evidence in the literature on the relevance of comfort with excess hair for work in the kitchen.

Almost 77% of kitchen workers of African descent agreed that they did not feel comfortable with excess hair in the kitchen. Considerably more respondents indicated that they were uncomfortable with excess hair and that being shaven would be more comfortable for working in the kitchen (64.2%). Table A3 indicates the common hairstyles amongst kitchen workers.

According to Esther (2008), local authorities in the UK require chefs to wear a hairnet even if bald. Wearing wigs can be uncomfortable and can be cumbersome with heat and humidity. A synthetic wig may melt near a hot stove or oven (Stephen 2018). Dreadlocks can be hot and heavy, especially when the temperature is 32.2 °C (90 °F). This is an uncharted field in thermal comfort in the kitchen.

7.5.4 Body shape, skin colour and type of nose

An individual's overall body shape is a superior indicator of climatic adaptation than a single facial feature. The widely used classification of body types is ectomorphic, mesomorphic and endomorphic (Abubaker 2010). Consistent with Bergmann's rule and Allen's rule, warm-adapted individuals tend to be lean ectomorphs, and cold-adapted individuals tend to be bulkier non-ectomorphs.

South African men working in kitchens tended to be stocky, with almost 65% having normal weight, whereas only 31% of women had normal weight for height. More than half the women workers were obese (55%) and endomorphic; however, only 16% of men were obese. Although none of the men were morbidly obese, 7% of women were. Nearly 20% of men were ectomorphic and lean, and seven (0.64%) women were lean and slender. Ganguly (2013) declared that mesomorphs maintain improved physical fitness and hence tolerate heat better with lower heat stress. There are no studies to indicate if the skin tends to 'burn easily' from indoor heat. Table A2 indicates that body type amongst kitchen workers is based on the researcher's perceptions.

Very fair skin tone, as well as extremely dark skin tone is observed in 2.9% of kitchen workers. Variation exists in the skin tones amongst African workers, from medium fair to dark. Medium-brown is the most commonly observed skin tone among Africans, in more than 54% of workers, as indicated in Table A4. As 90% of the workers were African, who tend to have a darker skin tone, the scale was converted from 10-point into a 7-point scale for easy data recording, as fairer tones are rarer in the survey.

A cross-tabulation between kitchen workers' skin tones and maintaining a comfortable lifestyle was significant. It seems that staff maintaining a comfortable lifestyle had lower heat stress. Not all workers can cool their bodies adequately at night, and such individuals are at greater risk for HRI (Frimpong 2015). It has not been established in the literature that the skin tones of kitchen workers have any benefit in dealing with indoor heat, specifically kitchen heat. Even the advantage of ethnicity and heat adaptation is contentious.

A relationship was established between the opinions of kitchen workers on heat in kitchens and the type of nose, with strong evidence to conclude that the variables are related (Table A5).

7.6 Conclusion

In conclusion, Chapter 7 explored the implications of physiological factors, genotype and behavioural factors on heat adaptation. Human heat adaptations vary widely. Heat in kitchens has been shown to be affected by kitchen activities, type of equipment, fuels used and cuisine. Physical and psychological heat stress symptoms were observed in some kitchens. It is important to have models for heat stress prediction to diminish thermal risk and avert heat-induced disorders in different exposure settings. The analysis and appraisal of answers require transdisciplinary and holistic approaches, including technical solutions and a mix of locally appropriate technologies integrated with a human rights and environmental justice frame. The next chapter will discuss how findings on kitchen ventilation rates affect thermal comfort and humidity levels.

Chapter 8

Data presentation, analysis and discussion: Ventilation and humidity

8.1 Architectural features suitable for kitchen ventilation

This chapter will discuss the findings on ventilation and humidity in kitchens. The discussion begins with airflow in kitchens, NV, kitchen spaces, air composition and CO_2 levels, followed by humidity. The findings will be presented according to the emerging themes. This section will be discussed under the following themes: sources of airflow in kitchens, kitchen fenestrations, open-plans and mechanical devices, high ceilings and large corridors, and NV from windows and doors.

Sources of ventilation in the kitchens are inclusive of open doors, open windows, hatches, fans, air coolers, air conditioners, whirlybirds, chimneys and HVAC extraction systems, as well as NV from the sea breeze, which helped dilute ventilation in kitchens. In some kitchens, these ventilation modes, according to Table 8.1, were found to be inadequate to cope with the heat and fumes. Greenplan (2015) posited that earlier building designs relied on NV to ensure adequate fresh air and acceptable thermal comfort, as seen in almost 80% of the kitchens.

How to cite: Gangiah, S 2022, 'Data presentation, analysis and discussion: Ventilation and humidity', in *Environmental ergonomics Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town, pp. 185–204. https://doi.org/10.4102/aosis.2022.BK346.08

It is surmised that coastal Durban has reasonable airflow that can be harnessed in kitchens, despite the wind-power potential in the general Durban region being classified as moderate (Bellingham, Davies & Human 2009). Prior studies linking natural sea breeze to restaurant kitchens appear to be unavailable.

It is also established that air infiltration in kitchens is assisted by fenestrations in the building envelope. None of the kitchens had tightly sealed doors and windows. The air infiltration from open doors, windows, whirlybirds and chimneys helped with NV. Not all kitchens had the same equipment or design layout, and this could have influenced NV. Commonly observed across the open-plan design of 13 kitchens with features in Table 8.1 was the airflow from the front doors and the cool airflow from dining areas. Open-plan kitchens benefit from the creation of cross-ventilation from high ceilings, large corridors, open doors and windows.

In this study, ceilings higher than 4 m in three kitchens helped to keep kitchens cooler. The kitchens had a mean of 3.03 m with the lowest ceiling height at 2.41 m, a median of 2.96 m and a maximum of 4.17 m. More than 30% of the kitchens had a ceiling height less than 3 m. Ceiling heights for commercial kitchens are, inappropriately, not mentioned in prior ventilation studies.

This study finds that two kitchens with large corridors observably have enhanced NV with higher airflow rates. An architectural element such as corridors creates cross-ventilation and connects the outdoor environment and isolated indoor space. In this regard per Table 8.1, kitchen 6 is ideally located in an open space on a hillock closer to the ocean. The kitchen is in the basement on one side and slopes up to ground level. The sea breeze is channelled through a long-curved corridor to reach the spacious kitchen, where it is removed by an extractor even though the velocity of the gushing air is reduced. Spacious kitchens (21.2%), high ceilings (12.1%) and large corridors (9.0%) were observed in the kitchens, although only one kitchen had all three ventilation facilities. However, the oxygen levels in these kitchens were 22% compared with other kitchens that indicated 21%.

Regarding NV from windows and doors, closed doors obstruct kitchen airflow (Bonderud 2015). In response, kitchen 11 accordingly installed a security gate that permitted leaving the back door ajar until closing time to permit airflow into the kitchen, hence improving cross-ventilation. Back doors were present in 23 kitchens and five kept them closed, using them only for receipt of deliveries. Air velocities varied from 0.10 m/s to 2.5 m/s at the back doors of the kitchens. Nearly 55% of the kitchens kept the doors open most times, allowing airflow that helped reduce ambient temperature and stuffiness. The NV in 30% of the kitchens in this study was restricted by the absence of back doors, which could be because of location factors and the availability of rental space.

TABLE 8.1: Ventilation facilities in sampled kitchens excluding extractors.

Kitchen no.	Fenestrations			Built spaces				Mechanical devices				
	Back door open	**Front door open**	**Window open**	**Large corridor**	**High ceiling**	**Spacious areas**	**Open-plan**	**Air conditioner**	**Air vents or diffuser**	**Whirlybird**	**Fans**	**Air curtain**
1.	✓	✓					✓				✓	✓
2.	✓	✓			✓	✓	✓		✓	✓		
3.					✓	✓						
4.		✓					✓		✓	✓		
5.		✓				✓	✓	✓				✓
6.				✓		✓		✓				
7.	✓			✓	✓	✓						
8.	✓											
9.	✓		✓								✓	
10.	✓	✓									✓	
11.	✓	✓									✓	
12.	✓		✓				✓				✓	
13.	✓				✓	✓						✓
14.		✓					✓					
15.		✓					✓			✓	✓	
16.		✓					✓					
17.		✓		✓			✓					
18.								✓				
19.								✓				✓
20.								✓			✓	
21.		✓					✓		✓	✓		
22.							✓		✓			✓
23.										✓		
24.		✓					✓		✓			
25.		✓					✓		✓			
26.	✓							✓	✓			
31.	✓											
27.		✓					✓			✓		
28.	✓	✓									✓	
29.	✓											
30.	✓	✓										
32.		✓	✓						✓		✓	
33.	✓	✓	✓									
Total (%)	**13 (39.4%)**	**16 (48.5%)**	**4 (12%)**	**3 (9.0%)**	**4 (12.1%)**	**7 (21.2%)**	**13 (39.4%)**	**6 (18%)**	**8 (24%)**	**6 (18%)**	**8 (24%)**	**4 (12%)**

To improve ventilation, strategic placement of windows and doors is recommended, informed by prevailing wind patterns; however, total dependence on NV to exhaust heat flux and emissions in a commercial kitchen is arbitrary.

Next, there will be a discussion of how whirlybirds and fans assist in NV; how air curtains, air vents and air conditioners keep kitchens cooler; and how kitchen spaces affect ventilation, size of kitchens and worker density in kitchens. Eighteen per cent of the kitchens (Table 8.1) installed turbine ventilators that improved airflow. Even in urbanised applications, the device is a viable complement to MV, as it can provide the recommended fresh air rates at relatively low external wind velocities in buildings. Fans were present in 24% of kitchens, circulating air to speed up the evaporation of sweat and give workers a cool feeling. High-velocity heavy-duty industrial fans, either pedestal or wall, were installed in 24% of kitchens to compensate for inadequate airflow.

Air curtains were installed in four kitchens at the entrance. Air vents (24%) and air conditioners (18%) helped to mitigate staff discomfort from heat and humidity with cool air. At least two combinations to improve ventilation were noted in 18 kitchens (Table 8.1).

Thirty per cent of the kitchen staff in this study considered the kitchen workspace inadequate; the airflow rate was therefore questionable. Airflow in a kitchen seemed to be affected by area and the volume of kitchens, volume of food cooked, cuisine, density of workers in the kitchen and air infiltration. Kitchens 29 and 31 have half-walls or semipartitions between different sections of the kitchen to permit air distribution. Indoor air quality in kitchens 3, 6, 7 and 14 in Section 8.2 was better compared with other kitchens, as the temperatures did not exceed 30 °C because of the presence of good NV from the ocean breeze, PPS, air conditioners and air curtains. These kitchens also had large unoccupied spaces, thus permitting airflow in different kitchen areas.

While most of the kitchens' areas were less than 100 m^2, a few had areas greater than 300 m^2. The calculated volume of kitchens ranged from 43.58 m^3 to 426.05 m^3 (Table 8.2). The standard minimum formula for a full-service dining establishment is 5 ft^2 (0.46 m^2) of kitchen space per restaurant seat: a 40-seat restaurant requires a 200 ft^2 (18.58 m^2) kitchen.

This study observed that the area of the kitchens varied between 17 m^2 and 334 m^2, and the mean value was 68.41 m^2; the number of meals consumed daily was between 85 and 1200.

A certain franchise kitchen with three different themes, cuisines and menus had smaller floor areas (approximately 17 m^2), operating with a large common

TABLE 8.2: Kitchen sizes and workspace ratio.

Kitchen dimensions	Mean	Median	*n*	Std. deviation	Minimum	Maximum	Range
Seating capacity	93.48	75.00	31	74.46	12.00	320.00	308.00
Number of employees	17.88	15.00	33	9.25	9.00	45.00	36.00
Width (m)	5.63	5.32	33	1.39	3.25	8.86	5.61
Length (m)	9.08	7.82	33	5.32	4.30	28.00	23.70
Height (m)	3.03	2.96	33	0.51	2.41	4.17	1.76
Area (m^2)	68.41	44.87	33	54.07	17.10	334.08	316.98
Volume (m^3)	204	132	33	170.04	40.8	1 053	1 012.00
No. of staff on duty	7.87	7.00	33	3.14	4.00	17.00	13.00
Workspace ratio (m^2/employee)	8.05	6.23	33	5.00	2.67	21.23	18.56

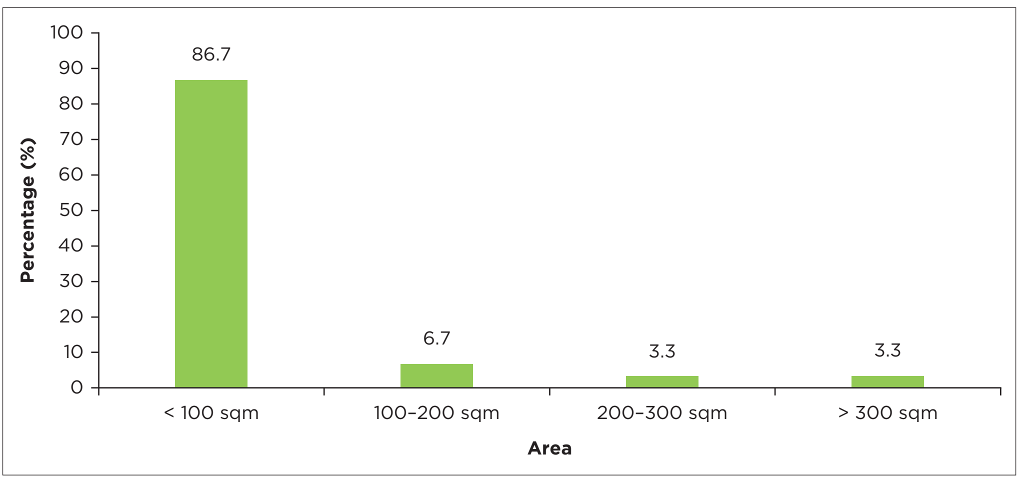
preparation area serving all three kitchens. Almost 91% of the kitchens had preparation areas of 18.5 m^2 or more, as per the City of Durban (2020) *Food By-Laws*.

The area of the kitchen seems to influence the airflow in the kitchen. Figure 8.1 indicates the area of the kitchens. Significantly, more respondents (86.7%) indicated that the kitchen area was less than 100 m^2. Kitchens 6, 7 and 14 had larger areas, leaving additional unoccupied space for air circulation, with kitchen areas ranging from 173 m^2 to 332 m^2.

Almost 88% of the kitchens fell in the range of 30% to 40% space allocated to the kitchen when compared with dining areas. About four kitchens were larger than most kitchens and occupied 60% of space when compared with dining spaces. This can be attributed to a kitchen servicing other satellite kitchens; another kitchen offered food 24 h a day, including room service, and had a patisserie attached to it, and another two kitchens offered fine dining services.

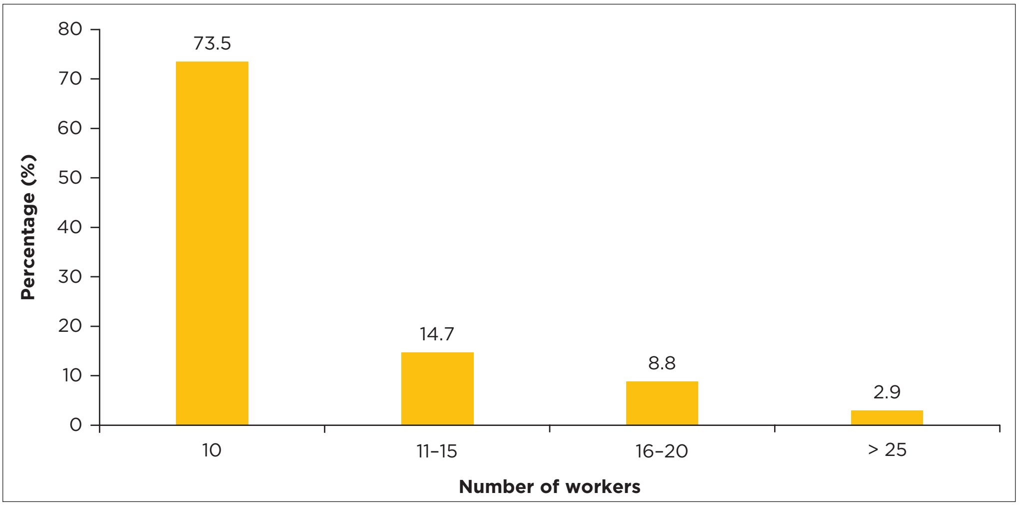
The number of staff members on duty (Table 8.2) varied from 4 to 17; however, South Africa has yet to formulate such a guideline. The number of staff members in the sample kitchens ranged from 4 to 31, depending on the shift and day of the week. The workspace ratio varied from 2.67 to 21.23 in the sample kitchens. Heavy-duty and light-duty kitchens have ratios of 7.88 and 9.4, respectively (Figure 8.3).

The author feels that a workspace ratio of 18 m^2 per staff member may be suitable in warmer countries. Under the South African *Facilities Regulations of the Occupational Health and Safety Act 85*, 2.25 m^2 of unimpeded space of open floor area must be available for every employee working in an indoor workplace. However, no mention of the hospitality and catering industry is made.



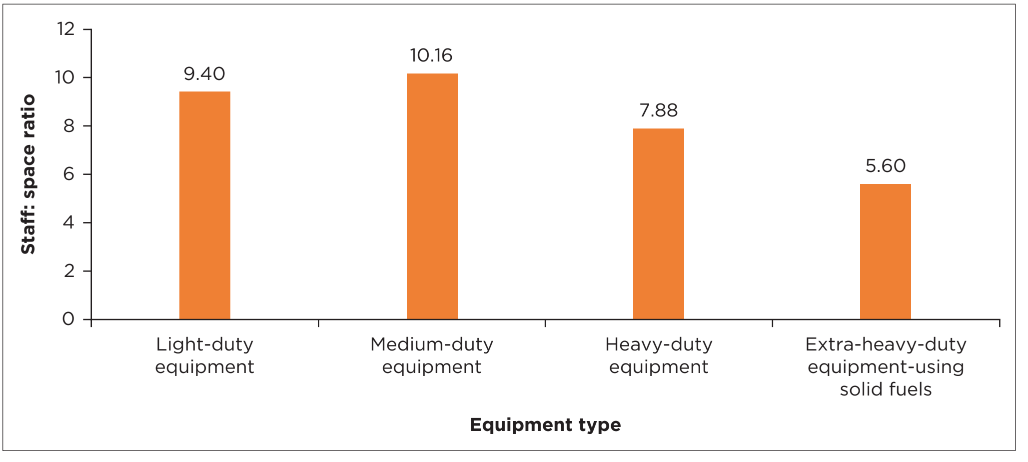
Source: Author's own work.

FIGURE 8.1: Kitchen areas in this study.



Source: Author's own work.

FIGURE 8.2: Worker density in the kitchen.



Source: Author's own work.

FIGURE 8.3: Workspace ratio.

Nearly 97% of the kitchens in this study followed a cook-fresh system or conventional food production system. On-site food preparation dominates production systems used in restaurant settings. The number of workers in kitchens can affect ventilation (Figure 8.2). The density of workers is important to determine environmental comfort because the greater the number of workers in the kitchen, the greater the space required to maintain adequate ventilation rates.

Seventy-four per cent of the kitchens employed at least 10 staff. Only 2.9% of kitchens had more than 25 employees in their food-service operation. Nearly 15% of kitchens had more than 15 employees in the food business. The distribution of staff according to kitchen load is indicated in Figure 8.3. The most common heavy-duty equipment kitchens (61%) had a workspace ratio of 7.88.

Medium-duty kitchens were found to have the highest workspace ratio of 10.16, whereas extra-heavy-duty kitchens had the lowest ratio of 5.60.

8.2 Airflow in commercial kitchens

This study indicated that there was no airflow in 12% of the kitchen zones of kitchens. Although 60% of the kitchens had an adequate airflow rate of 0.5 m/s, it was uneven in some areas. The mean airflow measures were between 0.08 m/s and 0.47 m/s in dishwashing areas and corridors, respectively. Moreover, the range from minimum to maximum across all kitchen work areas varied from 0.00 m/s to 2.5 m/s (Table 8.3).

About 56% of the workers complained in Table 8.4 that ventilation was inadequate in the kitchens; airflow rates ranging from 0.0 m/s to 0.63 m/s were recorded.

Only 27% of the kitchen workers complained that airflow was inadequate during peak periods as they reported stuffiness, especially during summer. Odours and stale air were reported by 2.9% and 2.3% of respondents in kitchens 11 and 22, respectively, at times during cooking. Thirty-three per cent

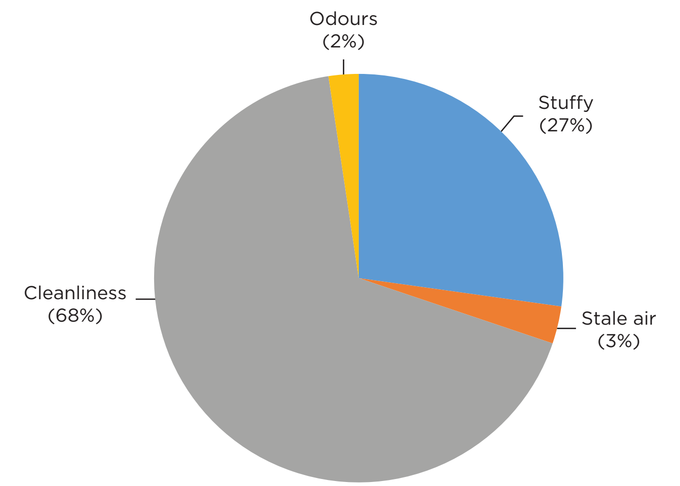
TABLE 8.3: Airflow range in kitchen areas.

Kitchen area	Mean	Median	*n*	Std. deviation	Minimum	Maximum	Range
Receiving area	0.33	0.10	31	0.58	0.00	2.00	2.00
Preparation area	0.29	0.10	32	0.32	0.00	1.00	1.00
Stove	0.27	0.10	31	0.39	0.00	2.00	2.00
Oven	0.10	0.10	31	0.15	0.00	0.50	0.50
Holding	0.15	0.10	33	0.15	0.00	0.50	0.50
Dish-washing area	0.08	0.00	32	0.13	0.00	0.40	0.40
Corridor	0.47	0.20	33	0.65	0.00	2.50	2.50

TABLE 8.4: Factor analysis of ventilation factors.

Q43	1 Discomfort	2 Uneasiness factor	3 Maintenance	4 Kitchen layout
12. The staff complained about humidity in the kitchen	0.268	0.708	0.055	−0.011
13. The staff are content with airflow in the kitchen	0.052	−0.144	0.155	0.866
14. The staff complained of hot or cold draughts in the kitchen	0.617	0.227	−0.215	0.097
15. The staff complained about difficulty in breathing	0.876	0.426	−0.012	−0.001
16. All kitchen equipment is installed as per specifications	−0.160	−0.057	0.693	0.134
17. The staff complained that it is too hot in the kitchen	0.090	0.844	0.072	−0.098

Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalisation.
Note: Rotation converged in five iterations.



Source: Author's own work.

FIGURE 8.4: Kitchen workers' opinions about peak period airflow.

of workers complained of ineffective ventilation (Figure 8.4), and almost 12% of head chefs considered ventilation to be inadequate. Moreover, kitchen 11 and kitchen 17 had hoods installed high in the ceiling with a distance greater than 60 cm (or 70 cm), leading to staff complaints of odour and stuffiness. A minor proportion (5.3%) of kitchens had equipment producing soot, as grillers and ovens were soiled and scheduled for clean-up. However, almost 58% of the kitchens had equipment that did not produce soot from burning of spills or unclean equipment.

This study recorded mean airflow at hoods ranging from 0.1 m/s to 1.5 m/s. Except for staff in one kitchen, there were complaints from staff from all other kitchens about excessive heat in the kitchens (Table 7.6). A greater number of concerns were expressed amongst those staff in kitchens that lacked a vent, diffuser or air conditioner.

Almost 67% of the kitchen managers assumed that the cooling sources in the kitchen were adequate. However, 33% of head chefs responded that it was inadequate and were supported by 45% of kitchen workers who also thought the thermal environment varied seasonally, and 41% of kitchen staff found the thermal environment uncomfortable. Of the kitchen workers, 64% commented that the air was clean; the rest complained of stuffiness and high humidity in dishwashing areas.

An examination follows of how drought affects airflow in the kitchens, prevention of draughts, uneven airflow in kitchens, extractors and airflow, and MM ventilation. Domestic and heavy-duty fans were the source of air movement in 35% of kitchens that pushed thermal plumes into the cooker hood along with NV. However, when not installed directionally correctly, the draught results in spilled heat, emissions and CO_2 from the poorly installed hood into the rest of the kitchens, as observed in kitchen 21, kitchen 29 and kitchen 33. Staff in the kitchens sometimes complained about hot draughts and a hot environment.

Kitchens 12, 13 and 16 had large industrial fans that ran on the maximum speed of 1400 rpm, causing draughts. The sensation of draught was lower in kitchen activity areas, and workers felt warm. The author further found that cold supply air flowed directly to the heads of the chefs, causing discomfort. Kitchen 22 had a functioning air cooler that provided closed windows in the preparation room in a humid kitchen, which increased discomfort amongst workers.

In kitchen 3, the air supply inlet installed at two sides of the extractor duct caused plume spillage from the sides of the duct, and air impurities spread throughout the kitchen. The air supply outlet spilled air directly onto the heads of chefs, causing discomfort. Using EFA, a factor loading of 0.876 for difficulty in breathing was used and was categorised into Component 1 (discomfort) (Table 8.4). The head chefs opined that only 2.9% of staff often complained about difficulty breathing.

Emissions from food preparation can spread to other parts of the kitchen. The correlation between staff complaints about difficulty in breathing (kitchens 11, 23 and 28) and staff complaints of hot draughts in the kitchen was significant. About 87% of staff never complained about difficulties in breathing. The correlation between staff complaints about difficulties in breathing and staff complaints about humidity in the kitchen was also significant.

About 73.5% of the staff never complained of hot or cold draughts in the kitchen. Some staff at times complained about hot draughts in kitchens 13, 16 and 23, as the movement of air from fans could have disturbed the thermal plume before entering the extractor if it was not fitted directionally accurately. Kitchen 6 had a PPS that cooled the chefs without any draught.

The corridors leading to study kitchens 6 and 7 showed higher flow rates from open doors with NV and air conditioners in the restaurants, near the kitchen entrance. Kitchen 6 had PPS installed above a range as well, and kitchen 7 had a large corridor for air movement and distribution. Five kitchens – 3, 7, 14, 19 and 13 favoured hybrid ventilation with airflow rates from 0.3 m/s to 2 m/s because of a sea breeze. While seemingly better for ventilation, such higher flow rates have come under criticism. Amongst others, this study indicates that the use of spot cooling fans, air-conditioning, general ventilation and local exhaust ventilation at high heat production points, while influencing kitchen workers' health and comfort, could simultaneously cause uneven airflow.

The NV from fenestrations and other mechanical means, as evident in Table 8.1, when combined with HVAC systems observed in all the kitchens, creates dilute ventilation and MM ventilation. During summer months, heat and humidity are severe as cold air is not pumped into kitchens lacking air conditioners or diffusers. Although only 11 kitchens had air conditioners, air curtains, ceiling diffusers and or air coolers to assist with temperature control to cool the kitchens and assist in circulating air in noncooking areas, the health and comfort of kitchen workers did not seem to be affected. Cooking areas had an airflow rate ranging from 0.1 m/s to 2 m/s. Even though 54% of the kitchens continued to run the extractor for a short while after the cooking process, 9% reduced the extractor speed.

The opinions of head chefs denote that 11.8% of the kitchens had workers who were discontent with airflow. In addition, 35.3% of the head chefs claimed that staff were always content with airflow. This study observed that the kitchen canopy hoods are wall-mounted or island hoods with a mean airflow rate of 1.77 m/s.

The length of extractors varied from 2.10 m to 14 m, the maximum being observed in a casino complex kitchen; the width of canopy hoods ranged from 0.19 m over a conveyor toaster to 4.22 m for a double island for a ranch-style family restaurant kitchen (Table 8.5).

Kitchens 7 and 31 had a good alignment of a hood with cooking equipment and a hood lip extending beyond the end of cooking equipment with length varying from 2 m to 14 m and width ranging from 0.19 m to 4.22 m. Conversely, some of the overhangs were extremely small, such as 0.06 m because of the Chinese design, with the maximum being 2 m, including the depth of the extractor hood. More than 40% of overhangs were less than 0.06 m, and 12% of overhangs were only 0.10 m long.

Almost 79% of the kitchens had NV incorporated along with mechanical devices and extractors. Five kitchens, namely 3, 7, 14 19 and 13, had a good balance of natural and MV. The principles of hybrid ventilation were well-applied where it combined the best of natural and MV with the combination of large corridors, high ceilings and open doors permitted sea breeze.

These kitchens maintained ambient temperatures of less than 30 °C with a RH of 55%, with extractors assisting during the cooking mode. Carbon dioxide levels measured were less than 600 ppm in all areas of the kitchen.

TABLE 8.5: Extractor sizes of the sampled kitchens.

Extractor measurements (metres)	Mean	Median	*n*	Std. deviation	Minimum	Maximum	Range
Length of extractor hood	4.84	4.55	32	2.46	2.10	14.07	11.97
Width of extractor hood	1.60	1.30	33	0.83	0.19	4.22	4.03
Number of enclosed sides	4.45	5.00	31	0.72	3.00	6.00	3.00
Number and size of grease filters	9.84	8.00	31	6.54	0.00	26.00	26.00
Adequate duct sizes and numbers	1.46	1.00	30	0.79	1.00	4.00	3.00
Canopy overhang	0.60	0.61	30	0.38	0.06	2.00	1.94
Number of HVAC extractors	1.77	2.00	33	0.43	1.00	2.00	1.00

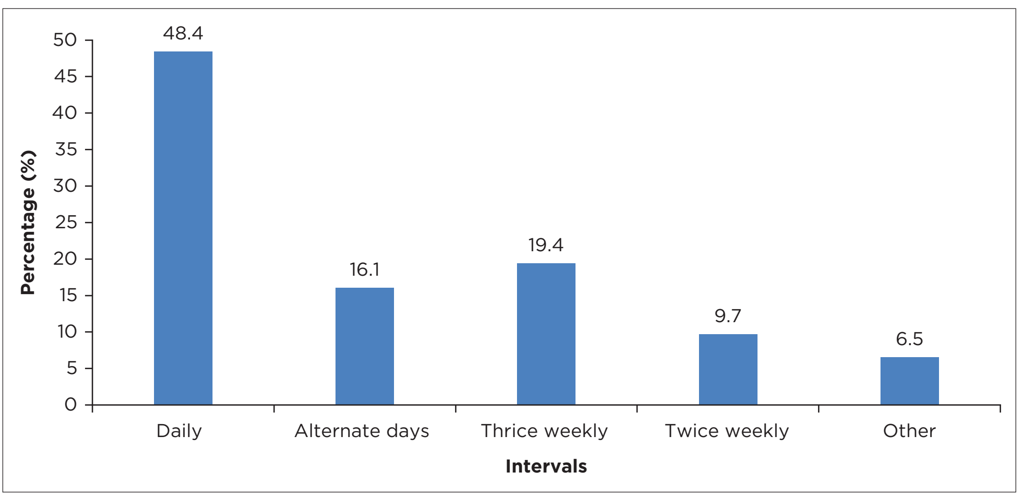
8.3 Air quality

Forty-six per cent of the workers complained about smoke and fumes during rush hour in cooking zones (Figure 8.6). The relationship between kitchen workers' perceptions of ventilation in their kitchen (inadequate or satisfactory) and fondness for Durban weather was substantial (Table A9). Just over 56% of the workers reported that ventilation was inadequate, affecting the air quality negatively. The mean airflow rate measured was between 0.08 m/s and 0.47 m/s in dishwashing areas and corridors, respectively.

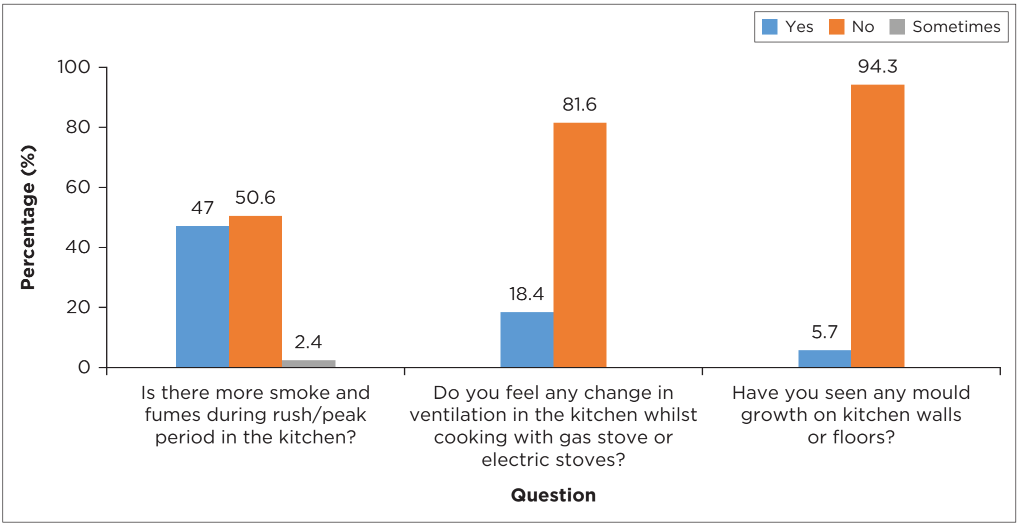
Also, placing layers of 'volcanic rock' on top of traditional gas grills has created harmful emissions, declining air quality, as observed in ranch-style family restaurant kitchens 25 and 26 of the population.

The effect of cooking methods on air quality will be discussed next; carbon dioxide levels indicate air quality and the effect of kitchen loads (fuels) and cooking equipment. Ninety-four per cent of the food-service operations sold fried food, 48% of the kitchens filtered the oil daily, and 13% of the kitchens changed the oil daily. The most common practice observed was to filter oil three times per week and change to fresh oil twice per week (Figure 8.5). It was observed that frying produced a lot of emissions and moisture that could add to the humidity levels, causing stuffiness (Figure 8.4).

Heavy-duty kitchens had the highest CO_2 concentrations near grillers, more than 1000 ppm. Amongst all the different equipment used, gas grillers or char-broilers seemed to generate the most emissions. Six kitchens (13, 20, 23, 24, 25 and 27) had CO_2 levels > 1000 ppm near grillers. The mean differences in CO_2 levels near grillers in medium-duty and heavy-duty kitchens were 170 ppm and 116 ppm, respectively, higher than with stoves (Table 8.6). The kitchens reported 440 ppm to 770 ppm for electric ovens.



Source: Author's own work.
FIGURE 8.5: Frequency of filtering frying pan oil.



Source: Author's own work.

FIGURE 8.6: Kitchen workers' opinion on fumes, gas stoves and moulds.

TABLE 8.6: Cuisine and CO_2 levels (ppm).

Zone	Fusion	Continental	Contemporary	Fast-food	East Asian	Indian	Italian
Preparation (*n* = 33)	544.6	478	527.4	491.5	593.5	760.6	557
Stove (*n* = 31)	807.2	503	738.5	0	875.5	850.6	785.14
Oven (*n* = 21)	644	491	0	465	0	983.25	557.16
Griller (*n* = 14)	1 014	0	920	638.25	0	0	863
Fryer (*n* = 31)	596.66	0	603.5	740.5	514	0	519
Dishwashing (*n* = 33)	509.2	491.5	546	480	580.5	734.4	475.8

Note: '0' indicates the absence of equipment or unused equipment.

The author contends that unsatisfactorily high concentrations of CO_2 inside commercial kitchens are likely to be attributed to blocked filters in a hood or insufficient fresh make-up air being introduced, which is precarious.

Measures of CO_2 levels in this study ranged from 401 ppm to 2 517 ppm in different restaurant kitchens. Seventy per cent of the kitchens were within the ANSI (Petty 2017) and ASHRAE 62 (1989) guidelines of 1000 ppm (Figure A6), whereas 80% of the different kitchen areas had CO_2 levels below 800 ppm (Table 8.7).

Grillers had the highest mean of 996 ppm for CO_2, and corridor areas towards the kitchen had the lowest average value of 506 ppm for CO_2 (Table 8.7). The mean levels of CO_2 in two restaurants (646 ppm and 819 ppm) were < 1000 ppm, and in the other six restaurants (ranging between 1012 ppm and 1820 ppm), it was > 1000 ppm. Kitchen 23 had high CO_2 levels, ranging from 1085 ppm to 1488 ppm, in all areas of the kitchen and a good workflow plan without any consideration for air displacement. Kitchens 11, 17 and 18 had higher CO_2 levels of 899 ppm, 1246 ppm and 1016 ppm because of canopy

TABLE 8.7: Mean CO_2 levels (ppm) in kitchens.

Kitchen zone	Mean	Median	*n*	Std. deviation	Minimum	Maximum	Range	Kitchen 12
Receiving	528.31	481.00	29	203.88	403.00	1 488.00	1 085.00	834
Preparation	562.47	510.50	32	164.70	420.00	1 210.00	790.00	840
Stove	838.39	823.00	31	354.69	432.00	2 155.00	1 723.00	899
Oven	691.60	623.00	30	226.64	435.00	1 229.00	794.00	844
Holding	562.68	502.00	31	153.07	431.00	1 135.00	704.00	852
Dish-washing	557.93	513.00	30	151.86	404.00	1 215.00	811.00	836
Corridor	506.16	465.00	31	133.46	401.00	1 086.00	685.00	753

hoods at greater heights above gas stoves, whereas kitchen 12 had higher levels, as cooking equipment extended beyond the hood length.

Comparison of different variables observed in prior research elicits several similarities to this study. Saha, Guha and Roy (2012) found associations between temperatures across the different kitchens and CO_2 emissions. The temperature varied from 25 °C to 38 °C at a height of 0.6 m from the floor and at 0.1 m from burners. Zones near grillers and gas stoves cook at higher temperatures and produce higher CO_2 levels. CO_2 levels were high (>1000 ppm) near grillers and tandoors in 30% of kitchens, and this could be because of ineffective HVAC systems caused by inadequate extraction and airflow.

Gas stoves could be gradually phased out in favour of induction cookers, which are reported as effective for food preparation, but these were found in only 6% of the kitchens, and these stoves are a new trend to reduce heat in the kitchen. Only two pizzerias had no stoves at all, as cooking required only ovens. Singer, Delp and Zhao (2021) urged the potential benefits of induction cooking appliances to reduce air pollutant emissions as well as other hazards, including burns and cooking-related fires.

Eighty-eight per cent of kitchens adopted no- pressure or low-pressure gas stoves. Gas pressure stoves are popular in authentic Indian kitchens because of their heavy-duty cooking. Wok stoves measured as heavy-duty equipment are gas pressure stoves that cook at temperatures of 315 °C.

More than 90% of the kitchens had an oven. Electric ovens were most used, and 90 l was a popular size installed in nine kitchens; it can generate temperatures of 204 °C to 232 °C. Wood-fired kiln pizza ovens are considered extra-heavy-duty equipment, generating heat of 371 °C, and they are more popular in restaurants, whereas electric pizza ovens are popular in takeaways. Different kitchen zones with varying ventilation loads had fluctuating CO_2 levels (Table 8.7). Besides heat and humidity, emissions from fuels specify kitchen load.

Although the use of biofuels was found to be uncommon, gas grilling was observed in 27% of the kitchens, including 8, 11, 13, 20, 22, 24, 25, 26 and 27; higher emissions of CO_2 were evident amongst heavy-duty load kitchens (Table 8.8). Gas stoves also contributed to increased CO_2 levels in these

TABLE 8.8: Mean CO_2 level (ppm) in kitchens with different heat output.

Areas	Light	Medium	Heavy	Extra-heavy
Receiving	442	481	561	459
Preparation	463	503	571	658
Stove	0	531	1 114	672
Oven	459	476	985	647
Griller	0	678	1 230	0
Fryer	0	535	798	581
Holding	467	620	595	647
Dishwashing	490	482	583	516
Corridor	425	457	543	473

Note: '0' indicates the absence of equipment or unused equipment.

TABLE 8.9: Analysis of variance for CO_2 and independent factors.

Model	Unstandardised coefficients		Standardised coefficients	*t*	Sig.	Collinearity statistics	
	b	Std. error	Beta			Tolerance	VIF
(Constant)	1 422.378	312.890	-	4.546	0.000	-	-
Natural ventilation	−12.068	65.025	−0.036	−0.186	0.855	0.972	1.029
Floor is dry – semi-wet – wet	−359.179	143.352	−0.486	−2.506	0.021	0.972	1.029

Key: Sig., significance; VIF, variance inflation factors.
Note: (1) Dependent variable: CO_2 near stoves DA 102.3. (2) Predictors: (Constant), floor is dry – semi-wet – wet, natural ventilation BC 64.

kitchens' cooking zones. Light-duty load kitchens had the lowest CO_2 levels; however, besides cooking activities, it seems that the presence of CO_2 in the kitchens was affected by the efficiency of extractors, draughts and the layout:

$$Y_{predicted} = b0 + b1 \times 1 \quad \text{[Eqn 8.1]}$$

The column of estimates provides the values for b0, b1 and b2 for this equation:

$$CO_2 \text{ near stoves} = 1422.37 + (-359.179 \times \text{floor is dry}) \quad \text{[Eqn 8.2]}$$

Natural ventilation: the coefficient for NV is −12.068. So for every unit increase in NV, a −12.068 unit decrease in CO_2 near the stove area value is predicted, holding all other variables constant (Table 8.9). All the kitchens under study have dry kitchens. Higher humidity levels in kitchens will hinder the drying of wet floors. Less use of gas as fuel means less CO_2 release and less humidity in kitchens.

Therefore, the wet floors will dry faster. Similarly, for every unit increase in dry floor, one can expect a 359.179 unit decrease in CO_2 near stove areas, holding all other variables constant. The best-fitting model for predicting humidity near stoves is a linear combination of 'floor is dry or wet'.

8.4 Humidity

More than 10% of head chefs felt that kitchens are humid, and 15% felt that it is sweaty in the kitchen. The mean RH values, ideally lower than 60%, could be because of the field study's weather conditions, cuisine and time period. Boiling food was unobserved in almost 45% of kitchens. Humidity is discussed under how humidity is affected by cuisine, humidity near stoves affected by worker characteristics, maintaining humidity levels in the kitchen, the effect of fuels and equipment on humidity, kitchen humidity and mould, and coping with humidity and heat by kitchen workers.

Humidity can have a profound effect on how food cooks. Relative humidity levels varied widely in the kitchens. Cooking areas with stoves had the highest mean value, as well as the highest minimum value, followed by the dishwashing areas. However, ovens produced higher maximum humidity values compared with stoves and dishwashing (Table 8.10). Several close associations were established between the type of food service, cuisine and kitchen load with chi-square tests (Table A7).

The amount of moisture released in cooking will vary, dependent on the type of food, whether the food is covered while cooking and the length and temperature of cooking.

$$Y_{predicted} = b0 + b1 \times 1 + b2 \times 2 \qquad \text{[Eqn 8.3]}$$

Humidity near stoves = 92.09 + (1.208 × shift) + (−0.161 × height of chef)

Cross-tabulation amongst nominal variables from the interview schedule and observation checklist revealed that RH, which is a dependent (outcome or response) variable experienced around stoves, was affected by the height of the chef and shift work, which are independent variables (predictors). The best-fitting model for predicting humidity near stoves is a linear combination of 'worker shift' and 'height of chefs' (Table 8.12).

More than 86.0% of kitchen workers in the sample were < 1.68 m tall, and almost 52.5% of kitchen workers were < 1.60 m tall. It seems that shorter chefs than taller chefs experience higher humidity; this is because a short chef is closer to the stove height.

TABLE 8.10: Humidity levels in kitchen zones.

Kitchen zones	Mean	Median	*n*	s.d.	Minimum	Maximum	Range
Receiving area	55.67	57.05	30	8.39	38.00	74.40	36.40
Preparation area	55.43	56.90	32	10.16	32.40	77.00	44.60
Stove	57.48	58.50	32	8.27	39.80	74.10	34.30
Oven	56.63	55.60	31	11.70	32.00	89.50	57.50
Holding area	55.33	55.50	33	8.79	34.60	74.10	39.50
Dish-washing area	57.02	57.80	33	8.75	33.40	75.50	42.10
Corridor	53.64	57.00	33	8.31	31.80	64.20	32.40

TABLE 8.11: Humidity near stoves is affected by worker shift and their height.

Model	Unstandardised coefficients		Standardised coefficients	*t*	Sig.	Collinearity statistics	
	b	**Std. error**	**Beta**			**Tolerance**	**VIF**
(Constant)	87.560	13.053	-	6.708	0.000	-	-
Height of worker A5	−0.201	0.072	−0.242	−2.784	0.006	0.724	1.382
Worker shift A13	1.165	0.464	0.186	2.509	0.013	0.993	1.007
Gender A3	−0.365	1.410	−0.023	−0.259	0.796	0.713	1.403
Race A4	0.634	1.024	0.046	0.620	0.536	0.976	1.025

Key: Sig., significance; VIF, variance inflation factors.
Note: (1) Dependent variable: humidity near stoves (DA 91.3). (2) Predictors: (Constant), shift, height.

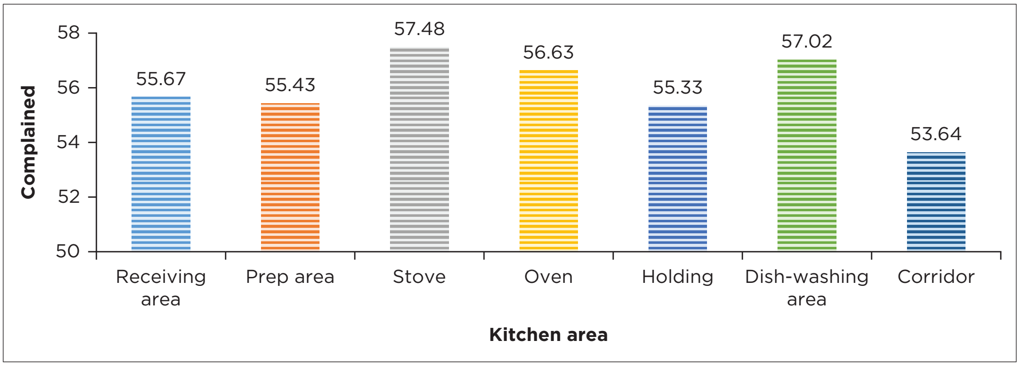
TABLE 8.12: Humidity near stoves.

Model	Unstandardised coefficients		Standardised coefficients	*t*	Sig.	Collinearity statistics	
	b	**Std. error**	**Beta**			**Tolerance**	**VIF**
(Constant)	35.067	8.186	-	4.284	0.001	-	-
Humidity near ovens	0.327	0.059	0.491	5.542	0.000	0.233	4.284
Humidity in corridor	0.243	0.089	0.242	2.744	0.017	0.235	4.255
Waiting period to repair or replace any malfunctioning equipment	2.186	0.339	0.432	6.451	0.000	0.408	2.452
Air conditioner	−2.888	0.944	−0.228	−3.061	0.009	0.330	3.033
Domestic fans	−3.614	0.771	−0.395	−4.685	0.000	0.257	3.891
Industrial fans	−0.333	0.393	−0.044	−0.848	0.412	0.679	1.473
Heavy sweating	−8.908	1.335	−0.460	−6.670	0.000	0.384	2.604
The staff complained about humidity in the kitchen	0.800	0.369	0.127	2.167	0.049	0.534	1.874
Headache	−3.987	1.770	−0.155	−2.253	0.042	0.389	2.573
Intense thirst	4.994	1.330	0.311	3.754	0.002	0.267	3.751
Irrational behaviour	−9.181	2.141	−0.296	−4.289	0.001	0.384	2.603
Work experience	−3.529	0.638	−0.300	−5.533	0.000	0.623	1.605
Race	−0.876	0.201	−0.277	−4.361	0.001	0.454	2.202
Heat in kitchen during peak hours	1.645	0.669	0.134	2.458	0.029	0.619	1.616
Gender	6.617	2.068	0.213	3.199	0.007	0.412	2.429
Decrease of motivation	7.722	2.194	0.249	3.520	0.004	0.366	2.733

Key: Sig., significance; VIF, variance inflation factors.
Note: (1) Dependent variable: humidity near stoves.

Highest mean RH values of 59.28% and 58.62% were obtained in cooking areas near gas grillers and gas stoves, with trimmed mean values of 52.37% and 51.30%, respectively. These values agree with Li et al.'s (2012) mean values varying from 45.8% to 68.4%.

Mould growth was observed in more than 5% of the kitchens because of excessive humidity and wet floors near dishwashing areas. Fifty-one percent (51%) of kitchens had 60% or more humidity levels in one or other kitchen zones but not in all the areas (Figure 8.7). Humidity was high enough to encourage mould growth on kitchen walls and floors in 5.7% of kitchens (Figure 8.6). However, moisture extraction through HVAC and provision for NV helped to reduce humidity.



Source: Author's own work.

FIGURE 8.7: Mean humidity levels in sample kitchens.

Twelve per cent of the kitchen managers in kitchens agreed that ventilation is insufficient to maintain optimal humidity levels and good air quality.

Increased RH levels increase thermal strain, specifically in cooking and dishwashing areas. The lowest RH mean values were recorded in corridors because of the air conditioners in restaurants. Data on the humidity in passageways to kitchens or corridors leading from the dining rooms to the kitchen are scarce. Corridors have a mean RH of 52.30%, even though RH levels ranged from 32% to 74.4%; the high value is because of rain during the field study. Nearly 52% of the kitchen managers claimed that, regarding humidity, staff complained about sweat not drying (30.3%), uniforms being wet (12.1%), and stickiness (6.0%) (Table 8.14).

A long mathematical model (Table 8.12) consisting of several variables, including race (ethnicity), mechanical devices for ventilation, and physiological and psychological symptoms of heat stress is obtained.

The following is the equation used:

$$Y = b0 + b1 \times 1 + b2 \times 2 + b3 \times 3 + b4 \times 4 + b5 \times 5 + b6 \times 6 + b7 \times 7 + b8 \times 8 + b9 \times 9 + b10 \times 10 + b11 \times 11 + b12 \times 12 + b13 \times 13 + b14 \times 14 + b15 \times 15 \quad \text{[Eqn 8.4]}$$

Humidity near stove = 35.067 + (0.327 × humidity near oven) + (0.243 × humidity in corridor) + (2.186 × waiting period to repair equipment) + (−2.888 × number of air conditioners in kitchen) + (−3.614 × number of domestic fans) + (−8.908 × heavy sweating) + (0.800 × staff complain about humidity) + (−3.987 × headache) + (4.994 × intense thirst) + (−9.181 × irrational behaviour) + (−3.529 × work experience) + (−0.876 × race) + (1.645 × heat in kitchen during peak hours) + (6.617 × gender) + (7.722 × decrease of motivation).

[Eqn 8.5]

The heat around stoves had a positive relationship with the presence of ovens and dishwashers in the kitchens. The heat from ovens and dishwashers contributes to the kitchen's temperature increase.

The most common physical symptom of heat in kitchens was heavy sweating. Psychological symptoms displayed included the use of foul language, and there was strong evidence to conclude that the variables are associated. The use of foul language has a positive relationship with heat near stoves.

The variables 'staff complaints (Table 8.13) about kitchen humidity' and 'heat near stoves' are strongly associated.

All kitchens have cooling devices, in addition to extractors, to reduce humid heat in kitchens. Section 8.2 and Table 8.14 discuss cooling devices. Kitchen workers and head chefs follow several interventions to cope with humidity. Tables 8.13 and 8.14 indicate that significantly more respondents reported fewer air conditioners and industrial fans. A strong correlation is indicated with $p = 0.040$, significant between kitchen workers' perceptions of ventilation in their kitchens being either inadequate or satisfactory and using an air conditioner in their residence. The cooling behaviour, such as using an air conditioner at home after work, is likely to help staff cool off and come to work well-rested, as discussed in Section 7.4.

Head chefs and kitchen managers claimed to have the extractors cleaned (44%) to reduce humidity in kitchens, whereas 41% declared humidity was not a problem (Table 8.15). Almost 30% of kitchen managers opened windows and doors and 35.3% installed fans to cope with humidity.

Kitchen workers stand near the air conditioner or fan, step out of the kitchen, move to the back door where airflow helps cope with stuffiness and heat or take a short break. The most common behavioural adaptation by workers was to drink cold liquid (94%), followed by the use of fans and air conditioners by kitchen workers (Table 8.16). Thirty-five percent (35%) of head chefs reported

TABLE 8.13: Staff complaints on kitchen humidity.

Complaints	Frequency	Percentage (%)	Validation percentage (%)	Cumulative percentage (%)
No complaints	17	51.5	51.5	51.5
Sweat not drying	10	30.3	30.3	30.3
Stickiness	4	12.1	12.1	85.3
Uniform is wet	2	6.0	6.0	100.0
Total	**33**	**99.9**	**99.9**	**-**

TABLE 8.14: Cooling devices in the kitchen.

Cooling device	Mean	Median	Std. deviation	Minimum	Maximum	*p*-value
Air conditioner	1.45	1.00	0.934	1	4	0.017
Domestic fans	1.55	1.00	0.688	1	3	0.078
Industrial fans	1.92	1.00	1.165	1	4	0.045

TABLE 8.15: Interventions to reduce humidity.

Head chef's intervention	Percentage (%)
No problem with humidity	41.2
Clean extractor	44.1
Open windows and doors	29.4
Install fan	35.3
Other	17.6

TABLE 8.16: Behavioural adaptation to cope with humidity and heat.

Coping strategy	Percentage (%)
Drink cold liquid	94.1
Step outside	8.8
Take a short break	35.3
Sit under a fan	14.7
Other	17.6

that workers took a short break or stepped outside to get respite from the heat (8.8%). Forty-seven percent (47%) of head chefs strongly agreed that work experience played a strong role in coping with heat, followed by race (37.5%). Fitness and body weight were also considered important to 20.6% and 14.7% of head chefs, respectively. Other strategies used by kitchen workers included going towards a cooler, sitting in the chiller, placing their heads inside the chiller, keeping the back door open and pouring water on their heads.

Other behavioural modifications included cooking on back burners, as all range hoods are much more effective when cooking occurs on back burners, and they increase the removal of cooking emissions as well; hence, they should always be used first, effectively reducing humidity (Singer et al. 2021).

8.5 Maintenance of kitchen equipment

Good maintenance standards of clean cooking equipment, such as clean ovens, gas stoves, burner ports, grillers and kilns, benefit air quality in the kitchens. This section will cover why regular upkeep of kitchen equipment is important.

Kitchen equipment such as ovens, stoves and cookers need regular maintenance. It is observed that 31 kitchens had stoves in good repair, but only 24% were maintained clean as was mandatory; 12% of equipment was only somewhat satisfactory. Just over 29% of the ovens and cookers were clean and 12.5% of the kitchens had a somewhat satisfactory report. A minor proportion (5.3%) of kitchens had equipment producing soot, as grillers and ovens were soiled and scheduled for clean-up. However, almost 58% of the kitchens had equipment that did not produce soot from burning spills or unclean equipment. Sixty-eight per cent of head chefs concurred that the equipment was in good repair at most times.

The correlation between all kitchen equipment installed as per specification and all equipment in good repair was significant. These two variables were positively correlated. More than 90% of the head chefs stated that all kitchen equipment was installed as per specifications.

Nearly 24% cleaned extractors once a month, a common feature amongst franchise food services. However, one kitchen cleaned extractors once a year, perhaps because of light use and low-volume cooking. Another two kitchens claimed that cleaning was weekly because of heavy use. Only 15% of the kitchens had HVAC cleaned quarterly, while 51% of the kitchens had HVAC cleaned biannually.

Almost 30% of head chefs and kitchen managers agreed that the electrical and mechanical equipment that malfunctioned was serviced within 24 h; 73.5% reported that all electrical and mechanical equipment was serviced once a week. A minority of respondents (8.8%) complained that equipment was serviced only when there was a malfunction or breakdown. Food-service workers believed that the maintenance of lighting was adequate.

A noteworthy correlation between adjusting oscillating fans and clean oscillating fans was established. Kitchen workers had access to clean fans. Another significant correlation between 'all the kitchen equipment is in good repair' and 'work experience' was proven. Thirty-eight per cent of kitchen managers strongly agreed that all the kitchen equipment was in good repair. About 68% of head chefs agreed that all the kitchen equipment was in good repair most of the time. Moreover, 89% of the workers felt that the kitchen equipment was in good repair. Respondents also stated that 76% of the gas stoves and 70.6% of the ovens were in good repair.

8.6 Conclusion

In conclusion, Chapter 8 indicated that reduced airflow accompanied by elevated temperatures and higher humidity levels is causing thermal discomfort. The use of NV induced by cross-ventilation between building fenestration supplemented by MV is endorsed in this study for the well-being of workers. Induction heating and electric equipment have lower emissions and lower cooking temperatures when compared with other equipment. Monitoring of cooking oil will help to reduce emissions in kitchens. Perforated perimeter supply for high heat-producing equipment will comfort kitchen workers. Higher ventilation rates will reduce humidity and discomfort in the kitchen. The next chapter discusses data analysis of the next parameter of kitchen ergonomics, namely noise.

Chapter 9

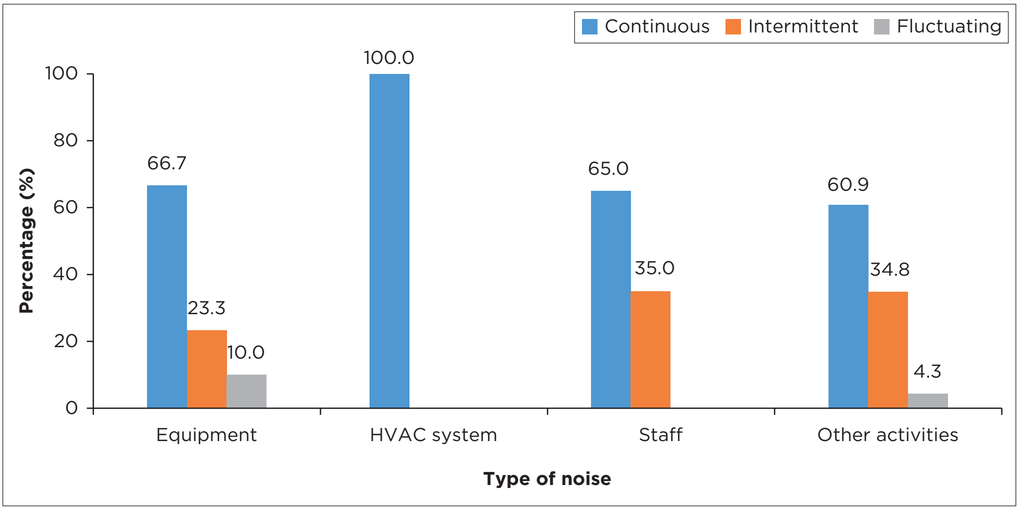
Data presentation, analysis and discussion: Noise in kitchens

9.1 Noise levels in kitchens

This chapter presents an analysis of data on noise in kitchens obtained from the interview schedule, questionnaires and observation checklist. Data from the primary areas for presentation in this chapter are noise from kitchen activities, equipment and extractors and kitchen maintenance. Also, source and type of noise, cooking activity noise, noise from equipment and grading or rating of equipment noise are discussed.

It is estimated that the drone of extractors is continuous noise (100%), whereas the cooking equipment noises are continuous, intermittent and fluctuating (Figure 9.1). Whistling of equipment such as boilers and pressure cookers is fluctuating noise (10%), whereas the noise from blenders, grinders, ice crushers and potato peelers is intermittent. Staff tend to talk over the kitchen noise and add to the clamour, including the head chef, kitchen manager, owner, kitchen workers, suppliers, takeaway delivery boys and visitors. Other activities included vacuum-cleaning, polishing floors, moving equipment, swinging doors, stacking stock, repairs in the kitchen and the sounds of telephones and radios.

How to cite: Gangiah, S 2022, 'Data presentation, analysis and discussion: Noise in kitchens', in *Environmental ergonomics Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town, pp. 205–219. https://doi.org/10.4102/aosis.2022.BK346.09



Source: Author's own work.
FIGURE 9.1: Types of noise in kitchens.

Noise from equipment generated because of food production activities adds to the noise in the kitchen. The preparation area in three kitchens has high noise levels > 80 dBA because of potato peelers and the salad dryer. The ringing of orders was recorded at 82.5 dBA in the holding area. The mean values in different areas of kitchens range from 43.2 dBA to 76.35 dBA (Table 9.1).

Per SANS 10 103 (SABS 2008), 55 dBA is the recommended maximum equivalent continuous rating level for ambient noise in kitchens, dissimilar to the higher noise levels in the review of empirical literature.

The collective activities in food preparation and cooking areas are observed in the current study to produce excessive noise levels. The mean noise level in the preparation areas is 71.47 dBA (Table 9.1). The mean noise levels from stoves in cooking areas ranged from 53.20 dBA to 75.26 dBA. Fryers and grillers recorded mean noise levels of 68.19 dbA and 53.20 dbA, respectively.

From Table 9.2, it can be deduced that the noise levels in the receiving areas are similar in all types of cuisine, as it is determined by the supplier communication as well. The Indian cuisine kitchens have louder noise levels in preparation areas because of the style of cooking, as indicated in Table 9.3. Wok cooking in Chinese or Thai cooking causes noise levels higher than 84 dBA.

More than 58% of institutional kitchens have dishwashing facilities, reducing the clanging of dishes, although dishwashing machines also add to the noise in kitchens. Almost 43% of quick-service restaurants and 15% of casual restaurant kitchens have dishwashing machines. Casual restaurants have higher noise levels of 76 dBA, with levels of 105 dBA in locally-owned casual restaurants.

TABLE 9.1: Mean noise levels (dBA) in kitchens.

Areas	Mean	Median	*n*	Std. deviation	Minimum	Maximum	Range
Receiving	70.84	68.00	31	17.79	59.00	124.50	85.50
Preparation	71.47	71.00	32	8.59	59.00	96.00	37.00
Stove	75.53	76.00	29	4.79	64.00	85.50	21.50
Oven	73.00	72.20	29	4.16	65.00	80.00	15.00
Holding	71.53	71.00	33	3.88	64.00	80.80	16.80
Dish-washing	75.96	78.00	32	5.38	65.00	83.30	18.30
Corridor	67.24	67.00	31	4.48	50.60	75.40	24.80
Outside	63.20	63.25	30	4.44	55.00	79.00	24.00

TABLE 9.2: Kitchen noise levels (dBA) and cuisines.

Kitchen areas	Fusion	Continental	Contemporary	Fast-food	East Asian	Indian	Italian
Receiving	69.14	69.55	67.13	67.01	62	66.96	66.96
Prep area	72.7	68.5	70.35	70.71	65	74.85	70.35
Stove	72.16	74.85	71	73	84.75	60.95	60.95
Oven, pizza, tandoor	71	64	70	80	0	69.63	47.43
Holding	67.94	73.45	75.26	70.28	65	70.38	70.38
Dish-washing	79.94	81.55	76.1	78	76.2	78.35	78.35
Corridor	65	55.3	68.38	70.91	70.3	65.97	65.97
Fryer	75	60.5	71.6	69.4	62.65	63.5	61
Griller	78	71.5	71.05	70	0	0	0

TABLE 9.3: Noise levels in authentic Indian kitchens.

Kitchen area	Noise levels (dBA)
Preparation area	65–96
HVAC	73–83.5
Stove	80
Fryer	80
Pressure cooker whistling	81

The empirical data illustrates that the HVAC extractor system in almost all kitchens produces a continuous noise that drowns other noises in the kitchen (Figure 9.1). It seemed that most staff have become acclimatised to the resultant hum and tend to talk louder to be heard over this noise. Consistent with their cultural practice, a larger number of staff members are loud talkers (Venter 2015). Most kitchens released more noise during the service period, when customers were present. The kitchens with authentic Indian cuisine had maximum noise during preparation time, attributable to pressure-cooking and grinding spices.

Table 9.3 specifically conveys that the highest noise level in preparation areas was from a crusher making a puree of tomato and onion. The noise was intermittent, with high and low peaks. Regarding HVAC, an extractor is loud because of the sound reflected from a metal roof. Pressure gas stoves add to the din, followed by crackling noise from the frying of food. It seems whistling from pressure-cooking of lentils is a common feature of Indian cuisine.

To elicit information on consequences of noisiness, I set out to determine whether worker age, gender and race influence reactions to noise emitted from stoves. The effect of partial eta-squared (η2) is summarised in Table 9.4 as follows: 0.02 – small effect, 0.06 – medium effect and 0.12 – large effect.

The results in Table 9.4 indicate that while reaction to stove noise is affected mildly by the age of the worker and their race, a moderate effect is observed in the gender of the kitchen worker. The reactions to stove noise seem to vary widely between men and women.

The kitchens emitted noise levels ranging from 64 dBA to 85.5 dBA, with higher values from gas stoves and lower values from electric stoves. This implies that food-service workers may suffer from NIHL, as the permissible noise exposure level, according to WHO, is 80 dBA.

Using EFA, item 34.1 in the questionnaire reveals a factor loading of 0.761, 0.883, 0.897 and 0.761 for ovens, boilers and steamers, gas stoves and fryers, respectively, and is categorised into Component 1 (noise index). This kitchen equipment was ranked according to the mean level of noise produced during food production. These variables load perfectly into a single component. A longitudinal study will elicit the effects of the noise measured in kitchens. The association of the high loadings of ovens, broilers, steamers, gas stoves and fryers could imply that the kitchen workers are constantly exposed to high noise levels.

A chi-square test of independence was performed to examine the relationship between different cooking equipment noise and their rankings in terms of maximum noise. As the *p*-value is larger than the significance level of 0.05, there is not enough evidence to conclude that the variables are associated.

The chi-squared test, as indicated in Table 9.6, tests how likely it is that the observed distribution is because of chance. Called a 'goodness-of-fit' statistic,

TABLE 9.4: Factors affected by noise from stoves.

Source	Type III sum of squares	Dependent variable		*f*	Sig.	Partial eta-squared (η2)
		dF	Mean square			
Q32.1	14.180	1	14.180	0.830	0.371	0.033
Q32.2	38.446	1	38.446	2.252	0.147	0.086
Q32.3	3.101	1	3.101	0.182	0.674	0.008

TABLE 9.5: Component matrix for noise from cooking equipment.

Cooking equipment	Noise index
Ovens	0.761
Boilers and steamers	0.883
Gas stoves	0.897
Fryers	0.761

Note: Extraction method: principal component analysis. One component extracted.

TABLE 9.6: Chi-square between stoves and noise in kitchens.

Cooking equipment	Chi-square	dF	Asymp. sig.	Exact sig.	Point probability
Ovens, *n* = 29	5	5	0.416	0.474	0.00
Boilers and steamers, *n* = 20	3.4	5	0.639	0.701	0.099
Gas stoves, *n* = 29	6.421	6	0.378	0.420	0.079
Fryers, *n* = 29	14.69	6	0.023	0.023	0.003

TABLE 9.7: Component matrix for dishwashers.

Dishwashing machine – noise and heat	Component 1
	Discomfort factor
Dishwashing machine producing noise	0.877
Dishwashing machine producing heat	0.877

Note: Extraction method: principal component analysis. One component extracted.

it measures how well the observed distribution of data fits with the distribution that is expected if the variables are independent, with significance levels equal to any value between 0 and 1.

The different pieces of cooking equipment produce diverse noise levels and do not influence each other. The number and size of equipment is wide-ranging, and the frequency of use is diverse in preparing different cuisines. Hence, it seems variations in noise levels are expected. The variable differences in noise levels from cooking equipment help to customise noise reduction plans in different kitchen zones to compose indoor environmental criteria for the design of restaurant kitchens in Durban with respect to noise.

Noise within dishwashing areas in this study is highest, with a mean level of 76.35 dBA; it is much lower than the 82.5 dBA in Lao et al. (2013) and Achutan (2009), where the mean value ranges between 72 dBA and 81 dBA. Using EFA, items reveal a factor loading of 0.877 and 0.877 for dishwashing machines producing noise and heat, respectively, and are categorised into Component 1 (discomfort factor).

Only 36.4% of the kitchens have dishwashing machines, and 33.3% of kitchen personnel are dissatisfied with dishwasher heat and noise. It seems noise from dishwashing machines can add to the din in the kitchen and distort hearing ability.

More than 66% of the dishwashing machines are inside the noise comfort range of 70 dBA, as asserted by Fox (2019), although Goldsmith (2013) only allocated a low noise level of 50 dBA for a domestic dishwasher. The noise of the wash cycle is perceptible in 17% of the kitchens. The noise levels ranged from 65 dBA to 79.8 dBA. However, no workers are exposed to noise above the OSHA PEL of 90 dBA, but dish-washing staff are exposed to noise levels > 85 dBA in high-volume restaurants. The author has observed that kitchen equipment and machinery like dishwashers vibrate and contribute to structure-borne noise.

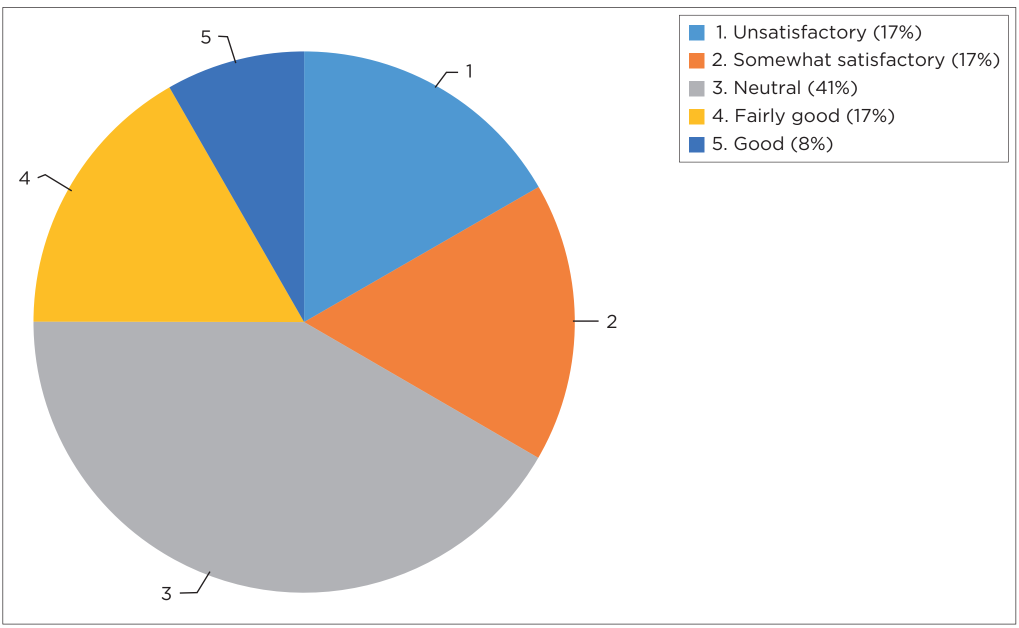
The noise from extractor systems varies from 70 dBA to 83 dBA. Specifically, the item in the questionnaire indicated in the rotated matrix component is 'staff complain about extractor making too much noise'.

Equipment noise levels subjectively ranked by head chefs and kitchen managers in Figure 9.3 indicates ranking by percentage. Whereas old air conditioners in a kitchen produced noise, environmental systems air conditioners in other kitchens demonstrated low mean noise emission.

Refrigerators in the kitchens had noise levels ranging from 64.5 dBA to 75 dBA, while 73 dBA was the mean noise level for freezers. The noise from grinders and blenders, despite its loudness, is mitigated by noncontinuous usage and only for short periods. Fans in convection ovens made noise upon switching to air circulation.

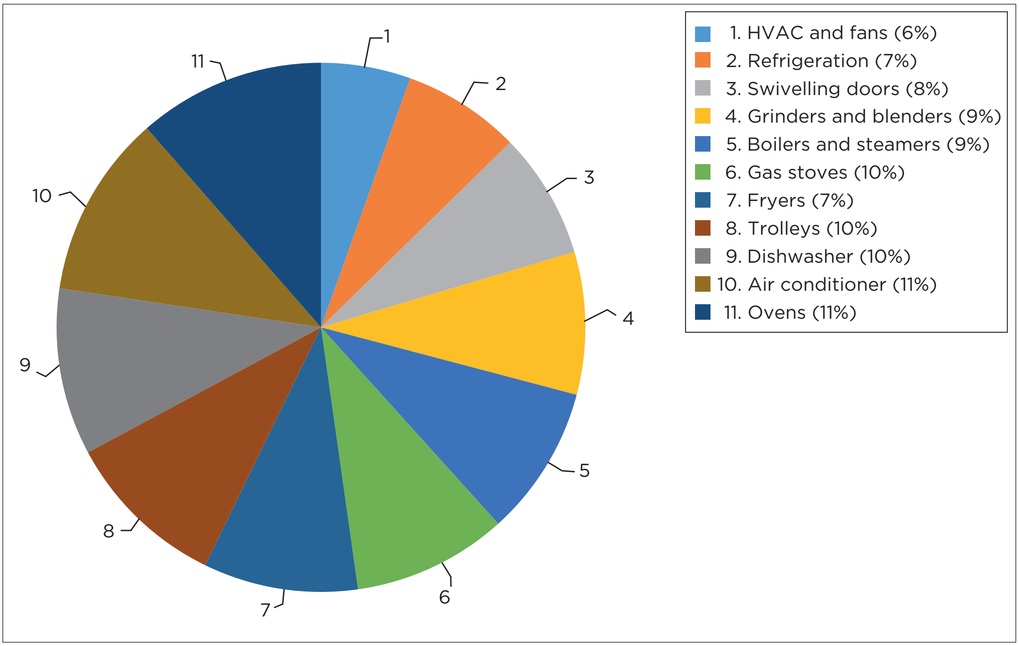
There is a need for a model that accounts for the variables that may affect noise ratings. Table A8 indicates weighted mean scores for equipment, from most to least noisy. About 10% of the head chefs subjectively ranked gas stoves, boilers and steamers (10%) as the notable sources of noise in kitchens, followed by ovens (6.3%) and fryers (3.4%). Notably, in 51% of kitchens, the noise from extractors is > 40 dBA, although all the head chefs claimed that extractors were fitted with fan silencers. A chi-square test indicates that the variables are associated.

This section will accordingly account for the findings of the effect of noise on kitchen personnel and elaborate on the variation with current outcomes and the implications on managing kitchen noise.



Source: Author's own work.

FIGURE 9.2: Researcher's opinion on dishwasher noise.



Source: Author's own work.

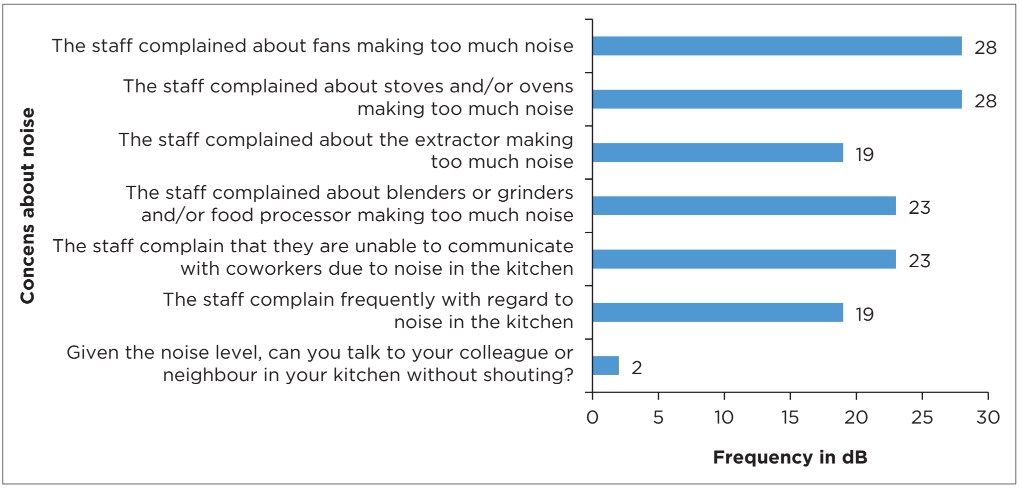
FIGURE 9.3: Common fitment and equipment noise rating.

9.2 Effect of noise exposure

Kitchen workers are especially exposed to high noise levels in catering (Carayanni et al. 2011). The work of Wong et al. (2011) is primarily because of the noise generated by cooking activities. While workers are vulnerable to noise exposure, they accept it as part of their occupational risk. Nonetheless, over 45% of the staff felt that noise was not a problem in their kitchen. This reflects their resistance to noise levels and not vulnerability. The interviews revealed that 11.5% of the workers thought it was a problem, and they could be prone to hearing loss. Similar results are obtained internationally.

The workers' opinion on sound levels in the kitchen is associated with the effect of noise exposure. The kitchen workers spoke louder over the din but were confident that NIHL did not occur in their kitchens. Nonetheless, a small proportion of kitchen workers (11.5%) responded that the noise levels at their workplace may affect their hearing; previously, only 3% of people were aware of it. Forty-seven percent (47%) of the kitchen managers responded that the kitchens experienced no noise-induced problems. They expected operating kitchens to be unavoidably noisy but tolerable. When the noise became louder, the coping behaviour was to switch off the offending equipment until it was needed.

The kitchen managers' opinions are important, as they are key to effecting measures that generate comfortable noise levels. The subjective response



Source: Author's own work.

FIGURE 9.4: Kitchen managers' opinion about noise.

indicates that only two of head chefs believed that with higher noise levels in kitchens, it is not possible to talk to colleagues without shouting. Practically 85% of head chefs sensed that kitchen workers complained about stoves and fans making too much noise. Twenty-three felt that blenders and grinders made noise and workers were unable to communicate with colleagues, although 19 agreed that staff complained about extractor noise as well.

The subjective judgement of surveyed staff revealed complaints about blenders, grinders and food processors making too much noise; objective measures found noise to be closely associated with the preparation area (cross-tabulation of interview schedule). As $p = 0.009$, there is strong evidence to conclude that the variables are associated, with higher noise leading to complaints (Table A9).

Nearly 35.3% of kitchen workers responded that they must raise their voices to talk to a colleague 1m away. Using EFA (Table 9.8), the items 43.6, 43.8 and 43.9 from the questionnaire reveal a factor loading of 0.621, 0.710 and 0.850 for complaints about noise in the kitchen, noise from grinders and noise from the extractor, respectively, and they are categorised into Component 2 (uneasiness factor) (Table 9.8).

The possible repercussions of high factor loading of noise in the kitchen, noise from grinders and noise from the extractor on worker complaints of equipment noise include the inability to communicate with other staff and consequently talking louder to them, adding to the din. The questionnaire further revealed that the level of noise from the operating extractors is ≥ 65 dBA in most kitchens, while in four kitchens it is noticeably higher (75 dBA) because of improper maintenance. Table 9.8 reveals a factor loading of 0.612, 0.917 and 0.900 for unable to communicate, grinders making too much noise

TABLE 9.8: Rotated component matrix: Noise complaints from kitchen workers.

Rotated component matrix[a]	1 Discomfort element	2 Uneasiness factor
The staff complained frequently with regard to noise in the kitchen	0.360	0.621
The staff complained that they are unable to communicate with co-workers because of noise in the kitchen	0.612	0.530
The staff complained about blenders or grinders and/or food processor making too much noise	0.328	0.710
The staff complained about the extractor making too much noise	0.105	0.850
The staff complained about stoves and/or ovens making too much noise	0.917	0.236
The staff complained about fans making too much noise	0.900	0.217

Note: Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalisation.
a. Rotation converged in five iterations.

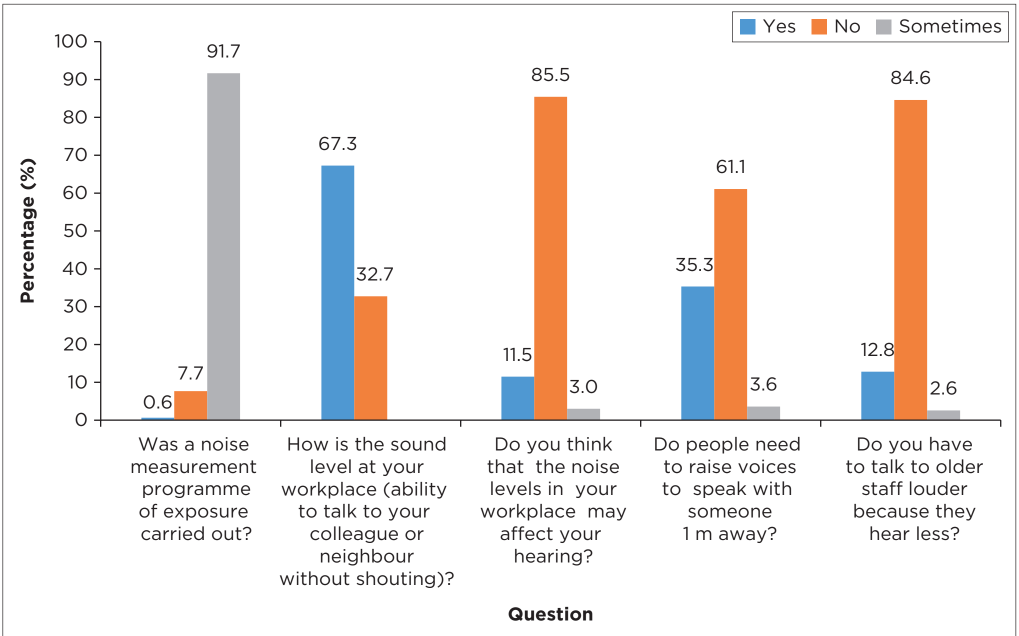
and noise from fans, respectively, and it is categorised into Component 1 (discomfort element).

Figure 9.5 accordingly illustrates that communication is difficult for at least 32.7% of the respondents, who must talk louder to their colleagues to be heard, and 35.5% of workers have to raise their voices to talk to their colleagues who are just 1 m away. It is suggested that a consequence of poor audibility in kitchens can fill the kitchen with excessive noise, causing delays and errors and ineffective emergency decisions. Cross-tabulation of the interview schedule reveals that 'staff complained that they are unable to communicate with co-workers because of noise in the kitchen' has a p = 0.504 and chi-square statistic of 31.29, with a significance level of 0.002 with 'staff complaining frequently about noise in the kitchen'. In contrast, the kitchen workers continue to talk loudly even when not required because of their cultural habits, yet the interview respondents complain that noise levels are high in the kitchen.

A strong negative correlation (p = −0.894) is seen between noise from air conditioners and noise from the HVAC system, with a significance level of 0.041. This means that both air conditioners and HVAC systems need not be noisier in any kitchen, making it easier to manage kitchen noise emissions. 'The staff complain about the extractor making too much noise' correlates with 'staff complain frequently regarding noise in the kitchen'.

Natural adaptation to noise will be discussed next. The aforementioned effect of noise on the kitchen worker has been eased by natural and artificial adaptations.

However, head chefs and kitchen managers agreed, per Table 9.9, that there are several natural and acclimatisation factors that shape the workers' ability to cope with noise levels in the kitchen. The average age of the kitchen workers is 31.28 years, with a SD of 8.56 years (Table 9.10). Head chefs and kitchen managers (38.2%) contended that age is the chief natural factor in adapting to noise in kitchens (Table 9.9). The findings disclosed that 12.8% of



Source: Author's own work.

FIGURE 9.5: Workers' experience of kitchen noise.

TABLE 9.9: Managers' opinion on adaptation to noise.

Factors	Percentage (%)
Age	38.2
Gender	5.9
Race	20.6
Work experience in kitchen	41.2
Work activity	11.8
Other	11.8

TABLE 9.10: Age of kitchen staff in the sample.

Kitchen staff	*n*	Minimum	Maximum	Mean	Std. deviation
Kitchen workers	170	19	62	31.28	8.557
Head chefs or kitchen managers	33	23	49	34.68	6.545

the kitchen workers believed that they must talk louder to older staff as they hear less. A further 2.6% of the respondents talked louder to older staff sometimes. Age is a significant possible cofactor of NIHL, as elaborated in Section in 4.4.

According to Table 9.10, the mean age of head chefs is 34.68 years with a SD of 6.545. Within the age category of 30–39-years-old, 77.8% are male. Within the category of males (only), 66.7% are between 30–39-years-old. This category of males between the ages of 30 and 39 years forms 41.2% of the total sample who can adapt to noise.

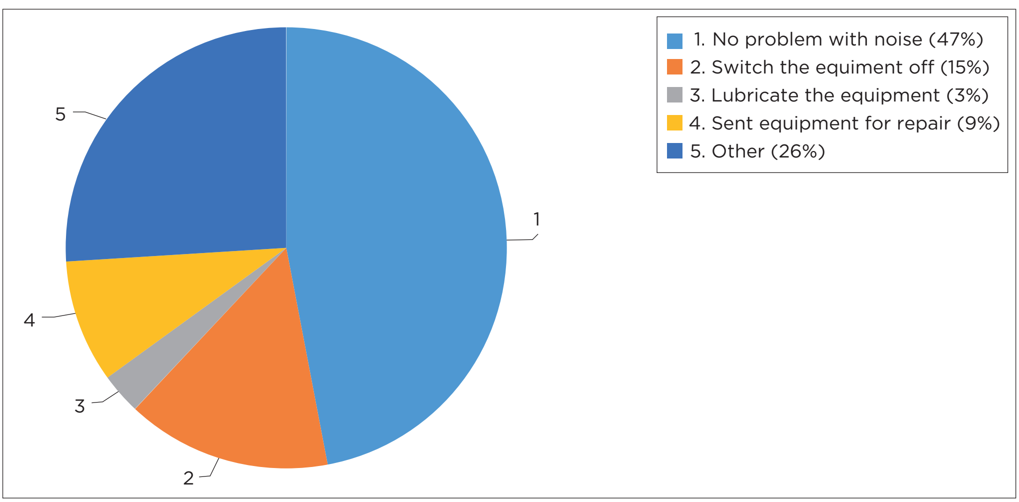
Almost 6% of the head chefs believe that gender affects adaptation to noise in kitchens. Kitchen workers are predominantly female, making up almost 64% of the food-service workers. Observation reveals that women are less sensitive to sound. This could also be because of the ethnicity factor. Nearly 21% of the head chefs assume that race is an important factor in adaptation to noise.

9.3 Kitchen noise reduction strategy

It is necessary to determine the cause of the noise to control noise at the source. While 47% of respondents did not experience any difficulty with kitchen noise, Figure 9.6 indicates the steps taken by staff to curtail noise.

Simple solutions like lubricating the machine reduced noise by 3% from equipment, whereas 9% sent equipment for repair. Fifteen per cent switched off the equipment and 26% placed mats under the blenders and grinders. However, the author could not observe any rubber mats installed under blenders and grinders to absorb the noise. It was observed that only 12% of kitchens had rubber mats on the floor near the sinks in the dishwashing area for non-slip purposes and absorbing noise generated from the manual dishwashing process. Rubber reduces heavy vibrations and disturbing sounds. The more expansive the kitchen area, the less noisy the perception by workers. Other strategies comprise placing kitchen towels or table mats under the equipment to absorb noise.

Regarding noise and kitchen spaces, we will now discuss how the area and volume of the kitchen affect noise; how the construction material of the ceiling, floors and walls affects noise; and how maintenance and equipment specifications and installation have a bearing on noise control.



Source: Author's own work.

FIGURE 9.6: Steps taken by staff to curtail kitchen noise.

The height of the kitchens varies from 2.41 m to 4.17 m. High ceilings create echoes. They also result in higher reverberation times, as sound waves must travel a long way before they are reflected by a hard surface. Therefore, high ceilings are bad for room acoustics.

The total floor area of kitchens in Figure 8.1 varies from 17.10 m^2 to 248.08 m^2. Sound waves in small rooms have less time to decay and thus end up creating interference that is more destructive. Very few kitchens have an area greater than 200 m^2. Significantly, more respondents (86.7%) indicated that the kitchen area was less than 100 m^2 ($p < 0.001$). The volume of kitchens varied from 43.58 m^3 to 426.05 m^3 (Table 8.2). The noise findings of worker well-being are attributed to high ceilings. For example, workers who have no problems with noise are mostly from large spacious kitchens (21%).

It is imperative to prevent sound waves from bouncing back off the kitchen walls and contain the sound in one location. Table 9.11 reports that 60.6% had plasterboards and 6% of the kitchens have metal ceiling tiles. Twenty-four per cent of the kitchens had concrete ceilings. Only one kitchen had a corrugated metal roof. Suspended ceilings absorb more noise than concrete ceilings, as hard surfaces reflect sound. However, 11% of the kitchens had false ceilings.

According to Table 9.11, more than 88% of the kitchens had glazed ceramic tiles on walls. Six per cent had brick walls covered with plaster. Soundproofing in some kitchens appeared to be successful. Acoustic tiles were not observed in any sampled kitchens because of a lack of awareness about noise levels in kitchens, according to the head chefs and kitchen managers.

The current study observed that concrete is commonly used for ceilings and floors. Except for noise emitted by grinders and blenders, other well-maintained kitchen equipment did not add to the loudness in kitchens, as voiced by the head chefs. Table 9.11 indicates that improved maintenance of HVAC exhaust systems can reduce noise in kitchens by frequent cleaning of extractors. Approximately 51% of the exhaust system is cleaned biannually.

TABLE 9.11: Summary of construction material in kitchens.

Construction	Finishes	Percentage (%)
Ceiling	Plasterboard	60.6
	Concrete	23
	False ceiling – gypsum	11
Floors	Porcelain tiles	78
	Vinyl	9
	Cement	13
Walls	Ceramic tiles	88
	Plaster	6
	Concrete	6

Nearly 90% of the respondents agreed that the equipment is in good repair ($p < 0.001$). This did not seem true because of the audibly excessive noise from the extractors, suggesting worker acclimation to noise. Hearing loss could notably set in because of noise exposures above 85 dBA, as discussed earlier in Section 9.2.

The management of noise in the interval between detecting and correcting noisy equipment has not received attention in the literature. Almost 40% of kitchens have a maintenance plan to repair or replace equipment within a week. Thirty percent (30%) of the kitchens repaired the equipment in a day ($p = 0.017$). I contend that a common dilemma every commercial kitchen operator faces is when a piece of equipment slows down or fails completely: does it fall under the maintenance schedule to repair to extend its working life, or should it be replaced altogether?

More than 70% of kitchens have a weekly maintenance program of equipment that helps to lower noise levels in kitchens. The author insists on planning for maintenance when purchasing the equipment. Eighty-nine (89%) of the head chefs felt that the kitchen equipment is in good repair. This could be because of preventative maintenance as franchise food (24%) enterprises have a policy as well as practice periodic maintenance.

About 11% of the head chefs believed that their kitchen equipment is in poor working condition. Almost 76% of kitchens (Table 9.12) had a weekly maintenance plan to service kitchen appliances.

The author adds that food manufacturers may have items like changing grease filters, fryer maintenance and boiler service as part of their maintenance schedule that, in turn, will reduce noise.

A minority (8.8%) practised breakdown maintenance, and the remaining kitchens serviced medium-size equipment monthly or as per the schedule with $p < 0.001$. This means that the auditory health of the kitchen workers is affected until the equipment is sent for repair.

The shortcomings in maintenance were found in the sample. In kitchens 14 and 28, the HVAC exhaust noise levels were 73 dBA. It was noisy, as no

TABLE 9.12: Frequency of equipment service intervals.

Service intervals	Frequency	Percentage (%)
Weekly	25	73.5
Monthly	1	2.9
Bi-annual	2	5.9
Yearly	1	2.9
When the equipment breaks down	3	8.8
Other	1	2.9
Total	**33**	**96.9**

TABLE 9.13: Rotated component matrix for noise and equipment condition.

Q43.4	Component			
	1 **Very poor maintenance**	2 **Poor maintenance**	3 **Good maintenance**	4 **Excellent maintenance**
1. All the kitchen equipment is in good repair	−0.120	−0.213	0.875	0.006
2. The amount of light in the kitchen is adequate	−0.152	0.204	0.752	0.080
16. All kitchen equipment is installed as per specifications	−0.160	−0.057	0.693	0.134

maintenance programme was in place. In kitchen 25, the maintenance schedule was pending, with noise levels of 83 dBA. In kitchen 16, the roof was made up of corrugated metal sheets, which reflected some of the extractor noise into the kitchen (78 dBA).

The high value of 83 dBA observed in kitchen 25 was because of the exhaust fan requiring maintenance. The kitchen HVAC was a source of noise annoyance (Astolfi & Filippi 2004). The noise level far exceeded the permissible range of NR40 – NR50, equivalent to 40 dBA to 50 dBA.

The current study has a maximum airflow rate of 2.5 m/s in kitchens, which is too low to cause noise. Approximately 29.4% of kitchen managers agreed that the electrical and mechanical equipment malfunctioned within 24 h after service occurred. An important correlation between all the kitchen equipment is in good repair and work experience was established. Thirty-eight per cent (n = 13) of the kitchen managers strongly agreed that all the kitchen equipment was in good repair. About 67.6% of head chefs agree that all the kitchen equipment was in good repair most of the time. Moreover, the author estimated that 76% of the gas stoves and 70.6% of the ovens were in good repair.

In both existing and proposed new installations, identifying noise sources and ranking them in order in terms of contributions to excessive noise is key to a noise control strategy. The smooth running of equipment is dependent on proper installation and maintenance (Webstaurant Store 2019). The opinions of head chefs denote that 2.9% of kitchens did not have all the equipment installed as per specification.

It is estimated that 88% of the equipment is in good repair, but 5.9% of the head chefs claim that all the equipment is not in good repair. The possible reasons for this huge variation could be because of the impression that chefs may have about the equipment in use which may not be true.

Using EFA, item 43.4, Component 3 (good maintenance), has three loadings of 0.875, 0.752 and 0.693 for equipment in good repair, adequate lighting and installation (Table 9.12). Implications of the component 'good maintenance' beyond the noise construct will be discussed in Section 10.5.

The adherence to the installation of equipment as per specification is a standard practice amongst head chefs, with a 76.5% compliance rate in commercial kitchens. Only one owner confessed that protocol was not followed for the installation of specific equipment because of unavailability of the specifications, although most equipment such as refrigerators, freezers, gas stoves, electric fryers and blenders generally found in commercial kitchens are installed as per specifications.

A noteworthy correlation between ‘all kitchen equipment is installed as per specification’ with ‘all the equipment in good repair’ is confirmed. These two themes positively correlated. More than 90% of the head chefs observed that all kitchen equipment is installed as per specification. Nonetheless, access to equipment specifications lies with the management and not with head chefs or kitchen managers because of the frequent turnover of staff.

9.4 Conclusion

In conclusion, this chapter established that noise levels in food-service operations are high. Discomfort and staff complaints about noise are observed in some commercial kitchens. Most kitchen workers are unaware that hearing loss can occur because of noise in kitchens. Work experience in kitchens and the age factor seem to influence noise adaptation amongst food-service workers. Noise perceptions are defined by ethnicity. Kitchen spaces can affect noise comfort, and good acoustics can reduce stress amongst kitchen workers. Maintenance and regular servicing of equipment help with reduced noise levels. The next chapter discusses data analysis, presentation and interpretation of lighting.

Chapter 10

Data presentation, analysis and discussion: Lighting in kitchens

10.1 Lighting in kitchen zones

This chapter will present the findings of the study, which were gathered from three research instruments and scientific test equipment. The findings will be presented according to kitchen work environment themes that emerged from investigations of lighting in kitchen areas, illumination requirements and maintainability.

Among the most essential requirements for any kitchen workstation is lighting. It is observable from Table 10.1 that the mean values of light measures from this investigation are compliant with mentions of the SABS, SANS and HSG 38 regulations in Section 5.7. Kitchens that will be assessed in 10.2 demonstrate that access to natural light indicates the best values for compliance.

Lighting emerging from different permutations of sunlight and artificial light in Table A7 illustrates a variation in the area of the kitchen. Nonetheless, the mean intensity of lux measures in receiving areas is the highest (Table 10.1). However, because of the observed wide variation in the minimum and maximum values, the suitability of the mean values cannot elicit information

How to cite: Gangiah, S 2022, 'Data presentation, analysis and discussion: Lighting in kitchens', in *Environmental ergonomics Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town, pp. 221–236. https://doi.org/10.4102/aosis.2022.BK346.10

TABLE 10.1: Mean lighting levels (lux) in kitchen zones.

Work areas	Mean	Median	*n*	Std. deviation	Minimum	Maximum	Range
Receiving	345.92	260.00	33	424.80	39.00	1 790.00	1 751.00
Preparation	322.85	240.00	33	241.44	25.00	1 003.00	978.00
Stove	204.23	190.00	31	94.83	25.90	410.00	384.10
Oven	281.57	189.50	30	217.72	30.00	960.00	930.00
Holding	284.60	185.00	33	319.60	36.00	1 613.00	1 577.00
Dish-washing	211.19	190.00	33	150.42	28.00	630.00	602.00
Corridor	298.96	180.75	32	394.74	25.00	1985.00	1960.00

on lighting levels from the perspectives of worker eye strain, headaches, tiredness, irritability and ergonomics in different kitchen areas.

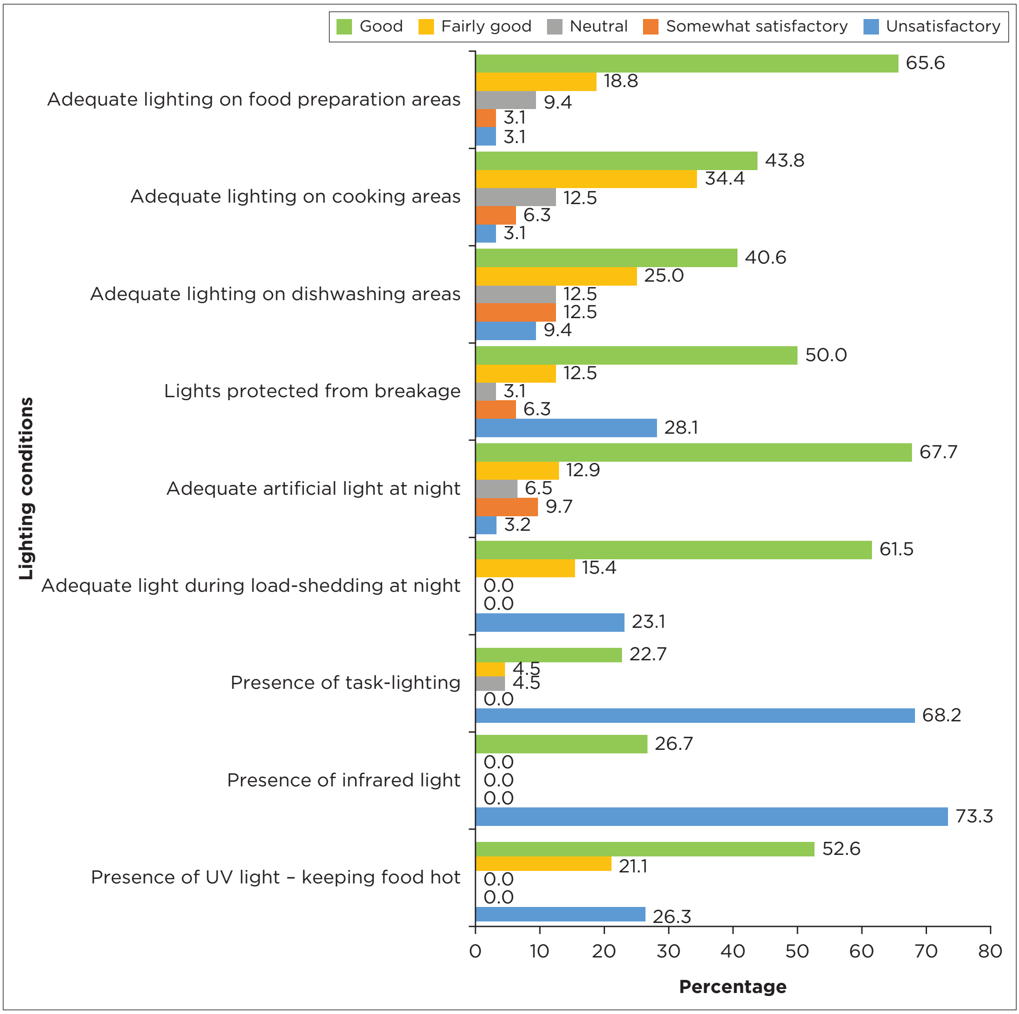
The requirement for corridors by SANS and South African legislation is 100 lux as per the *Occupational Health and Safety Act*, 1993 (South African Legal Information Institute 1993), which is much lower than the observation of 298.6 lux. This could be because of the presence of sunlight.

The UV lamps in the holding area contributed considerably to the mean of 284 lux. Better light emits from grease-free lighting sources. Similarly, large differences in lighting levels in receiving areas could be because of the presence of sunlight from the open door, glass walls and windows. The holding, corridor and receiving areas elicited the highest SD values because of a huge difference in the minimum and maximum values in Table 10.1. The found SD is suitable in five kitchen zones for worker lighting comfort, except the stove area, where the lighting value (95 lux) is below SANS criteria.

Figure 10.1 uses the author's subjective estimation. Allan et al. (2019) advanced that subjective evaluations of lighting are an important complement to objective photometric information. These subjective observations of lighting adequacy are recorded in Figure 10.1. More than 65% of the kitchens have lighting in food preparation areas categorised as being adequate (323 lux). More than 34% of the kitchens have dim lighting in preparation areas, and 57% have dim lighting in cooking areas.

Almost 43% of the kitchens have adequate lighting in cooking areas (204 lux). Lamps inside the canopy hoods provide most of the lighting. The stove area in Table 10.1 has the lowest mean because of the presence of canopy hoods that prevent light from illuminating the ranges and stoves, as well as because of the absence of lighting fixtures in the canopy hood. Three kitchens have lighting fixtures with fused light bars. Kitchen managers and head chefs seem to assume that the presence of general lighting will suffice in the stove area. There is no specific light bulb for oven areas – these areas receive lighting from general areas.

A major correlation between adequate lighting in food preparation areas and adequate lighting in cooking areas is verified. This is a positive indication



Source: Author's own work.

FIGURE 10.1: Researcher approximation of lighting in kitchens.

for worker lighting comfort in kitchens. Further to an individual investigation of each task area conveyed in Table 10.1, EFA is applied to survey items relevant to lighting in the kitchens. The result of the analysis reveals factor loadings of 0.955, 0.932 and 0.895, respectively, in preparation, cooking and dishwashing areas in kitchens (Table 10.2). These are categorised into Component 1 (area illumination). Less than 40% of kitchens have adequate lighting in dishwashing areas. Dishwashing areas in kitchens seem to have the lowest amount of lighting when compared with other areas in the kitchens surveyed. Almost 10% of the kitchens seem to have unsatisfactory lighting in all the different zones.

Exploratory factor analysis further generates factor loadings of 0.482, 0.947 and 0.947, respectively, for lights protected, presence of task light and

TABLE 10.2: Rotated component matrix on facility design and layout.

Variable	Component		
	1 Area illumination	2 Precise fixtures	3 Light specifications
13. Adequate lighting on food preparation areas	0.955	0.023	0.192
14. Adequate lighting on cooking areas	0.932	0.126	0.275
15. Adequate lighting on dishwashing areas	0.895	0.249	0.157
16. All lights protected from breakage	−0.140	0.482	0.329
17. Adequate artificial light at night	0.631	0.046	0.710
18. Adequate light during load-shedding at night	0.355	0.073	0.664
19. Presence of task-lighting	0.224	0.947	0.085
20. Presence of infrared light	0.224	0.947	0.085
21. Presence of UV light – keeping food hot	0.131	0.250	0.830

Note: Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalisation. Rotation converged in six iterations.

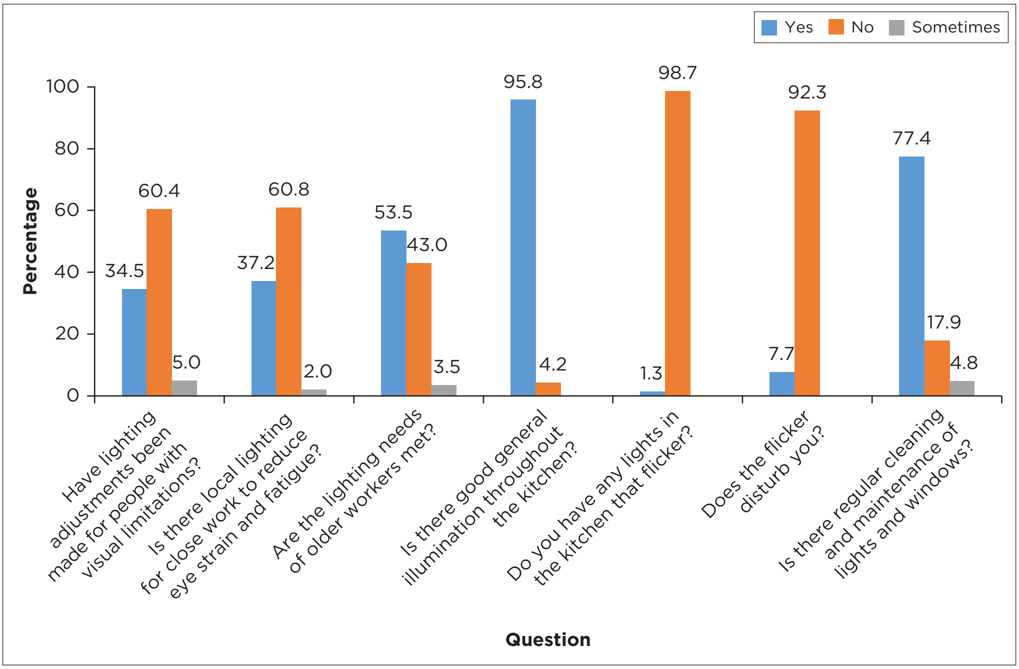
presence of infrared light. These are categorised into Component 2 (precise fixtures); 15.2% of the kitchens have the presence of task lights, and 12.1% of the kitchens are observed to have installed infrared light (Figure 10.1), to be discussed in Section 10.2. Local lighting is not provided in more than half of the kitchens in preparation, cooking and dishwashing areas. In this regard, task-lighting will be discussed in Section 10.4. Component 3 (light specifications) will be discussed in Section 10.3.

10.2 Visibility

The Likert-scale observation in Figure 10.1 indicates wide variations in scoring patterns from the kitchens. The first seven statements illustrate higher levels of 'good' rating for the first six and a significantly greater level of 'unsatisfactory' for statement 7. There is no significant difference in the scoring for the last two statements. Dishwashing areas in almost 17% of the kitchens are inadequately illuminated. Ultraviolet heat lamps are prevalent when compared with halogen lamps in the pick-up section. This section will discuss illumination and fitting arrangements, natural light, artificial lighting and lighting in work areas.

Eighty-seven per cent of the kitchen workers believe that general lighting is adequate in their kitchens (Figure 10.2). Kitchen interior design is significant in this regard. For instance, because light reflects off walls, ceilings, floors and surfaces, the choice of colour, material and finishing of these surfaces must be carefully considered as the reflectance can be a factor in the luminance level of the area. The detail of this aspect is beyond the scope of this study.

I have estimated that 87% of kitchens have adequate general lighting (Figure 10.1). This research recorded mean lighting levels of 286 lux at fryers and 211 lux at grillers.



Source: Author's own work.

FIGURE 10.2: Workers' opinions on lighting conditions in kitchens.

Storage areas, washrooms and dining areas must be provided with lighting levels of 150 lux to allow for proper cleaning operations. This study finds that lighting levels seemed to meet the requirements in all task areas except in one kitchen; measurements taken indicate compliance with SABS recommendations. However, it falls short of complying with OHSA recommendations indicated in Table 5.3. Nevertheless, 96% of workers estimated that there is good general illumination throughout the kitchen (Figure 10.2). A significant number (62.5%) of kitchens in this study are observed to have all the lamps protected from breakage; however, 21% of kitchens have a few unprotected lamps (Figure 10.1).

The lack of local lighting in 70% of the kitchens suggests inadequacy in the number of light sources. The preparation areas in kitchens are especially hazardous in the absence of adequate lighting. Additionally, disclosures of commercial kitchen lighting from multiple studies suggest that its importance seems to be ignored by management.

The result of EFA (Table 10.2) reveals a factor loading of 0.818 for the presence of natural light and the presence of direct glare, respectively; they are categorised as illuminance.

The designs of the kitchens favoured daylight. Almost 73% of restaurants in this study had glass walls or large windows permitting light into the kitchens, and only 15% had skylights in the kitchens. However, the kitchens were not all fitted with windows; 50% of them had no windows or the windows were covered for privacy. Hence, natural sunlight is denied to the staff. According to my estimation, 10.3% of kitchens had fairly good natural light, while 34.5% had somewhat satisfactory natural light (Figure 10.5).

To avoid visual fatigue and provide adequate illuminances for safety purposes in kitchens, 100 lux is recommended in Health and Safety Executive (1997). Almost 15.2% of kitchens had optimal lighting levels in kitchens because of the influx of sunlight (Table 10.3). Most areas in kitchens met the lighting criteria for 300 lux to 500 lux, as recommended by SANAS, OSHA, WHO, CIBSE, BOSH and Australian Standards.

The commercial kitchens in Table 10.3 were well-designed with proper implementation of lighting for the staff to perform their tasks of food preparation, cooking, presentation and cleaning efficiently and safely. At the same time, reflections and glare were absent. Kitchen 27 did not use artificial lighting in the daytime unless the sky was grey or overcast. Because of the location of the kitchen in the commercial complex, kitchen 4 had bright artificial lights and no windows. The presence of glass walls in the front and open back doors flooded different kitchen areas with sunlight, depending on the layouts.

Giving impetus to the need for artificial lighting, EFA (Table 10.2) reveals Component 3 (light specification), the component derived from the factor

TABLE 10.3: Lighting levels (lux) in kitchens with optimal natural light.

Kitchen code	Receiving	Preparation	Cooking	Dishwashing	Mean (kitchen)	Daylight source	Artificial lighting
2	270	480	500	230	370	Open-plan, open front doors, one back door, two windows	Recessed louvre double fluorescent lights
4	640	900	360	610	627	Hatch, windows absent	Recessed louvre double fluorescent lights
11	1 770	460	280	300	700	One back door, four windows	Recessed louvre double fluorescent lights, suspended fluorescent lights
14	260	510	230	428	357	Double back doors, one skylight, four windows	Suspended fluorescent lights
25	301	730	560	125	430	Open-plan, open front doors, glass wall, one back door, no windows	LED panel lights
26	340	1 003	460	375	545	Open-plan, open front doors, glass wall, double back door, no windows	LED panel lights
27	1 790	760	360	330	810	Double back door	Fluorescent lights
Mean (areas)	767	690	390	340	-	-	-

loadings of 0.710, 0.664 and 0.830, respectively, for artificial lighting at night, adequate light during load-shedding at night and heat lamps for keeping food hot.

Almost 63.6% of the kitchens have adequate artificial light at night; 30% have rechargeable LEDs in addition to lights connected to a generator; 30.3% of the kitchens have heat lamps for keeping food hot (Figure 10.1 and Table 10.4).

Artificial lighting in 30.3% of the kitchens comprised heat lamps for keeping food hot. Lighting in holding areas in 18% of the kitchens in Table 10.4 was very bright because of the presence of UV light. Heat lamps seem to increase the heat in the area as well. Almost 53% of kitchens had UV lamps and 26% had infrared lights. Only two kitchens had halogen lamps. Ultraviolet heat lamps are popular compared with halogen lamps to keep food hot without drying in the holding area.

Table 10.5 depicts the association of the presence of natural lighting with the presence of sunlight to model improved lighting in preparation areas. Consequently, the preparation of high-quality food in poorly lit kitchens can be challenging. However, this study's appraisal reveals that 85.2% of the kitchens with no skylights had unsatisfactory lighting in some kitchen zones: $Y_{predicted} = b0 + (b1 \times 1) + (b2 \times 2)$.

The column of estimates provides the values for b0, b1 and b2 for this equation. The equation is written as:

$$\text{Preparation area lighting} = 108.121 + (134.058 \times \text{Natural Light}) + (-104.870 \times \text{Skylight}) \quad \text{[Eqn 10.1]}$$

TABLE 10.4: Presence of UV light keeping food hot.

	Estimation	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
Valid	Unsatisfactory	5	15.2	26.3	26.3
	Fairly good	4	12.1	21.1	47.4
	Good	10	30.3	52.6	100.0
	Total	**19**	**57.6**	**100.0**	-
Missing	System	14	42.4	-	-
	Total	**33**	**100.0**	-	-

TABLE 10.5: Correlation coefficient for lighting in preparation area.

Model	Unstandardised coefficients		Standardised coefficients	*t*	Sig.	Collinearity statistics	
	b	**Std. error**	**Beta**			**Tolerance**	**VIF**
(Constant)	108.121	126.259	-	0.856	0.410	-	-
Presence of natural light	134.058	50.044	0.660	2.679	0.021	0.836	1.196
Presence of skylight	−104.870	47.577	−0.543	−2.204	0.050	0.836	1.196

Key: Sig., significance; VIF, variance inflation factors.
Note: (1) Dependent variable: lighting (lux) in preparation area (Q93.2). (2) redictors: (Constant), AB25 = presence of natural light, AB26 = presence of skylights.

The modelled predictor indicates that for every unit increase in skylight, a −104.870 unit decrease in lighting needs in the preparation area is predicted for good vision, holding all other variables constant.

10.3 Visual comfort

This section will accordingly discuss lighting awareness, eye strain and flickering lights. There appears to be minimal kitchen worker sensitivity to the role of light in their task environment, as evidenced by 70% of the workers' responses that they were unaware of good lighting. Some kitchens did not have adequate lighting levels, and this shortcoming appears to have affected some workers who strained to work and sometimes even had headaches. Lightbulbs are not replaced until they burn out; this is because of ignoring the reduced effectiveness of light as the bulb ages. Chefs and workers are unaware of these changes and continue working without replacing them.

Almost 17.6% believed that tenure of work in commercial kitchens enables workers to see in the available lighting in kitchens. Unsurprisingly, while age is an important determinant of vision, only 8.8% believed it influenced vision. A probable contributor to this view may be that only two staff members above 60-years-old lamented that they strained their eyes because of inadequate lighting.

Also, 76% of the workers felt that the lighting needs of older workers were met (Figure 10.2). The age of kitchen workers in Table 7.1 varied from 19–62-years-old, with a mean of 31-years-old ± 8.55. More than 60% of food-service workers reported that lighting adjustments for people with visual limitations, especially older workers, were not provided. It seems that existing minimum lighting design regulations are unlikely to satisfy elderly kitchen worker needs. Elderly work-going persons may be exposed to very low levels of illuminance in a space and adapt to low levels of illumination.

10.4 Visual discomfort

This section will discuss visual discomfort, local and task-lighting, and how they cause eye strain. The loss of lighting in preparation areas by the cleanliness of lighting globes and fixtures became evident in a multivariate regression model. The model also provided evidence that dim lighting in preparation areas or too much bright light can cause headaches amongst kitchen workers.

The multivariate regression model $Y = b0 + b1x1 + b2x2$ that lighting in preparation area = (−881.86) + (92.341 × headaches) + (112.088 × clean lights and fixtures). The inverse relationship reflects that lower levels of lighting are needed in preparation areas when the lights and fixtures are clean and bright lights cause headaches.

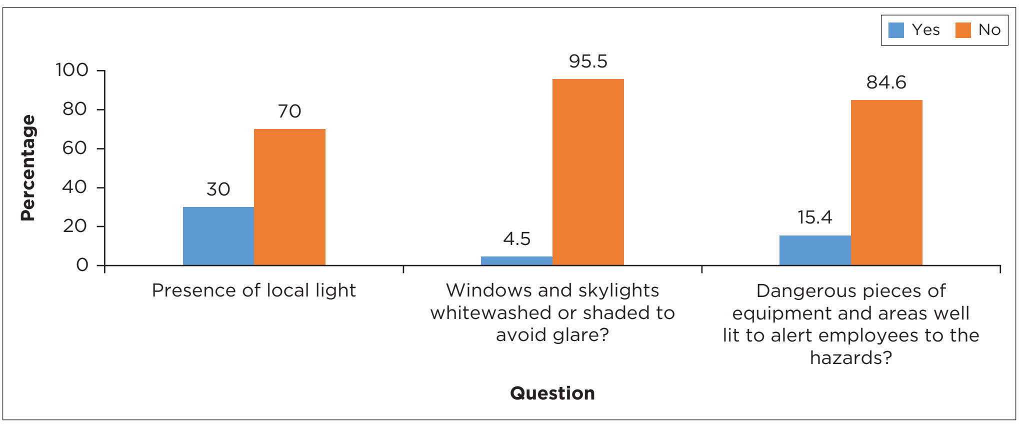
Working in a dimly lit environment, as well as working under bright lights, can be equally uncomfortable. Dim light can cause eye strain and make the eyes tire quickly. Seventy-one per cent of the kitchens had clean bulbs, and almost 66% of kitchens had clean fixtures. Almost 18% of the kitchen workers assumed that the lightbulbs were not cleaned on a regular basis.

Almost 61% of the kitchens had unsatisfactory task-lighting (Table 10.9), although all the kitchen workers were complacent about personal control of lighting, as switches were easy to reach. Three staff found that local lighting varies with the allocation of their workstations. Figure 10.3 indicates that only 30% of kitchens had provision for local lighting, and only one kitchen had windows and skylights whitewashed to avoid glare. A minor proportion (15.4%) of the kitchens provided for dangerous pieces of equipment and areas to be well-lit to alert employees to the hazard. In all instances, more responses were 'No', with the differences being significant for the last two statements.

A lower percentage of 'no' in Table 10.5 could be because the head chefs and kitchen managers are unacquainted with inadequate lighting in kitchens. It seems that appropriate action is lacking because of the ignorance of lighting requirements in kitchen areas.

Lighting may be necessary for delicate kitchen work. Over half of the workers (52.6%) (Table 10.9) complained that no local or task-lighting was provided at their workstations. Eighty-three per cent of head chefs additionally responded that mobile task-lighting was not provided. The opinions of kitchen managers and head chefs about VC in kitchens were positive (94%). Using an observation checklist, the author's approximation indicated (Table 10.2) that 68% of the kitchens had unsatisfactory task-lighting.

A majority (84.8%) of head chefs responded that mobile task-lighting is not provided. For the best balance, at least three sources of light should be available in every space, including sunlight.



Source: Author's own work.

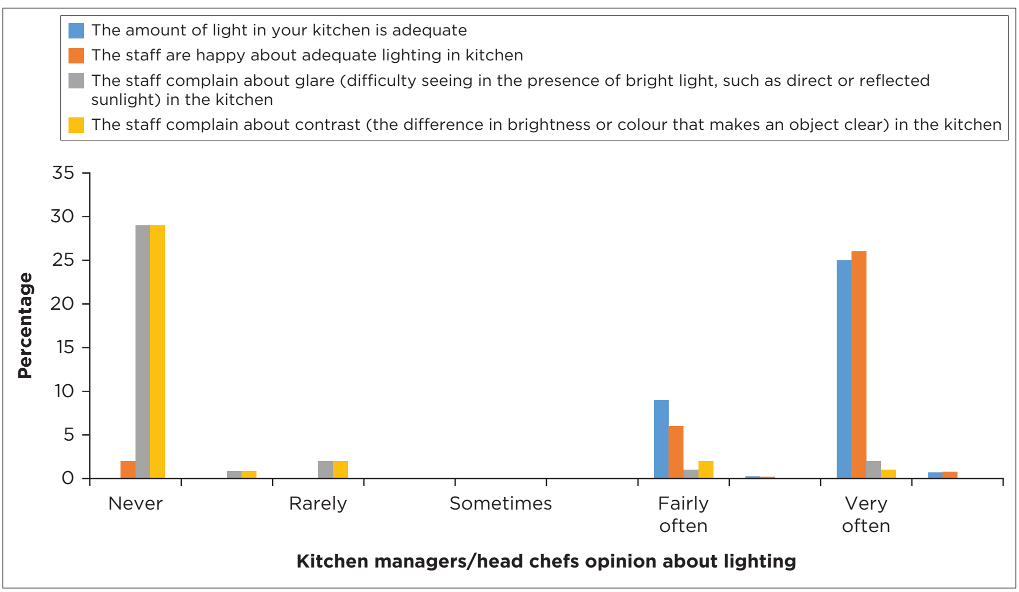
FIGURE 10.3: Author's observation on lighting arrangement in kitchens.

The opinions of head chefs reflect that 88.2% (Figure 10.4) of kitchens have work areas free from shadows. The author's approximation reveals that only 6.75% of kitchens are unsatisfactory and 50% rated well without shadows (Figure 10.5). However, head chefs felt that almost 90.9% of the kitchens are free from shadows. Questionnaire responses from kitchen managers and head chefs indicated confidence that workers do not have complaints about glare and contrast (Figure 10.3).

Figure 10.2 indicates that local lighting was provided to 32.2% of workers for close work in the kitchen to reduce eye strain and fatigue. Whereas only 73% of workers felt that the VC at their workplace was satisfactory and free from glare, reflections and contrast, a higher 93.9% of the kitchen managers believed that employees could comfortably see their work without straining their eyes. This gap is likely to account for reduced well-being amongst workers. Almost 95% of kitchens used fluorescent lights in the common zones, including all areas except pick-up sections and canopy hoods.

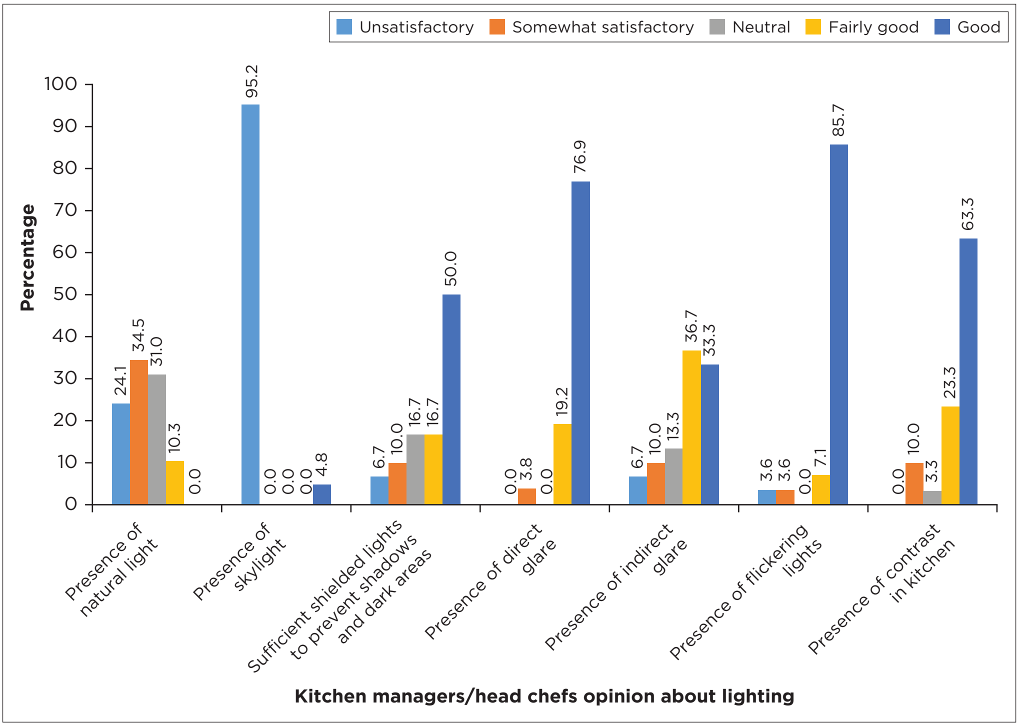
The extent of eye strain depends on whether a light source is steady or flickering, as flickering light tends to create eye strain. Using EFA, Component 1 (brightness) reveals a factor loading of 0.613 for the presence of flickering lights (Table 10.12).

Of the observed kitchens, 72.7% of kitchens have no flickering light. The chi-square values are 55.143 with p = 0.000 flickering lights in the kitchens. Additionally, the interviews reveal that less than 2% of kitchen workers perceive flickering lights in their kitchens (Table 10.10).



Source: Author's own work.

FIGURE 10.4: Head chefs and kitchen managers' opinions about glare and contrast.



Source: Author's own work.

FIGURE 10.5: Author's observation of kitchen lighting.

TABLE 10.6: Presence of flicker in kitchens.

	Estimation	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
Valid	Yes	2	1.17	1.3	1.3
	No	150	88.23	89.55	100.0
	Total	**152**	**89.4**	**100.0**	-
Missing	System	19	11.1	-	-
	Total	**170**	**100.0**	-	-

A minority of below 2% of kitchen workers respond that flickering lights exist in one kitchen, which shows that flickering may not be a common feature in commercial kitchens. I approximated that 85.7% of the kitchens have no flicker from observation; however, 3.6% have unsatisfactory lights with flicker. Almost 56% of the kitchen workers were aged less than 30 years.

Exploratory factor analysis (Table 10.12) reveals a factor loading of 0.818 and 0.613 for the presence of natural light and flickering lights, respectively, and is categorised into Component 1 (brightness). Slightly over 21.2% of the kitchens had unsatisfactory natural light. Almost 72.7% of kitchens had no flickering lights, and only one (3.0%) kitchen had flickering lights. Unfortunately, responses from five kitchens on flicker were blank. About 19 kitchen workers were not sure about flicker. Similarly, 158 workers had no clue about disturbance from flicker. The chi-square values are 3.966 and 55.143, with $p = 0.265$ and $p = 0.000$, respectively, for natural light in the kitchen and flickering lights.

The presence of contrast and glare were not common in most of the kitchens investigated. Contrast and glare are controlled, as was borne out in less than 4% of the kitchens exhibiting such spots, mainly because of the shine from new equipment (Table 10.7). This study finds that *p*-value is 0.739 with a significance level of 0.001 and chi-square statistic of 66, for the correlation between 'the staff complains about the contrast in kitchen' and 'staff complain about the glare in the kitchen' (Figure 10.3). Almost 88% of head chefs in this study were confident about the absence of glare in kitchens.

Glare in the kitchen is experienced when lamps, windows, luminaries, and other areas are brighter than the general brightness in the environment. It is also noted that in one of the kitchens in this study, skylights were whitewashed to prevent glare. One kitchen exhibited a discernible direct glare, as all the equipment was new and shining, while two other kitchens presented indirect glare. Figure 10.5 indicates that only two kitchens, or 6.7% of kitchens, had indirect glare as an estimation.

Over the summer data collection, glare occurred in two kitchens from sunlight reflection on shiny surfaces (Figure 10.3). Further to sunshine, five kitchens had countertops that reflected bright light off the surfaces. The observational study (Figure 10.3) further revealed that 3.8% and 6.7% of kitchens had direct glare and indirect glare, with chi-square values of 23.154 and 11.667, respectively. As $p = 0.000$ and $p = 0.020$, less than the significance level of 0.05, this is strong evidence to conclude that the variables 'glare' and 'brightness' are associated. Triangulation of data from the three instruments reinforces the validity of data obtained from each.

The opinion of head chefs elicited on 'the staff complain about glare in the kitchen' (Figure 10.4) denotes that glare is controlled, as less than 4% of kitchens had spots attributable to shine from new equipment. According to Table 10.7, 85.3% of the staff did not complain about glare in their kitchens, with $p = 0.000$ and chi-square statistic of 66, expressing strong evidence to conclude that the variables the presence of glare in kitchen and complaints about glare are associated. There are insignificant correlation values for items related to the negative effect of glare, a deduction evidenced by 93.9% of the

TABLE 10.7: Staff complain about glare.

	Estimation	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
Valid	Never	29	87.8	87.8	87.8
	Rarely	2	5.9	5.9	93.7
	Fairly often	1	2.9	2.9	96.6
	Very often	1	2.9	2.9	100.0
	Total	**33**	**100.0**	**100.0**	-

kitchen managers (Table 10.5), indicating that employees could comfortably see their work without straining their eyes. Additionally, 73% of the workers felt that the VC at the workplace was satisfactorily free from glare. The latter corroborates the kitchen worker interviews (Figure 10.4), where only two (1.2%) kitchen workers complained about glare.

Using EFA (Table 10.8) reveals a factor loading of 0.827 for direct glare, categorised into Component 1 (brightness). The questionnaire further reveals that although 76.5% of the head chefs claimed that their staff are happy about adequate light-illuminance in kitchens, 8.8% of the staff complained about glare. The presence of direct glare was only observed in one kitchen. Using EFA (Table 10.9), a factor loading of 0.851 and 0.801 for complaints about glare and contrast is revealed, and it is categorised into Component 1 (visual discomfort). For the correlation between 'staff complains about contrast in kitchens' and 'staff complaints about glare in the kitchens', a *p*-value of 0.739 with a significance level of 0.001 is ascertained. About 60.6% of the kitchens had no direct glare; only 3% had direct glare.

Contrast, when subjected to EFA, reveals a factor loading of 0.801 and is categorised into Component 1 (visual discomfort) (Table 10.10), as mentioned above. Table 10.9 indicates that 87.8% of head chefs believed that kitchen staff had no complaints about contrast. The questionnaire further reveals one item: 'the staff are happy about adequate lighting' is categorised into Component 4 (fitting illuminance), with a factor loading of 0.800. The author's approximation indicates that none of the workers had any complaints about contrast (Figure 10.5).

Interviews reveal that 1.8% of the staff complained that VC was not good in their kitchens' work areas (Figure 10.2). The observational study further revealed that 9.1% of the kitchens had contrast, with chi-square values of 66. As $p = 0.000$, less than the significance level of 0.05. This is strong evidence to conclude that the variables 'contrast in kitchens' and 'areas free from shadows' are associated. 'Staff are happy about lighting in kitchens' had $p = -0.480$ with a significance level of 0.004. The fewer the staff complaints

TABLE 10.8: Rotated component matrix: Author's opinion on lighting ergonomics.

Variable	Component	
	1 Brightness	2 Luminance
25. Presence of natural light	0.818	0.205
26. Presence of skylight	0.337	0.268
27. Sufficient shielded lights to prevent shadows or dark areas	0.607	0.701
28. Presence of direct glare	0.827	−0.278
30. Presence of flickering lights	0.613	0.274
31. Presence of contrast in kitchen	−0.039	0.934

Note: Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalisation. Rotation converged in three iterations.

TABLE 10.9: Rotated component matrix: Chefs' opinions on lighting ergonomics.

Variable	Component			
	1 Visual discomfort	2 Luminance	3 Conservation	4 Fitting illuminance
1. All the kitchen equipment is in good repair	−0.120	−0.213	0.875	0.006
2. The amount of light in your kitchen is adequate	−0.152	0.204	0.752	0.080
3. The staff are happy about adequate lighting in kitchen	−0.061	0.208	0.047	0.800
4. The staff complained about glare (difficulty seeing in the presence of bright light, such as direct or reflected sunlight) in the kitchen	0.851	−0.046	−0.050	0.073
5. The staff complained about contrast (the difference in brightness or colour that makes an object clear) in kitchen	0.801	0.257	−0.147	−0.192
6. All kitchen equipment is installed as per specifications	−0.160	−0.057	0.693	0.134

Note: Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalisation. Rotation converged in five iterations.

TABLE 10.10: Kitchen workers complain about contrast.

	Estimation	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
Valid	Never	29	87.8	87.8	87.8
	Rarely	2	6.06	6.06	93.8
	Fairly often	1	3.03	3.03	96.83
	Very often	1	3.03	3.03	100.0
	Total	**33**	**100.0**	**100.0**	

about light contrast in the kitchen, the higher the incidence of adequate lighting in kitchens, with staff being happy about it.

All kitchens in the study used artificial lights during the day (Figure 10.1).

The author's subjective evaluation revealed that kitchen workers' views were similar on lighting. Only objective evaluation of kitchens indicated the accurate state of lighting conditions.

Using EFA, contrast reveals a factor loading of 0.934 and is categorised into Component 2 (luminance). Keeping with the claim that staff are happy about adequate light with Component 4 (fitting illuminance) in kitchens with a factor loading of 0.800, 9.1% of the kitchens had slight contrast in some areas, although 76.5% of the head chefs (Figure 10.5) agreed with it. Staff complained about contrast in the kitchen, and this has a negative correlation, with $p = -0.480$, with the component 'inadequate lighting in kitchen', with a significance level of 0.004. 'Staff are happy about lighting in kitchen', with $p = -0.480$, had a significance level of 0.004. Thus, the fewer staff members who complain about lighting contrast in kitchens, the higher the incidence of adequate lighting in kitchens and staff being happy with it.

TABLE 10.11: Contrast in kitchens.

Dependent variable	Type III sum of squares	*df*	Mean square	*f*	Sig.
Adequate lighting (lux) on food preparation areas	7.5	2	3.75	9.375	0.02
Adequate lighting (lux) on cooking areas	11.3	2	5.65	7.635	0.03

Note: AB31 = presence of contrast in kitchen.

As p = 0.02 and p = 0.03, less than the significance level of 0.05, this is strong evidence to conclude that the variable contrast and lighting in preparation and cooking areas are closely associated.

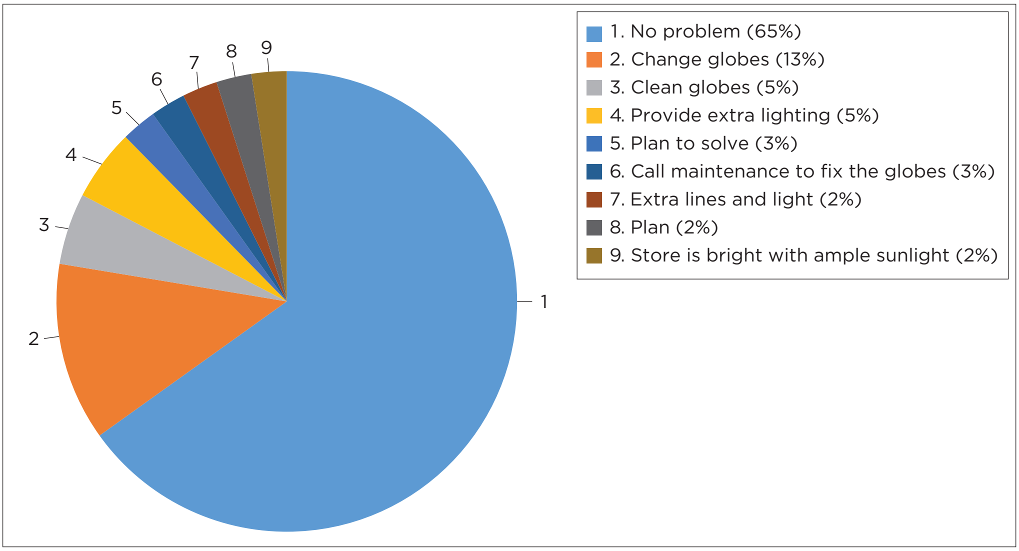
Clearly, adequate lighting in preparation and cooking areas affects the degree and presence of contrast in kitchens (Table 10.11). While proper lighting in the cooking areas can speed up work and raise accuracy, deficient lighting can make cooking troublesome and raise the probability of accidents.

10.5 Lighting maintenance plans

All the kitchens in this study followed corrective maintenance, where light bulbs and fixtures are repaired or replaced after wear, malfunction or breakdown. An important correlation between clean lights and adequate lighting in cooking areas is proved. Preventative or scheduled maintenance, where equipment or facilities are inspected, maintained and protected before breaking down is recommended for the maintenance of the brightness of lights to circumvent low lighting levels because of dullness of bulbs in kitchens.

Using EFA, maintenance reveals a factor loading of 0.752 and is categorised into Component 3 (conservation). The opinions of head chefs denoted that 73.5% of kitchens had adequate light (Figure 10.2). Only one kitchen had drastically low lighting, in tune with the theme of the restaurant. The p-value is 0.595 for the correlation between ‘the amount of light in the kitchen being adequate’ and ‘all kitchen equipment is in good repair’ with a significance level of 0.001. There is also a positive correlation between ‘adequate light in the kitchen’ and ‘all the equipment is in good repair’, with a p-value = 0.595 and a chi-square value of 33.52 and p = 0.000. Whereas over 87% of the respondents claimed that there was no problem with lighting, 12% believed that changing globes would solve the problem of lighting (Figure 10.6).

Food-service workers believed that maintenance of lighting is adequate. According to Standard (2019), lighting fixtures must be resistant to a variety of conditions such as escaping steam, smoke plumes, grease and food splatter. Light bulbs can be a source of injury in a commercial kitchen fire. As temperatures rise, bulbs can explode, sending fragments flying at high velocity, and workers can be in danger of being injured by these high-velocity shards.



Source: Author's own work.

FIGURE 10.6: Options to solve problems of kitchen lighting.

Maintenance plans are adequate but need further improvement to improve vision for older staff and provide local or task-lighting in specific work areas. Figure 10.3 indicates that 95% of the staff agreed that regular maintenance of lighting takes place in their kitchens.

10.6 Conclusion

In conclusion, Chapter 10 began with lighting levels in the kitchen, natural and artificial lighting, and effective lighting in work areas. Thereafter, correlation in lighting areas and correlation for headache was expressed. Staff were unaware of the brightness of light, and task-lighting was not a common feature in commercial kitchens. Age is an important factor in adaptation to light; however, additional lighting was not provided for elderly staff. Although familiar with the presence of contrast and glare, the kitchen workers were unacquainted with the occurrence of flicker. The next chapter proceeds with a summary of the study and recommendations.

Chapter 11

Conclusion and recommendations

11.1 Introduction

The final chapter summarises the main findings, provides absolute deductions based on the analysis and interpretation of the data and suggests a way forward on how the study objectives in the commercial kitchen environment are addressed. Although this study was restricted to Durban, South Africa, the findings are of general importance in all countries with similar climatic conditions.

This study set out to investigate the impact of heating, lighting, acoustics, ventilation and humidity on the IEQ and the well-being of food production workers. The study provides a nuanced description of an underexplored research area, the inherent challenges and its potential. The central research aim has four objectives.

11.2 Summary of the theoretical alignment

This study set out to investigate the impact of heating, lighting, acoustics, ventilation and humidity on the IEQ and the well-being of food production workers. The summary that follows will clarify the alignment of the primary study with the prevailing theory.

How to cite: Gangiah, S 2022, 'Conclusion and recommendations', in *Environmental ergonomics Commercial kitchens in a semi-tropical city*, AOSIS Books, Cape Town, pp. 237–274. https://doi.org/10.4102/aosis.2022.BK346.11

11.2.1 Heat

The general evaluation criteria for thermal comfort are often used in other work areas. For example, the adoption of Fanger's standard PMV or PPD index common to office environments could not be applied in commercial kitchens. The HAM was adopted in the study because a functional commercial kitchen comprises combinations of high activity levels, high air temperatures and high radiant temperatures that render Fanger's standard unsuitable for application in commercial kitchens.

Thermal comfort is predicated by individual factors comprising age, gender, WBGT, fitness, acclimatisation and ethnicity, and the type and scope of kitchen activities. The latter comprises cuisine, style of service, the volume of meals prepared, number of plated meals and peak activity time.

The theory posits that the cooking equipment's range, type and size affect the heat generated in the kitchen. Extra-heavy-duty equipment cooks at a higher temperature and produces radiant heat, as experienced by workers near traditional kilns and tandoors.

In the summer months, heat and humidity, according to the theory, are severe in kitchens without air-conditioning or vents in the kitchen. The minimum and maximum discomfort indices indicated that staff in Durban kitchens are uncomfortable during peak periods of business. Higher levels of humidity, especially during peak periods, raised kitchen temperatures.

11.2.2 Ventilation and humidity

The flow of fresh air is undisputedly a feature of good ventilation. Consistent with theory and further to the kitchen location, kitchen airflow in this study was mediated by combinations of open back doors, open windows, open front doors, hatches, fans, air coolers, air conditioners, whirlybirds, chimneys and extraction systems. However, these have limited ability to remove kitchen heat and fumes, especially in urban areas. Natural ventilation is further beset by challenges, such as the irregularity of airflow, because of the wind forces being either unreliable or inadequate. Nonetheless, coastal Durban has reasonable airflow that could be harnessed in the kitchens. The wind-power potential in the general Durban region is considered moderate.

Kitchen airflow was facilitated by mechanical means and fenestration design. Theory points to airflow slower than 0.5 m/s as pleasant and comfortable at an airspeed of about 0.25 m/s. In this regard, 12% of the kitchens that had no airflow at all in some work areas are unsatisfactory. Prior empirical studies indicate that indoor air distribution determines IAQ and human comfort.

Airflow into kitchens was assisted by openings, along with an open-plan design that maximises cross-ventilation. High ceilings and large corridors in kitchens facilitated air movement. Closed doors obstructed the kitchen airflow, whereas NV was improved by open windows. Fans and whirlybirds assist with NV. According to theory, air curtains are beneficial in kitchens, while air vents and air-conditioned cool air help to mitigate staff discomfort from heat and humidity.

Authoritative literature points to the influence of design with respect to kitchen area and volume, the number of diners, volume of food cooked, cuisine, air infiltration and density of workers in the kitchen on airflow, features equally reflected in this study. The measures of the staff–space ratio were prominent for their variation from 2.67 to 21.23.

The type of cooking equipment, ingredients, recipes and procedures, fuel types, temperature and ventilation equipment used are cited in theory to affect the extent and composition of emissions generated during the cooking process. This study confirmed that the widespread use of gas and electricity generates higher emissions of CO_2.

Along with fumes and moisture, the measures of CO_2 had mean values within 1000 ppm, although the values ranged from 403 ppm to 2155 ppm. The measure of CO_2 concentrations, according to the literature, is a primary indicator of air quality, and inadequate ventilation leads to elevated CO_2 levels. Beyond the visibly higher levels of smoke and fumes during peak periods, CO_2 concentration was substantially higher (>1000 ppm) from the use of gas flame grillers and tandoors.

There is conclusive evidence from the theory that fuel and equipment used for cooking affect the humidity in the kitchen. Humidity in commercial kitchens in Durban was also influenced by climatic conditions, with higher RH levels near cooking and dishwashing areas. More than 10% of kitchen managers felt that Durban kitchens were humid, and 15% felt that it was sweaty in the kitchen.

Thermal perception is the temperature as ‘felt’ by the body of workers and is affected by humidity levels. The food-service workers exhibited symptoms of heat stress and heat strain, such as tiredness and intense thirst, with 23.5% demonstrating a decrease in attention and or irritability.

The need for attention to the design and location of exhaust hoods for effective kitchen ventilation is imperative. Humidity and temperature, according to theory, increase if the hoods are not able to capture all the thermal plumes. Also, foul air extraction was found to benefit during the expelling of thermal plumes and can prevent mould growth. Incorrect specifications of extraction systems reduce tolerable levels of fumes, grease and moisture. Some of the overhangs were extremely small (0.06 m) because of the Chinese design; the size of the extractors seemed to be inadequate

(2.10 m) in two kitchens, as cooking equipment extended beyond the hood length. A hood overhang of 0.1 m is a requirement in Chinese kitchens.

Good maintenance standards and procedures are a pivotal requirement for better ventilation and humidity management in kitchens. It is established that ventilation was insufficient to maintain optimal humidity levels and good air quality because of an inverse relationship between maintenance and air quality.

People felt comfortable at an airspeed of about 0.25 m/s or 15 m/min and that airflow slower than 0.5 m/s felt pleasant. Airspeeds less than approximately 0.1 m/s as conveyed in literature will usually cause a sensation of staleness and stuffiness, even at relatively low temperatures. The findings in Section 8.3 similarly recorded that 56% of the workers complained that ventilation was inadequate in the kitchens, and the mean airflow rates in the dishwashing and oven areas were particularly low. Prior theory recommends an airspeed of 1.2 m/s at 30 °C with a RH of 80%.

Durban, with a subtropical climate, is known for high humidity levels that cause discomfort. The RH levels in the kitchens ranged from 32% to 74.4%; the high value was because of rain during the field study. The maximum RH values exceeded 60% and were as high as 89.5% near ovens. Staff complained about humidity, such as sweat not drying (30.3%), uniform being wet (12.1%) and stickiness (6.0%).

11.2.3 Noise

The literature contends that noise is generated from food preparation and that cooking with food-service equipment added to the noise in the kitchen. The average noise levels across cooking areas ranged from 70 dBA to 80 dBA. While kitchen workers are vulnerable to these noise exposures, they accept it as part of occupational risk.

The literature, as expected, points to noise and poor acoustics hindering communication. Kitchen workers found difficulty in communicating with other kitchen workers. This situation as described in prior studies could have been exacerbated by NIHL; however, it was not present in the kitchens.

Amongst the kitchen workers, the theory points to dishwashing staff at risk for overexposure to noise. Ware washers have the highest exposures to noise in this work environment. As well, 33.3% of the kitchen personnel were dissatisfied with the noise from dishwashers, with a mean noise level of 76.35 dBA.

Extractors, according to the literature, produce continuous noise during operation in the kitchen. In catering enterprises, kitchen staff were exposed to noise from different sources, including the extractors, with noise levels ranging from 70 dBA to 83 dBA. Improved maintenance of HVAC can reduce noise in kitchens.

More than 70% of kitchens had a weekly maintenance program of equipment that helps to lower noise levels in kitchens. Preventative maintenance, in theory, prevents breakdowns and ensures that equipment is 99% operational and safe to use.

Age, according to the literature, is associated with hearing loss, and NIHL is prevalent most amongst individuals over the age of 65 years. Amongst personal factors, age is the most important in adapting to noise.

11.2.4 Lighting

According to theory, bright and direct lighting is required in all food preparation, cooking and dishwashing areas. Workers were found to be more alert, less fatigued and more energetic in the bright light conditions, as it decreases sleepiness and improves psychomotor vigilance performance. The complete disparity in Section 10.2 indicates that some kitchens did not have adequate lighting levels and it affected workers, who strained to work and sometimes even developed headaches.

Organisations lack training in ergonomics that would benefit workers, according to theory. The importance of the qualitative nature of lighting, such as contrast, glare and colour in relation to kitchen work, was frequently not sufficiently appreciated. Most kitchen staff are unaware of good lighting, even though insufficient lighting can cause eye strain and headaches amongst workers. Section 10.4 affirms that 68% of the kitchens had unsatisfactory task-lighting and contrast, glare and flicker are controlled.

The literature contends that older workers have higher lighting needs. An average 60-year-old person's eye requires three times more illuminance than an average 20-year-old person's eye. Complaints of inadequate lighting over kitchen work surfaces are common among elderly people. Section 10.4 disclosed that 76% of the workers felt that the lighting needs of older workers were met, although the older staff complained about visual discomfort.

However, Section 10.5 revealed that food-service workers believed that maintenance of lighting was followed adequately. Improper lighting installation and the adequacy of lighting maintenance in the workplace were shown in the literature to affect the health and safety of people.

11.3 Summary of the empirical study

An empirical study is the collection and analysis of primary data based on direct observation or experiences in the field. It is a way of gaining knowledge by means of direct and indirect observation or experience (Anguera et al., 2018). The empirical evidence will be summarised in this section. The quality of the data, as elucidated in Chapter 6 (ss. 6.4, 6.5 and 6.6), confirm that the quantitative and qualitative measures have been met to validate the quality of the study. The triangulation of the various data collection techniques and statistical data analysis offered ample evidence of the accuracy of the data collected.

11.3.1 Heat

More than 98% of kitchen workers prefer Durban weather and feel comfortable in its subtropical coastal climate. Notwithstanding, a high discomfort index (mean values of 100 to 105) from the heat was observed in most kitchens. The discomfort index values for dishwashing areas (98) are lower than for cooking areas (103) because of the absence of radiant heat. During summer, heat and humidity are severe in nine kitchens, as no cold air is pumped into kitchens without air conditioners or vents. Of these, five kitchens use whirlybird installations to reduce the heat load in the kitchens.

The heat from ovens and dishwashers contributes to the increase in temperature in the kitchen along with the heat from the stoves, $p = 0.011$ and $p = 0.015$. The relationships with air conditioners ($p = 0.00$) and domestic fans ($p = 0.031$) indicate that the greater the number of cooling equipment, the lower the heat experienced near stoves. There is strong evidence to conclude that the variables are negatively associated. The most common physical symptom of heat in kitchens is heavy sweating, with $p = 0.003$. Psychological symptoms displayed included the use of foul language and, as $p = 0.008$, there is strong evidence to conclude that the variables are associated.

Head chefs declared the kitchen staff's socio-economic status to contain factors influencing their ability to cope with kitchen heat and to include work experience (47%), age (35%) and correct body weight (14.7%). Regarding demography, race (37.5%) and fitness (70%) were advanced as mediating factors in coping with heat, with 20.6% accepting fitness as the highest influence on coping with kitchen heat. Exploratory factor analysis further revealed a factor loading of 0.780, 0.850 and 0.554 for gender, race and fitness, respectively, amongst factors influencing coping with kitchen heat.

As anticipated, cooking emerged as the primary and highest generator of kitchen temperature. Thermal strain on workers existed in commercial kitchens across load spectrums, with the preparation cook or line cook encountering extreme heat. A noteworthy feature in the sample is that a particular menu does not need the presence of stoves in kitchens, as the cooking method has changed. Light-duty load appliances, such as pizza conveyor ovens in pizzerias, were used to prepare pizzas without utilising any other cooking equipment; conventional stoves were lacking in these kitchens.

A range of factors affected the heat experienced by kitchen workers, particularly those near stoves. The primary factors revealed in the statistical analysis were kitchen height, red face and sweating symptoms, discomfort index, space ratio and state of the uniform. The grillers and bakers of the kitchen brigade are particularly heat-exposed.

'A regression model' showed that the equation for dependent variables, titled secondary factors affecting heat near stoves, helps to compose indoor environmental criteria for the design of restaurant kitchens. The implications from the model proved that these variables are strongly associated, $p = 0.039$ for job position; $p = 0.045$ for years of employment; $p = 0.024$ for worker shift; and $p = 0.012$ for type of kitchen. One of the best-fitting linear regression models for predicting heat near stoves is a linear combination of the type of kitchen, job position, years of employment and worker shift. For every unit increase in heat near stoves, a 2.013 unit increase in discomfort index value was predicted, holding all other variables constant.

The preparation zone of kitchens practising East Asian cuisine was recorded as having the highest temperature of 31.85 °C, which was attributable to the high wok cooking temperature. Italian cuisine kitchens have brick kilns that increase operative temperature near wood-fired ovens to a mean of 31.4 °C.

All the areas in the cooking zone in food-service operations, particularly in extra heavy-duty load kitchens, had temperature ranges from 30.66 °C to 32.20 °C (fryers) in the study. Grillers experienced higher mean temperatures of 33.75 °C, and 97.1% of the workers in this group were reported as stove exposed. Almost 70% of the kitchen workers claimed that food preparation produces heat with a high temperature of 31.85 °C, and kitchens are hot.

Seventy-five per cent of the kitchen workers claimed that the kitchens were extremely hot during maximum kitchen capacity utilisation. Almost 41% of kitchen staff found the thermal environment uncomfortable. Measures of humid areas indicate that it is uncomfortable near stoves and dishwashers. More than 15% of chefs on duty were observed to be red-faced. Another model for predicting heat near the stove is a linear combination of symptoms of red face amongst kitchen workers and discomfort index (heat from stove or oven). Another stepwise regression model for predicting heat near the stove is a linear combination of South African Indian, black South African, area of the kitchen, output in the number of meals per day and other cuisines.

The best-fitting linear regression model for space and heat experience indicated that for every unit increase in area, a 1.3 unit decrease in heat experience near the stove area is predicted, holding all other variables constant, provided this increase in space is not occupied and permits air movement to dissipate heat. Considerably more head chefs and kitchen managers (86.7%) indicated that the kitchen area was less than 100 m^2 ($p < 0.001$).

Factors involving genotypic and phenotypic heat response characteristics amongst kitchen workers include the shape of nose, skin colour and type of hair. Almost 89% of kitchen workers were Africans with funnel noses (64.4%).

Medium-brown skin tone was most frequently observed amongst kitchen workers (54.7%) belonging to African and Indian races. However, no relationship was found between skin colour and heat tolerance. Almost 48% of African workers had dreadlocks, hair extensions, and hair weaves – elaborate synthetic hairstyles were observed amongst 28%. Phenotype features include body stature. Almost 65% of men had mesomorphic body types, whereas 55% of women had endomorph body types. Heat tolerance was affected by body mass index and not absolute body shape.

Against the raised thermal conditions in the kitchen, worker discomfort from excess hair was indicated in 64.2% of respondents. In this regard, 76.5% perceived that a shaven head would make working in the kitchen more comfortable.

The correlation $p = 0.000$ is significant between the kitchen worker's uniform and the number of meals cooked per shift. A chef's uniform can prevent heat dissipation. The greater the meal output, the greater the discomfort from workers' uniforms.

A strong correlation was indicated with $p = 0.040$, significant between kitchen workers' perceptions of ventilation in their work kitchen as either inadequate or satisfactory and using an air conditioner in their residence. Using an air conditioner at home after work is likely to help staff cool off and come to work well-rested.

Sweating is a common response to thermal discomfort and kitchen workers' tiredness and intense thirst. Several kitchen workers (23.5%) were observed to suffer from a decrease in attention, confusion (14.7%) and loss of concentration (8.8%), even though more than 50% of head chefs denied any psychological symptoms because of excessive heat. Kitchens also reported impaired perception and impaired thinking (2.9%). Symptoms of heat strain were observed amongst 14.7% of staff.

11.3.2 Ventilation and humidity

11.3.2.1 Ventilation

Air movement in the kitchens was attributable to a combination of NV and fans. Approximately 79% of the kitchens had deliberate inclusion of NV in the design. The sea breeze of coastal Durban was observed to improve airflow through large open doors and windows in the kitchens. High-velocity heavy-duty industrial fans in 24% and turbine ventilators in 18% of the kitchens compensated for shortfalls in airflow.

The ample kitchen ceiling height, with a mean of 3.03 m and a maximum of 4.17 m, enabled airflow. Two kitchens with especially large corridors were effective in channelling and delivering airflow into parts of a building. The practice of open kitchen doors in 55% of kitchens permitted airflow of 0.10 m/s to 2.5 m/s that helped reduce ambient temperature and eliminate stuffiness. Additionally, the half-walls used in zone partitioning in two kitchens permitted air distribution.

However, common to kitchens was that 30% of the kitchen workers considered the workspace inadequate, and the reported low rate of airflow is questionable. The area of the kitchens varied between 17 m^2 and 334 m^2, and the mean value was 68.41 m^2. The calculated volume of kitchens ranged from 43.58 m^3 to 426.05 m^3.

Airflow was mediated by measures of kitchen air velocity ranging from 0.00 m/s to 2.5 m/s. Less than 60% of the kitchens had an adequate airflow rate of 0.5 m/s in all kitchen areas. About 56% of the kitchen workers complained about inadequate airflow, as 12% of the kitchens had no airflow at all in some areas. Almost 27% of the kitchen workers complained that airflow was inadequate over peak periods, and 33% of the workers affirmed that the ventilation was ineffective.

Domestic and heavy-duty fans pushed the thermal plume in 35% of the kitchens into the cooker hood. Nonetheless, almost 59% of the workers experienced thermal discomfort because of poor airflow.

The variation of the kitchen workspace ratio to a high density of 21.23 is unfavourable for individual ventilation needs. The number of kitchen workers on the same shift varied from 4 to 17.

The measure of toxic compound levels of kitchen emissions of CO_2 ranged from 401 ppm to 2 517 ppm. About 70% of kitchen-emitted CO_2 within published guidelines of 1000 ppm, whereas kitchen zone measures indicated that 80% of the different kitchen areas had CO_2 levels below 800 ppm. The presence of CO_2 in the sample frame was observed to be affected by the efficiency of extractors, draughts and the layout.

11.3.2.2 Humidity

The RH peaked at 60% in most kitchens, and 12% of the kitchen managers affirmed that existing ventilation was deficient in maintaining optimal humidity levels and good air quality. The raised humidity levels in cooking and dishwashing areas increased thermal strain in 40% of the kitchens.

The use of partial eta (η) revealed that cooking fusion cuisine has a medium to large effect on humidity, whereas East Asian cuisine has a small effect. Fusion cuisine obtained a higher value of $\eta = 0.091$, a value close to 1, indicating a high degree of association; however, East Asian cuisine obtained a lower value of $\eta = 0.027$.

As regards the effect of height on humidity, the best-fitting predictive linear model indicates that for every unit increase in worker height, a 0.161 unit decrease in humidity experience near the stove area value is predicted; this may be explained by the shorter chefs observed to work closer to the stove.

A further multiple regression equation of predictor variables for humidity near stoves confirmed that genotype or ethnicity, mechanical devices for ventilation and physiological and psychological symptoms lead to heat stress.

Draughts from fans caused discomfort and could be prevented by lower fan speeds, as observed in the three kitchens. Three commercial kitchens had installed perforated perimeter air supply to cool off the chefs without any draughts. However, the system was functioning only in kitchen 6. The correlation between adjusting oscillating fans and clean oscillating fans was statistically significant r [13] = +0.698, $p = 0.008$, two-tailed, which means that kitchen workers have access to clean fans.

The minimal use of gas as fuel means less CO_2 released and less humidity in kitchens; the wet floors will accordingly dry faster. In this regard, the best-fitting model for predicting humidity near stoves is a linear combination of 'floor is dry or wet'. For every unit increase in dry floor, a 359.179 unit decrease in CO_2 near stove areas may be expected, holding all other variables constant.

11.3.3 Noise

Beyond the noise from regular cooking activities, kitchen noise was observed to stem from kitchen appliances and verbal communications between the cooks. External noises were negligible and, therefore, not accounted for in the study.

The continuous drone of extractors constitutes continuous noise, whereas recorded cooking equipment noises were in continuous, intermittent and fluctuating combinations. The whistling of equipment, such as boilers and pressure cookers, constituted 10% of fluctuating noise. The highest intermittent noise was estimated to be 35% from staff talking.

The mean noise values across different kitchen areas ranged from 43.2 dBA to 76.35 dBA. Potato peelers and salad dryers in the food preparation zones of the three kitchens were the source of noise levels higher than 80 dBA. The cooking zone noise ranged from 53.20 dBA to 75.26 dBA. Most kitchen stoves emitted noise levels ranging from 64.00 dBA to 85.50 dBA, with higher emittance from gas stoves and lower values from electric stoves. Fryers and grillers recorded mean noise levels of 68.19 dBA and 53.20 dBA, respectively. Almost 10% of the head chefs subjectively ranked gas stoves, boilers and steamers as notable sources of noise in kitchens, followed by ovens and fryers. Exploratory factor analysis revealed the component named 'noise index' for noise from ovens, boilers and steamers, gas stoves and fryers. The highest loading of 0.897 for gas stove noises indicates its dominant influence on the variable.

Furthermore, factor loadings of 0.612, 0.917 and 0.900 were observed for 'unable to communicate', 'grinders making too much noise' and 'noise from fans', respectively, with noise from grinders being the most influencing factor on the noise levels in the preparation area and contributing to the discomfort element. Factor loadings were used as correlation coefficients between observed variables, such as noise in the preparation area, and common latent factors, such as discomfort elements. Another EFA revealed a factor loading of 0.877 and 0.877 for a dishwashing machine producing noise and heat, respectively. The significant p-value −0.649 indicates that the kitchen workers were unable to communicate with co-workers because of noise levels in the kitchens. Similarly, staff were unable to communicate with co-workers because of noise in the kitchen, having a $p = 0.504$ with a significance level of 0.002, with staff complaining about noise in the kitchen.

The holding areas in the sample frame exhibited negligible noise, with a mean of 71.53 dBA. Intermittent raised levels were, however, recorded for the ringing of orders at a high of 82.5 dBA.

The highest noise levels were in dishwashing areas, with a mean of 76.35 dBA and noise levels ranging from 65 dBA to 79.8 dBA. In this regard, the noise of the wash cycle was perceptible in 17% of the kitchens. The use of dishwashing machines was confined to 36.4% of the kitchens, with 33.3% of the kitchen personnel expressing discomfort with the noise from dishwashers. Notably, in 51% of the kitchens, the noise from extractors was greater than 40 dBA, with the higher noise levels ranging from 70 dBA to 83 dBA. A strong negative correlation ($p = -0.894$) was achieved between noise from air conditioners and noise from HVAC systems, with a significance level of 0.041, denoting that both pieces of equipment in a kitchen need not be noisier.

The interviews revealed that 11.5% of the workers thought that higher noise levels in kitchens were a problem and that they could be prone to hearing loss. Head chefs' specific criticisms of kitchen noise were approximately 70% concerning blenders and grinders, 58% of extractor noise and 85% about stoves and fans. Almost 47% of the kitchen managers responded that the kitchens had no problems with noise.

The effect of partial eta-squared ($\eta 2$) indicated that while reaction to stove noise is affected mildly by the age of the worker and race, a moderate effect is observed by the gender of the kitchen worker, varying widely between men and women.

11.3.4 Lighting

Almost 95% of kitchens used fluorescent lights in all the kitchen areas, except in pick-up sections and some canopy hoods of cooking areas. Pick-up sections used infrared lamps, ultraviolet lamps and sodium lamps; canopy hoods of cooking areas used incandescent globes.

The lighting design in kitchens was found to be poorly planned in 36.4% of the sample frame, as was evidenced by inadequate lighting in kitchen areas. Less than 50% of the kitchens were found to have adequate lighting in cooking areas. Additionally, the lack of local lighting in 70% of the kitchens suggests inadequacy in the number of light sources.

The researcher's appraisal revealed that 85.2% of the kitchens with no skylights had unsatisfactory lighting in some kitchen areas; more than 21% of the kitchens had unsatisfactory natural light. Less than 50% of the kitchens had adequate lighting in cooking areas. The result of the EFA revealed factor loadings of 0.955, 0.932 and 0.895, respectively, in preparation, cooking and dishwashing areas with regard to lighting in the kitchens. These loadings indicate the extent of relevance of these areas in explaining the influence of lighting levels in kitchens, with lighting in preparation areas having the most influence on area illumination. The correlation undertaken between adequate lighting in food preparation areas and adequate lighting in cooking areas was found to be statistically significant, r (32) = +0.677, p = 0.001, two-tailed. This is a positive indication of worker lighting comfort in kitchens.

An illuminance of 204 lux in almost 43% of the kitchens constitutes adequate lighting in cooking areas, mainly from lamps inside the canopy hoods. However, the dishwashing areas in almost 17% of the kitchens were inadequately illuminated.

The association of the presence of natural light and skylights in a mathematical model improved lighting in preparation areas (Table 10.6). The escalation of the lighting measures to a multivariate regression model revealed the association of human well-being in the workplace (headaches) with a preventable cause (clean lights and fixtures). For every unit increase in clean lights and fixtures, a 112.08 unit increase in lighting in the preparation area was predicted, holding all other variables constant (s. 10.5).

The maintenance of lighting sources varied. While a higher 71% of the kitchens had clean bulbs, approximately 66% of kitchens had clean fixtures. Almost 18% of kitchen workers assumed that the light bulbs were not cleaned regularly. Visual discomfort, strain and weakened eyes were likely in the kitchens' flickering lights of 3.6%.

The component 'good maintenance' was elicited from three loadings of 0.875, 0.752 and 0.693 for equipment in good repair, adequate lighting and installation that entails regular maintenance compliance for better lighting in kitchens. The correlation between all the kitchen equipment being in good repair and work experience was statistically significant, r (33) = +0.591, $p < 0.001$, two-tailed, implying that kitchen managers strongly agreed that all the kitchen equipment was in good repair. The correlation between clean lights and adequate lighting in cooking areas was found to be statistically significant, r (30) = +0.592, $p = 0.001$. The p-value was 0.595 for the correlation between 'the amount of light in the kitchen which the researcher considers to be adequate' and 'all kitchen equipment is in good repair', with a significance level of 0.001. There was also a positive correlation between 'adequate light in the kitchen', and 'all the equipment is in good repair' with a p-value = 0.595 and a chi-square value of 33.529 and $p = 0.000$.

The presence of task lights and low ambient light in some spots created contrasting lighting effects in 9.1% of the kitchens. The control of contrast and glare was evident, as less than 4% of the kitchens exhibited such spots. About 91% of the head chefs and kitchen managers affirmed that their kitchens had shadow-free work areas. Exploratory factor analysis further generated factor loadings of 0.482, 0.947 and 0.947 for variables such as lights protected, presence of task light and presence of infrared light in the kitchen. The latter two variables have the most influence on precise fixtures. 'Staff complains about the contrast in the kitchen' had a negative correlation with $p = -0.480$, and 'inadequate lighting in the kitchen' had a fair correlation with a significance level of 0.004. 'Staff are happy about lighting in the kitchen' with $p = -0.480$ had a significance level of 0.004. Common magnitudes in the social sciences are low to moderate communalities of 0.40 to 0.70 (Costello & Osborne 2005). The fewer the staff complaints about light contrast in the kitchen, the higher the incidence of adequate lighting in kitchens, with staff being happy about it.

The mean opinions on lighting between kitchen workers and their supervisors differ substantially. Whereas only 73% of the workers felt that the VC at their workplace was satisfactory and free from glare, reflections and contrast, a higher 93.9% of the kitchen managers believed that employees could comfortably see their work without straining their eyes.

There were insignificant correlations for items related to the negative effect of glare, a deduction evidenced by 93.9% of the kitchen managers indicating that employees could comfortably see their work without straining their eyes. Nonetheless, almost 7% of kitchens exhibited indirect glare, and only 1.2% of the kitchen workers complained about the glare; 73% confirmed glare-free lighting.

The analysis indicated that *p*-value was 0.739 with a significance level of 0.001 and chi-square statistic of 66 for correlation between the staff complaints about the contrast in the kitchen and staff complaints about the glare in the kitchen. Sixty point six per cent of the kitchens had no direct glare; only 3% had direct glare.

Up to this point, the study attempted to explore environmental ergonomics in restaurant kitchens in Durban as influenced by kitchen conditions of heat, lighting, acoustics, ventilation and humidity. In doing so, it is hoped that the study provided a nuanced description of an underexplored research area, the inherent challenges and its potential. This section will provide a summary of the alignment of the study with the four objectives.

11.4 Objective 1: To examine indoor airflow, humidity, lighting and acoustics in restaurant kitchens

This objective set out to assess the influence of indoor airflow, humidity, lighting and acoustics as environmental ergonomic parameters in commercial kitchens in Durban.

11.4.1 Ventilation and humidity

The use of NV and the selection of mechanical devices to cope with indoor airflow and humidity emerged as vital components in kitchen ventilation and humidity management. Safe opening of back doors assists airflow and improves kitchen ventilation. Kitchens must install whirlybirds on their roofs or the sidewall even in a crowded city, as they remain operational in the absence of wind flow. Management of high humidity in coastal restaurants necessitates the installation of a dehumidifier near preparation, cooking and dishwashing areas. Kitchen fenestrations can be placed on the windward side, providing NV that can supplement MV. Given the close attention to NV, a considered specification of operable windows, doors, ceiling heights and vents is indispensable.

High ventilation rates to maintain thermal comfort and air quality are especially needed in compact kitchens or higher-density kitchens. Kitchens should be designed with optimal ceiling height to allow NV during free runs in uninsulated buildings. The provision of a large corridor in the building complex will facilitate greater air movement in kitchens. A PPS unit with a lower airflow rate fitted to heavy-duty equipment decreases heat emissions and hence reduces thermal discomfort. Grilling and broiling units should not be at the end of the hood. The electric equipment is a cleaner fuel with lesser discomfort levels.

Extraction techniques that trigger increases in the volume of displaced air and enhance airflow ventilation rate at a minimum of 0.5 m/s improve comfort. The ineffectiveness of canopy hoods is attributable to their installation exceeding the optimal of 60 cm. Extractors must run at maximum for a short time after cooking to exhaust heat and pollutants efficiently. In fact, these should run at maximum flow rate during and after busy periods (Sjaastad 2010). An overhang of less than 60 cm overwhelms existing cross-ventilation.

11.4.2 Noise

The installation of kitchen noise-absorbing materials can be fixed under worktables, shelves and cupboards, echo-absorbing insulation to its ceilings, noise-catching aluminium ceiling panels and soundproofing treatments on the doors and soundproofing paint on the walls. Maintenance contributes substantially to noise control in kitchens with extraction systems across kitchens and mechanical equipment.

11.4.3 Lighting

Inadequate attention to kitchen lighting is a significant contributor to eye strain. Management of glare, contrast and reflections offers VC in kitchen work. Kitchens should have access to sunlight for a better worker attitude. The effective maintenance of natural and artificial lighting sources is a key contributor to VC. A loss of light intensity occurs because of the accumulation of dirt and dust on fittings and fixtures.

11.5 Objective 2: To determine the thermal environment and heat stress amongst food production workers using gas and electrical kitchen appliances

Improvement in the kitchen environment can occur because of the introduction of electric stoves instead of the use of gas stoves.

11.5.1 Kitchen thermal environment

Heat production in the sample frame is influenced using equipment, cuisine (menu and cooking methods), individual human factors and activity. Kitchens with extra-heavy-duty equipment have higher ambient temperatures and emissions, as per IMC (2015). The cook-serve method is very popular in restaurant kitchens.

The cooking fuels in the kitchens vary with the cuisine on offer. Cuisines prepared by stir-frying with gas stoves are key to higher temperatures in kitchens. Indian cuisine kitchens use gas stoves for all cooking except frying. The cuisine varies widely in casual, institutional and QSR kitchens. The mean values indicate that WBGT is highest near electric ovens (27.28 °C) in the casual restaurant kitchens, whereas grillers (30.40 °C) record higher values in institutional kitchens and fryers (30.16 °C) in quick-service restaurants. The number of meals cooked per day and heat generated from the equipment impact the heat produced.

Staff in kitchens express a higher number of complaints because of a lack of vents, diffusers, or air conditioners in the kitchens. The WBGT ranged from 27.13 °C to 35.58 °C. As per ILO regulations, this is much higher than the permissible limit of corrected effective temperature ranging from 23.0 °C to 25.0 °C. The thermal experience by chefs is found to be associated with job position, work shift, type of kitchen load, years of employment and race. The best-fitting model for predicting heat near the stove is a linear combination of the type of kitchen, job position, years of employment and worker shift. Heat experienced by kitchen workers near stoves is influenced by the kitchen ceiling height, staff–space ratio and state of staff uniforms. Thirty-nine per cent (39%) of chefs and kitchen managers respond that humidity is high, and more than 48% indicate that staff complain about humidity.

11.5.2 Effect of gas and electrical appliances on heat stress

The HI in kitchens indicates discomfort and even heat stress at a WBGT index of 26.8 °C. The food-service workers are uncomfortable during peak periods of business, pointing to greater heat stress levels during this period. Almost 74% of the energy produced on an electric range transfers to food, compared with about 40% on a gas range, whereas induction cooktops transfer up to 90% of the energy to food. While only 15.2% of the workers are ‘red in the face’ from the heat in cooking areas, the statistic could be misleading, as 78% of African workers are dark in complexion because of ethnicity, which is not apparent. Some Indian chefs are also dark in complexion.

More than 45% of the kitchen workers show physical symptoms of heat stress from electrical and gas equipment. However, 18% of the supervising head chefs reported that they did not experience heat stress. Approximately 57% of kitchen workers in this study reported that they sweat in the work environment. Sweating is obvious amongst 11.1% of staff. Heavy sweating, along with headaches, was reported by 3% of workers reported heavy sweating and headaches. The most prevalent consequence of heat stress is reported to be manifested in tiredness and intense thirst, commonly experienced by 35% of kitchen workers. Notable amongst the kitchen workers, 23.5% suffered from a decrease in attention or irritability, 14.7% from confusion, 8.8% from loss of concentration, and impaired perception and impaired thinking are each reported at 2.9%.

11.6 Objective 3: To investigate the perception of food production workers' adaptability to selected indoor environmental conditions

An increase in understanding of individual adaptability will contribute to a better understanding of employee behaviour, performance and well-being in complex and changing work environments.

Specific factors raised by kitchen worker supervisors regarding their subordinated workplace adaptability to heat are revealed as age (59%), task experience (47%), fitness (20.6%) and body weight (14.7%). The race of workers was also raised by 37.5% of the kitchen worker supervisors as important in the ability to adapt to heat in the kitchen. Exploratory factor analysis located the socio-economic index, with loadings of 0.801, 0.400 and 0.672 for age, work experience and correct body weight, as influencing kitchen heat adaptability.

Almost 86% of the kitchen workers believed that they possess fitness. Nearly 30% of head chefs or managers felt that fitness does not affect surviving heat in the kitchen; 70% felt that it plays an important role. Each female worker assumed she was 1.45 times physically fitter than she actually was, which helped the female worker cope better with heat, as this had a positive psychological effect. Shift times of kitchen work are likely to impact kitchen workers susceptible to raised body mass index. An estimated 47% of head chefs strongly agreed that kitchen work experience plays a substantial role in managing heat adaptability; also, years of employment contribute to work experience and acclimation to heat.

About 17.6% believed that tenure of work in commercial kitchens enables kitchen workers to see in lighting available in kitchens. While age is an important determinant of vision, only 8.8% believed it influences vision. About 76% of the kitchen workers perceived that the lighting needs of older workers were met. A majority of kitchen workers perceived that their workstations are free of glare, reflections and contrast, to the extent that 73% of the workers felt that the VC at their workplace is satisfactory.

The extent of noise discomfort is influenced by kitchen worker age, as 38.2% of kitchen managers perceived age as the foremost natural factor in adapting to kitchen noise. Understandably, age is a significant possible cofactor of NIHL. The role of work experience (41.2%) also seemed to be in psychological preparation for the expected kitchen noise level. Although 67% of kitchen workers indicated that they are unaffected by kitchen noise, 11.5% perceived that noise levels at their workplace might affect their hearing. Intermittent noise from blenders as a nuisance was reported by 91% of kitchen workers. Almost 6% of the head chefs perceived that gender affects adaptation to noise in kitchens. In fact, the perception of differences in noise tolerance is more attributable to race. Nearly 21% of the head chefs perceived that race is an important factor in adaptation to noise.

11.7 Objective 4: To compose indoor environmental criteria for the design of restaurant kitchens in Durban in respect of indoor airflow, humidity, thermal environment, lighting and acoustics

The upgrading essential to advance the kitchen environment is discussed here. The statements on criteria improvement will better assure worker well-being and overall comfort levels in commercial kitchens. The indoor environmental criteria for the design of restaurant kitchens in Durban is accordingly enumerated in the sections that follow, along with relevant rationales.

11.7.1 Indoor airflow

1. Maintain air velocity consistent at 0.25 m/s to 0.5 m/s in all areas of kitchen workstations.
2. The staff–space ratio must be no less than or at 13 m^2 per employee in any kitchen shift; a minimum of 2.25 m^2 of unimpeded space of open floor area is to be available for every employee working in an indoor workplace.
3. Determination of kitchen size based on restaurant seating is the most effective metric to inform airflow requirements.
4. Kitchens to be designed with provision for MM MV and NV.
5. Installation of PPS in cooking zones is necessary to prevent draughts in kitchens, instead of using fans.
6. The dimensions of the extraction hood overhang, the hood shape, hood alignment to cooking equipment and height of hood installation must be of equal importance to the hood design.
7. The installation of carbon dioxide detectors is necessary for commercial kitchens.
8. Heating, ventilation and air-conditioning systems or extractors must embrace the use of gas fuel emissions.

9. Proper upkeep of kitchen equipment is necessary to avoid unpleasant odours, as clean cooking equipment reduces fumes and extractors improve air quality.

11.7.2 Humidity

1. The provision of deliberately higher airflow rates in kitchens with those cuisines that generate higher humidity levels.
2. A dehumidifier is a requisite in commercial kitchens in tropical geographical areas.
3. The characteristics of workers near stoves are to be integrated into the humidity management plan.
4. Heating ventilation, air-conditioning, and extractors must account for the prevalence of gas-fuelled cooking equipment.
5. Establish protocols for special instruction to new and existing staff on behavioural adaptation to cope with humid heat.

11.7.3 Heat

1. The design of stove ranges must account for the kitchen worker's gender, age and race.
2. The prediction of heat near stoves must factor in the linear combination of the type of kitchen, staff job position, years of employment and worker shift: Kitchen staff perception of heat near stove = 35.341 + (−0.103 × job position) + (−0.091 × years of employment) + (−0.403 × worker shift) + (−0.722 × type of kitchen).
3. Specific aspects of worker physiology and the physical structure of the kitchen must inform the management of worker experience of heat near stoves. When the heat generated is left unchecked, the experience of heat near stoves = −6.795 + (−2.162 × symptom of a red face) + (0.446 × discomfort index). The experience of heat near the stove has an inverse relationship with symptoms of a red face. As a worker gains experience working in a hot kitchen, adaptation to heat leads to fewer symptoms of heat strain.
4. The management of worker experience of heat in the kitchen must be informed by specific personal factors and the work status of kitchen workers.
5. Maintain air velocity to 0.5 m/s in all areas to sustain lower temperatures.
6. The benchmark for the design of kitchens must be guided by ceilings no lower than 3 m.
7. The height of work counters must account for ethnic differences.
8. Cooling devices, along with extractors, must be installed in kitchens.
9. The use of electric and induction stoves reduces thermal discomfort.

11.7.4 Acoustics

1. Specific personal factors of kitchen workers should be accounted for in the acoustic design of kitchen workstations.
2. The variation of food production activities should be accounted for in the acoustic design of kitchen workstations.
3. The kitchen design must take cognisance of the cuisine and scope of menu items in different action zones.
4. Perception of acoustic design in kitchens must consider the type of food-service operation.
5. A scheduled maintenance system should be designed for corrective repair to ensure the equipment's consistent operation and reliability.

11.7.5 Lighting

1. The optimal balance of natural light and skylights should be derived for every kitchen area. Preparation area lighting = 108.121 + (134.058 × natural light) + (−104.870 × skylight).
2. A stringent cleaning routine should be followed. In this context, the study finds an association of headaches with a preventable cause, clean lights and fixtures, expressed in the equation: Lighting in preparation area = (−881.86) + (92.341 × headaches) + (112.088 × clean lights and fixtures).
3. Lighting design must take cognisance of the presence and extent of contrast in kitchens.
4. Lighting design must take cognisance of the existence and magnitude of natural light in kitchens.

11.8 Recommendations

As informed by research and evidence, the following recommendations for practice suggest prompt actions to be taken in commercial kitchens, particularly in the Durban area. These assist in worker well-being.

11.8.1 Ventilation

Kitchen fenestrations are to be placed on the windward side of a crowded city building or on the leeward side in an open space for NV. This supplements MV; moreover, windows strategically designed and left ajar will improve NV in kitchens.

Adapting ventilation systems, as per the IMC classification of extractors based on the heat load in kitchens and the required exhaust flow rate, will help maintain acceptable humidity and CO_2 levels in kitchens. The change will alleviate breathing problems, reduce odours and PM in the air, reduce mould growth and improve thermal comfort. Monitoring oxygen levels in kitchens is another important factor that indicates that carbon monoxide levels are within safe limits.

Ventilation rates in commercial kitchens should be based on the load generated by the kitchen equipment and accounted for in building codes and guidelines. Also, periodic preventative inspections of hoods on heavy-duty operations could be a workable way to reduce risks. Good quality of design and installation of extractors is essential.

Consistent with the IMC, 507.1.5, this study maintains that exhaust outlets should be installed to optimise the capture of PM. Each outlet should not serve more than a 3.658 m section of the hood. It is recommended that these be incorporated in South African municipality by-laws. Reclassifying kitchen extract systems as local exhaust ventilation would mean they are subject to more stringent regulation and inspection, which improves their ability to remove harmful fumes and organic compounds from the air. The management should maintain a planned schedule and regular follow-ups to check on the efficiency of the ventilation system and exhaust rate.

Besides the kitchen workload, ventilation systems should be designed according to the shape and layout of the kitchen; the cooking equipment used, based on cuisine; the number of kitchen staff; ease of maintenance; and energy efficiency. To attain optimum exhaust operation, modern kitchens often make use of variable-speed drive fans. These may use hood thermostats to assess the ventilation needs of a kitchen at a specific time. As they generally run slower outside peak times, they still maintain effective air exchange while significantly cutting energy costs.

Specific information on the seating capacity of the restaurant, maximum food production capacity, number and type of equipment installed, expected heat production from cooking appliances, maximum power of cooking appliances, the volume of the kitchen space and the number of staff members working in the kitchen per shift should be estimated while installing a hood. If the hood covers the cooking area, the extractor fan is selected for the size of the hood; this design concept, when not considering other factors, will cause ventilation inadequacy.

Hard-wired CO_2 detectors designed for commercial catering environments should be used. These give an audible alarm, are linked with an automatic gas shut-off system as a fail-safe, and require manual intervention to restore the gas supply. Institution of Gas Engineers and Managers (2015) and Section 8.3 prove that installing CO_2 monitors in the kitchen will help to determine the discomfort levels, oxygen levels and adequacy of a ventilation system.

The frequent filtering of oil and adding fresh oil to frying oil will improve the quality of oil and reduce fumes, as per Zhou et al. (2019). Monitoring frying oil safety by adopting at least one method of testing oil quality to be made mandatory by the municipality by-law will help to control the use of reheated cooking oil. Test strips for free fatty acids, p-anisidine value or total polar compounds must be evaluated. Regulations on frying oil safety and systematic monitoring of oil quality help to control the use of reheated oil that will reduce emissions in the kitchens.

Installation of a well-designed MV system is necessary to prevent mould growth that can cause SBS and reduce indoor air quality. Mould growth is observed in more than 5% of the kitchens because of excessive humidity and wet floors near dishwashing areas. About 51% of kitchens have 60% or more humidity levels in one or other kitchen zones but not in all the areas, although it is high enough to encourage mould growth on kitchen walls and floors.

11.8.2 Heat

Male workers cope better with heat in kitchens and are suitable for stove exposure. Even though men cope better with radiant heat generated from grillers and ovens, women cope better with humid heat. Female workers can be placed at stations where stove exposure is minimal, or indoor environmental design regarding the thermal environment can be upgraded to enable female staff to cope with the heat in the kitchen.

The benchmark for the design of kitchens should be improved by increasing air velocity in all areas and maintaining lower temperatures by installing diffusers, PPS and air conditioners. Currently, the standards necessitate extractors' use; however, installing cooling devices in hot kitchens is not compulsory.

The job position of a kitchen worker seems to influence the ability to cope with the heat in the kitchen. Workers can gradually rotate from low stove-exposure stations to high stove-exposure stations to develop heat acclimatisation. Although this is an ideal situation, cooling devices can be installed to reduce heat stress if it is not feasible.

Work shifts should be rotated to provide an opportunity for workers to experience high and low heat during peak periods and different shifts. Continuous stove exposure of workers will reduce, and newly employed workers will develop heat acclimatisation.

Similarly, older workers and female workers should be moved to stations with lower stove exposure, according to their skills, to reduce ill health.

Alternately, a PPS can be installed near high-heat appliances used for grilling, frying and baking sections to reduce the effect of radiant heat near the equipment, promoting lower heat illness and better working conditions.

As equipment such as ovens, boilers and steamers, gas stoves and fryers contribute to substantial heat in the kitchen, they should always be installed under Type I or Type II hoods, as per heat load specifications.

For kitchen workers, longer tenure, experience with warm weather, heat acclimation with service during peak periods, and a comfortable lifestyle at home will improve acclimatisation and prevent heat illness.

The appropriate measures are to be instituted to ensure that the uniform is worn in the kitchen. Newer, heat-resistant, comfortable uniforms should be provided for kitchen workers. These should be supplemented by newer methods of keeping cool, such as cooled wipes or towels that will help keep workers' body temperatures cooler.

Improving the standards for the design of kitchens with higher ceilings and maintaining lower staff–space ratio will reduce discomfort, flushing, sweating and wet uniforms from sweating. Increasing air velocity in all areas and maintaining lower temperatures by installing diffusers, PPS and/or air conditioners will alleviate symptoms of discomfort. The improved indoor environmental design regarding thermal environment will enable staff to cope with the heat in the kitchen, especially during peak periods, and alleviate symptoms of heat stress.

The practice of cooking of suitable foods in advance can reduce the heat generated from the stove during peak periods.

A heat-rejecting film that could reflect 70% heat from sunlight and cool a building while still letting in a good amount of light can cover kitchen windows.

Installing a thermal work limit index calculator could indicate to staff that they need to cool off. These indices are a better tool for evaluating heat stress amongst kitchen workers who perform their tasks in warm and humid environments, as thermal work limit index is better than WBGT in discriminating between acceptable and unacceptable levels of heat stress and can be more useful in planning intervention strategies and assessing their effectiveness. Ahmed et al. (2020:179) recommend that in the workplace with the WBGT index, a complementary assessment by thermal work limit should be used.

Maintaining an integrated, harmonious environment at work with basic factors such as temperature, noise levels, amount of space and workspace cleanliness will provide worker comfort. In addition, proportional factors such as air quality, amount of light, VC, ease of interaction and maintenance will create well-being amongst workers. Bonus factors such as daylighting, external views through windows and individual controllability of indoor environments, when provided could improve staff's overall satisfaction at work.

A combination of approaches for adaptation to heat in kitchens is recommended: comfortable uniform, simple hairstyles, minimal make-up, pacing work during summer, maintaining optimum kitchen temperatures, humidity levels and airflow.

Kitchen workers should arrive hydrated at work and prevent perpetuating a cycle of dehydration. Water–electrolyte balance can be maintained amongst workers by facilitating fluid consumption, such as by providing drinking water and monitoring cool drinking water (1 cup every 20 min or drinking water 5 l/day). In addition, drinking cool drinks and lemon juice low in sugar will assist in hydration.

It is recommended that broader diet and lifestyle structures are implemented along with heat stress awareness training for workers. Preplacement screening of susceptible workers, using proper clothing, resting in cool places during breaks, providing shielding from radiant heat, training staff on symptoms of heat stress and pacing will help to prevent heat illness. Training on heat stress, improving ventilation, loose-fitting clothing and breaks during work are recommended. Chefs from different restaurants have different strategies, such as installing air-conditioning, spending a long time in walk-in refrigerators to cool off and wrapping cold, damp towels around their necks.

The efficacy of kitchen extractor systems in regulating air quality, heat and humidity must receive greater attention in kitchen design decisions. Further to staff complaints of summer heat and humidity, nine restaurants were found to have CO_2 levels higher than 1000 ppm near grillers, tandoors and stoves outside of peak periods.

Specific rules and guidelines should be developed for working in high-temperature workplaces and for monitoring the implementation of such regulations. Training programs about prevention and control of heat-related complications for workers and employers must be organised. All workers must pass heat adaptability courses before starting work to prevent heat stress's effects. Employers must screen kitchen workers while recruiting them to identify those more susceptible to heat.

It is highly recommended that employment density guidelines for kitchens in restaurants and cafés must be prioritised for formulation by the South African Department of Labour.

Work counters should be modified to accommodate the variation in height, considering ethnicities. Shorter people find the standard counter height too tall to work comfortably. Many people of less than average height find 0.81 m (32 in) to be a comfortable work surface height.

The greater the tenure in the kitchen, the better the acclimatisation to heat. Acclimatise female workers, particularly workers belonging to races other than Indian or African, for a longer period to improve their ability to cope with the heat. Per their employment contract, workers can be acclimatised during in-service training and orientation programs. Similarly, newly employed workers without any work experience must be acclimatised for a longer period to improve their ability to cope with the heat.

Worker shifts can be rotated to provide an opportunity for workers to experience high and low heat during peak periods and different shift periods. Continuous stove exposure will reduce workers' heat stress from heat acclimatisation, and newly employed workers will develop heat adaptation.

11.8.3 Noise

Installation of vibration-damping sheets on extractor hoods and metal ducting is recommended. Reduction of the vibration using damping materials can provide a possible sound-power reduction of up to 6 dBA, assuming that the other parameters are kept constant. Noise from extractors can be mitigated by regular maintenance and installation of soundproof materials. The soundproofing material deadens harsh noises and blocks sound transfer.

Tables used for preparation with equipment placed on them require an isolation mount. Vibration and noise from small to medium equipment such as the salad dryer, hand blender, ice crusher or coffee grinder will be efficiently absorbed, reducing noise in kitchens by placing them on a silicone mat away from a wall. To stop structure-borne noise, heavy equipment can be placed on isolation mounts or pads. To reduce airborne noise from the same equipment, absorber combination acoustical blankets can be used to construct enclosures.

The use of soundproofing material should be made obligatory in the kitchen ceiling. As changes in structure are not feasible, alterations can be made in the ceiling by incorporating acoustic tiles suitable for kitchens and sound absorption paint can be added to the walls. Floor coverings with a high Impact Insulation Class rating help reduce sound transmissions' impact to lower levels, thus reducing or eliminating those bothersome noises.

Cuisine requiring elaborate preparation utilising noise-generating equipment necessitates intricate noise absorption arrangements. Noise reduction strategy should be incorporated during the construction stage. Concrete-constructed kitchens should have inner structures with softer, more flexible materials, such as wooden studding filled with insulating material and interior wallboard to reduce sound transmission. Sound-absorbing materials such as acoustic tiles on walls can reduce sound transmission. Architectural elements such as built-ins or alcoves can help immensely by breaking up soundwaves.

The enforcement of equipment specification and installation protocols compliant with the SANAS, SABS or *Occupational Health and Safety Act 85 of 1993* in South Africa will reduce noise levels.

Noise absorption and heat-rejecting film that could reflect 70% heat from sunlight should be coated on kitchen windows. This would not only reduce the building's air-conditioning use and costs by 10%, but it would also reduce noise from the lower use of air conditioners.

Focusing interventions to reduce noise exposure to cooks may be useful in some kitchens, but other food services have dishwashers as the most highly exposed workers. Customising noise reduction plans in different kitchen areas is necessary. Rearrangement and careful planning of buildings and equipment with the organisation of production lines will have noisy equipment separated from workers as much as possible.

Materials used for noise control applications should possess good sound absorption and dampening properties. A novel, cheap, biodegradable natural fibre, jute, can be used for a new noise control application. Applications in kitchen appliances to absorb noise in blenders and grinders can be explored. Similarly, coconut coir fibre, applied as a porous layer backing during construction, can improve the noise absorption of walls.

With the Lombard effect and competitive speech, staff talk louder to be heard and can cause hearing loss to their colleagues. Staff training on speaking in lower tones must be emphasised in the instruction manual, staff contract, training sessions, employee rights or work ethics guidelines. The statement from Ecophon (2010) and Section 9.3 support that staff talking in lower tones will reduce kitchen noise levels.

Noise reduction of the kitchen environment can be achieved by installing the noise reduction system by triple glazing of walls, cabinetry and flooring of a typical kitchen environment.

As many kitchen workers have shifts that are longer than the traditional 8 h, reduced shift length may be an option to control at-risk noise exposure.

The kitchen smalls, such as pots and pans, crockery, cutlery and glassware, should be stacked gently to reduce noise in the clearing section, dishwashing areas, storeroom and pantry. Servers or dishwashers should be trained to pace themselves better so they do not end up juggling armfuls of clanking plates. The report by Achutan (2009) and Section 9.3 support that reduced stacking of dishes will lower clunking noise from dishes.

Kitchens should have a square-shaped layout with irregular walls. The rectangular or long narrow kitchen will cause a bowling alley effect and noise will be reflected again and again across walls. A room without parallel walls greatly helps with acoustics, as sound waves cannot build up and bounce back and forth between walls as easily as nonparallel walls.

Noise from outside can be prevented from entering kitchens with an outdoor sound curtain barrier wall, which is a reinforced loaded vinyl noise barrier and thick, vinyl-coated, polyester-faced, quilted fibreglass absorber panels, which are cleanable, weatherproof and ultraviolet-resistant.

11.8.4 Lighting

All glazed windows, doors, glass curtain walls, and skylights should be kept clean to permit sunlight into kitchens. Solid wooden and metal windows and doors must be kept open, with the installation of metal bars and security gates to allow natural light into kitchens. During the renovation of kitchens, if possible, adequate window provision and skylight should be incorporated. Similarly, all lamps and light fixtures must be kept clean for greater diffusion of artificial light. Cleaning schedules should include lighting fixtures and lamps. Green Seal (2014) and Section 10.5 proved that lighting fixtures, diffusers and lamps be cleaned once a month.

Drawbacks in the visual acumen of older kitchen workers are relieved by additional lighting or higher-intensity or luminance lamps in workstations (Kunduraci 2017). In support, Section 10.3 finds that kitchen workers of an average of 60-years-old require more illuminance when compared with a younger person.

Strong lighting in small enclosures is avoided for its increased potential to create glare. More than one lighting source in each kitchen area will prevent glare. Appropriate, balanced lighting is an essential factor in designing glare-free environments.

Sunlight is the preferred lighting in kitchens, and adequate lighting on worktables makes workers more comfortable. From Section 10.2 and the SANAS that endorses 300 lux, lighting levels in preparation areas are inadequate. 'Light duct' or daylight duct systems contain light-collecting and light-emitting units (Iwata et al., 2016). Solar tubes that reflect light from the roof should be installed through a tube into a kitchen, helping chefs to see food and preparation better in dark kitchens (Gibson, 2013).

11.9 Suggestions for future studies

The concept of future research addresses unanswered aspects of a research problem. As this investigation is exploratory, the need has been observed for further research in key and novel areas for the investigation of IEQ in commercial kitchens. These areas spread across both methodological and content-related spaces. An interesting concept may be to apply the current findings in a post-coronavirus disease 2019 (COVID-19) world, where IEQ and space have taken on a new level of importance with optimal ventilation and physical distancing amongst kitchen workers.

11.9.1 Thermal environments in commercial kitchens

The existing ASHRAE RP-884 benchmark database (Licina et al., 2018) needs informed empirical supplementation to provide a more recent and wider benchmarking database to guide norms for thermal comfort. Studies beyond the existing database for houses, classrooms and offices may be undertaken. The opportunities may further be used to localise these to the South African context.

Creating benchmarks currently unavailable for IEQ performance in respect of all the parameters interacting together in a kitchen will help compare all deviations in a criteria set, with adjustments for weather conditions. Although this study showed no IEQ associations of the five parameters interacting together, these results are to be interpreted with caution, and similar studies will generate a wider body of knowledge.

Thermal comfort is elucidated by many variables, including worker metabolism, clothing, indoor air temperature, MRT, air velocity and RH. Several factors that influence thermal comfort sensation include cultural and behavioural aspects, age, gender, race, space ratio, kitchen layout, the possibility of control over the environment, user’s thermal history and individual preferences. These interrelationships create mathematical models that will help with the comparative influence of these factors. An improved IEQ can be derived from better thermal comfort models. These models provide valuable information on person-environment relationships and factors that affect comfort in a built environment.

There is a gap in thermal comfort studies, particularly in relation to collaborative research. The association with other disciplines in psychology, physiology, sociology, philosophy, ergonomics and engineering can be of great value for developing meaningfully integrated models of IEQ in commercial kitchens. Such integration has substantial potential for superior practices from improved comprehension of human dimensions.

There is a lack of studies in respect of psychological adaptation to heat and other parameters in Africa and South Africa. While this study has stated the findings, comparatives do not indicate the deviations and influences of confounding factors.

Longitudinal studies on lifestyles and person-centred thermal records of kitchen workers will help to understand adaptive behaviours in different regions and to evaluate activities amongst different cultural groups on coping with temperature changes.

Research on the relationship between workers being comfortable with excess hair such as wigs, dreadlocks, hair extensions and thermal stress needs to be established. Many male kitchen workers preferred a shaved head to reduce sweating from the head to ease heat stress.

An evaluation of a direct association between body mass index and heat stress amongst kitchen workers will emphasise the importance of fitness.

An investigation of the influence of shift work, as well as job position, with regard to heat stress in a kitchen, indicates different thermal exposure. The exposure to heat varies widely amongst kitchen workers based on shift and workstation allocated.

A study on the impact of the region-specific diet on thermal comfort in various geographical areas will reveal suitable seasonal food for heat. Cooling foods can be recommended for consumption during breaks for better heat-coping abilities amongst kitchen workers.

A framework of recommendations regulates the standard specific design values for indoor environments that apply to countries with temperate climates. No specifications have been put forth for a humid subtropical climate like Durban, a Mediterranean climate like Cape Town, or a cool semi-arid climate like Johannesburg. Tropics may necessitate altered levels of comfort parameters authorised in the standards.

A framework developed on heat control measures can be performed by (1) designing appropriate infrared heat absorbers around the heat sources to diminish heat stress and heat strain, (2) managerial control by increasing the rest times, (3) using suitable workwear, and (4) using appropriate personal protective equipment where the high heat load exceeds the standard. These actions would augment employees' competence, resulting in increased quality, enhanced production and revenue.

It is vital to advance estimates for countries where economies are more reliant on seasons or where current temperatures are higher than in the USA. These countries are also generally poorer and prepared with less infrastructure; hence, recognising realistic and life-preserving adaptations is imperative. The climatic factors that influence health in poorer nations are also many more because of greater dependence on agriculture.

Additional exploration will contribute to reducing the human health problem of climate change and advise the development of a rational climate strategy, which entails knowledge of health and other expenses of climate change from around the world. There is a persistent need to develop records and research designs to study additional forms of adaptation in South Africa and elsewhere. Adaptation is both economically important and contributes to reducing mortality attributable to temperature extremes.

The physical microclimatic parameters that dominate a subject's thermal perceptions need to be explained in terms of the native weather conditions. Individual variances should be considered, as certain control measures and technological fixes may not be applicable. Climate adaptation strategies should be ethnically inclusive. Kitchen ergonomics creates standards for the average user, not for an individual user. The closer kitchen ergonomics get to an ideal state, the more it should be concerned with the people who work in the kitchen.

11.9.2 Noise

An investigation is needed to control the level of noise in different kitchens and the noise emission levels from different equipment and to measure workers' reactions in terms of their satisfaction levels. Some noises disturbed the workers more than other noises in the kitchen, as noise levels vary widely in different areas.

The development of a model based on PMV or PPD with high prediction accuracy for acoustics needs to be established for acoustic comfort and guidelines developed for maintaining lower noise levels in different kitchen areas to improve hearing ability amongst workers in noisy kitchens.

The perception of loud noise as a nuisance varies amongst ethnic cultures. There is a need to examine the impact of demographic variables on workers' perceptions of kitchen noise on the dining experience. The noise from kitchens interferes with the diner experience and communication that could influence business. The impact of kitchen sound leaks on a diverse sample of customers and restaurants in different geographical locations needs investigation.

Comparative studies could assist with identifying confounding factors for acoustic comfort in and around kitchens. The sound leak from nearby rooms, shops and buildings could impact kitchen noise and dining noise levels.

The influence of structural materials and finishes in kitchen spaces and their role on noise levels and worker exposure is a less investigated domain. Such investigation will inform prudent combinations of materials, finishes and design for specific types of kitchens based on cuisine, kitchen load and worker density.

The investigation of focused psycho-socio-acoustic studies aims to establish the precise correlations between the choice of acoustic indices, noise annoyance, the effect of background noise and noise emergence. Such investigations will assist in better acoustic design to benefit kitchen workers and customers.

11.9.3 Ventilation and humidity

The physical principles of cooking are influenced by the manner in which the kitchen staff uses the appliances and the ventilation in kitchens when impacted by cooking options. The Association of these two parameters in future studies will disclose the confounding factors affecting ventilation and humidity that impact IEQ.

Further studies should embark on associating the discharge velocity from PPS with thermal comfort in commercial kitchens. Mechanical device modifications, specifically considering age, worker height, gender and race, will alleviate thermal discomfort.

Analysis of the effect of the association of CO_2 levels higher than 1000 ppm and decrement in the decision-making performance of kitchen workers need further research. This would lead to a better understanding of kitchen workers' reactions to heat stress.

There is a need for an enhanced understanding of cooking emissions around the world, particularly traditional food from Africa, in commercial kitchens and CO_2 emissions, depending on fuels used and cooking methods. This study included diverse cuisines; however, African cuisine was omitted.

It is a necessity to examine the composition of cooking fumes in commercial kitchens of South Africa, particularly in African cuisine. A lack of published studies on emissions from African cuisine hinders improvement in IAQ in African kitchens.

Research is needed on creating mathematical models with the volume of airflow displaced by extractors, air velocity from diffusers, cooling air temperatures, temperatures near stoves at various heights and discomfort levels in kitchens. The resulting equations will help to appreciate the dynamics of a commercial kitchen. This appreciation is vital for better ventilation and humidity, which enormously impacts IEQ.

Data on humidity and airflow in passageways to the kitchen or corridors leading from dining rooms to the kitchen must be gathered to understand the relationship between ventilation and workspace. The relationship must be assessed between multiple components of the workspace ratio, which greatly impacts airflow and thermal comfort, ventilation adequacy and kitchen load in commercial kitchens, contributing to the uniqueness of IEQ of a commercial kitchen.

11.9.4 Lighting

Against a background of varied employee vision and the detail required for some kitchen activities, investigations to elicit better lighting for specific tasks will reduce visual discomfort. Along with fixture selection, such studies will serve to reduce the strain and weakening of kitchen workers' eye function.

The relationship between the use of energy-efficient light sources with minimal heat emissions and measures to eliminate glare and flicker for VC needs to be established for better visual and thermal comfort.

As each worker has a unique personality, it is important to consider individual non-visual light effects when designing new kitchens and new standards for electrical light and daylight. The non-visual effects of lighting influence circadian rhythms, alertness, cognitive functions and worker well-being. Evaluate interindividual aspects of the light requirement that vary with age when integrated with designing light at workspaces, highlighting individual VC. This will assist in preventing eye strain, fatigue and unnecessary bending for better vision.

11.10 Conclusions from the review of the literature and this study

In addition to functional suggestions, this study also offers additions to current literature. It advances contemporary identification of how commercial kitchens should be effectively managed for fundamental improvements in the indoor environment quality for the well-being of kitchen workers. The wide-ranging analysis of this study adds to existing research by identifying and reinforcing several personal factors that affect kitchen workers' experience of environmental parameters. Albeit exploratory, this is a pioneering investigative study for two reasons: firstly, for its Durban location, and secondly, for the investigation of the effects of all five indoor environmental parameters. However, no significant combined relationships between the parameters can confirm. The study has confirmed that further to building design characteristics, kitchen workers' adaptation to heat, ventilation, noise and lighting influenced the individual genotype and phenotype, such as age, height, race, work experience and correct body weight.

Novel equations derived in the study account for the role of multiple variables affecting various dimensions of the environmental parameters in a commercial kitchen. Although some researchers collected primary and secondary factors in earlier studies, the influence of several weighty variables on IEQ is discussed partly and/or not reported. These equations, reported for the first time, indicate that even subtle changes in certain minor elements and features in kitchens can affect the experience of kitchen workers.

While the results of the study nonetheless affirm prior empirical work, it expands existing notions in the prediction of heat near stoves by accounting for the combined effects of the explanatory variables, namely the type of kitchen, job position, years of employment and worker shift in a multiple linear regression model. Increased space in kitchens tends to reduce worker heat experience. The study reveals a newer model to understand 'heat near stoves', not observed in previous accounts.

The best-fitting model for predicting heat near a stove is a linear combination of symptoms of 'face is red' amongst kitchen workers and discomfort index (because of heat from stove or oven). Several mathematical models discovered another stepwise regression model for predicting heat near a stove.

Amongst these were a linear combination of races – South African Indian, South African (African) – area of the kitchen, output in the number of meals per day and other cuisines. The study unveils several factors affecting the heat experienced by kitchen workers, specifically for those near stoves, grillers and bakers. These include kitchen height, symptoms (face red, sweating, discomfort index), workspace ratio and state of the uniform.

The current knowledge extends in respect of the perception of thermal comfort for kitchen workers. The study affirms that thermal comfort can be determined by individual factors such as age, gender, body mass index, fitness, acclimatisation, ethnicity, type and scope of kitchen activities, cuisine, style of service, the volume of meals prepared, number of plated meals and peak activity time. In addition, the study elicits that the ability of the kitchen worker to cope with thermal strain can occur from the combined influence of age, gender, race, body weight, fitness and work experience.

The research underscores a strange phenomenon of assumption and prediction of the body mass index of a kitchen worker. Female workers tend to assume that their fitness has a positive psychological effect on heat adaptation.

As expected, the study results indicate that the combined effect of temperature and humidity – WBGT is high in different kitchen zones. Besides higher readings of WBGT, excess hair on the head or wearing of wigs in kitchens increases worker discomfort from heat.

The study affirms an increase in discomfort index caused by heat from the stove or oven together with the effect of poor airflow. The research finds that the ideal balance of natural and MV remains elusive and is a factor certainly not mentioned in prior studies on kitchen IEQ. An effective, practical solution to staff complaints about difficulty in breathing and hot draughts can be alleviated by higher ventilation rates by simply opening kitchen back doors. This can improve oxygen levels to 22%.

The study also develops the present concept of predicting humidity near stoves by several factors. The understanding of humidity is extended further by the recognition of ethnicity, mechanical devices for ventilation and physiological and psychological symptoms of heat stress.

The escalation of the lighting measures to a multivariate regression model reveals the association of human well-being in the workplace in respect of headaches that can be prevented by an increase in natural light and clean lights and fixtures. The study shows that effort for clean lights, adequate lighting and good maintenance of lighting provide VC in commercial kitchens. The significant correlations between light, clean fixtures, and adequate lighting in cooking areas are seemingly obvious but not mentioned in earlier studies. With the addition of task lights and infrared light, the incidence of adequate lighting in kitchens is likely to result in fewer staff complaints about contrast in the kitchen.

Further to the significant and well-published benefits of sunlight in work areas, satisfaction with VC arises from adequate and clean lighting and lighting equipment being in good repair. By contrast, visual discomfort derives from inoperable windows, unequal distribution of natural light, glare and contrast. Several aspects of kitchen lighting and their effects on workers are illustrated in this study.

Correspondingly, as predicted by previous studies, workers are unable to communicate because of noise from gas stoves and grinders. A new element highlighted in this research shows that the reaction to stove noise can be affected by gender, age and race of the worker. The study also establishes that noise and heat produced from dishwashing machines are sources of discomfort.

This study elicits new information on the adequacy of kitchen workspace and the need for workspace ratio measures in South Africa. The role of worker density in commercial kitchens that has not featured in prior work emerged as affecting ventilation and hence thermal comfort.

One of the significant shortcomings in this literature is the scarcity of readings or publications relevant to kitchen environmental ergonomic parameters. The study embraces the opportunity to identify new gaps in the prior literature and to present the need for further development in this area of study to contribute to the body of knowledge. The studies on worker comfort are very limited; hence, this is a pivotal study.

The investigation results emphasise an employee well-being approach for enhancing worker comfort levels in terms of heat, ventilation, humidity, airflow, noise and lighting that may contribute to sustained worker health and retention. It also provides insights to advance understanding of the cause-and-effect relationship of five study parameters with human responses in a commercial kitchen. Of these five, personal factor analysis reveals that in comparison, thermal comfort is more influenced in the kitchen than the other four other parameters. In this regard, age, gender and BMI emerged as significant personal factors influencing thermal comfort.

The recommendations offer kitchen and restaurant management advance a better work environment to achieve the goals of a restaurant or catering business. Worker satisfaction is a necessary ingredient for improved survival, performance and productivity.

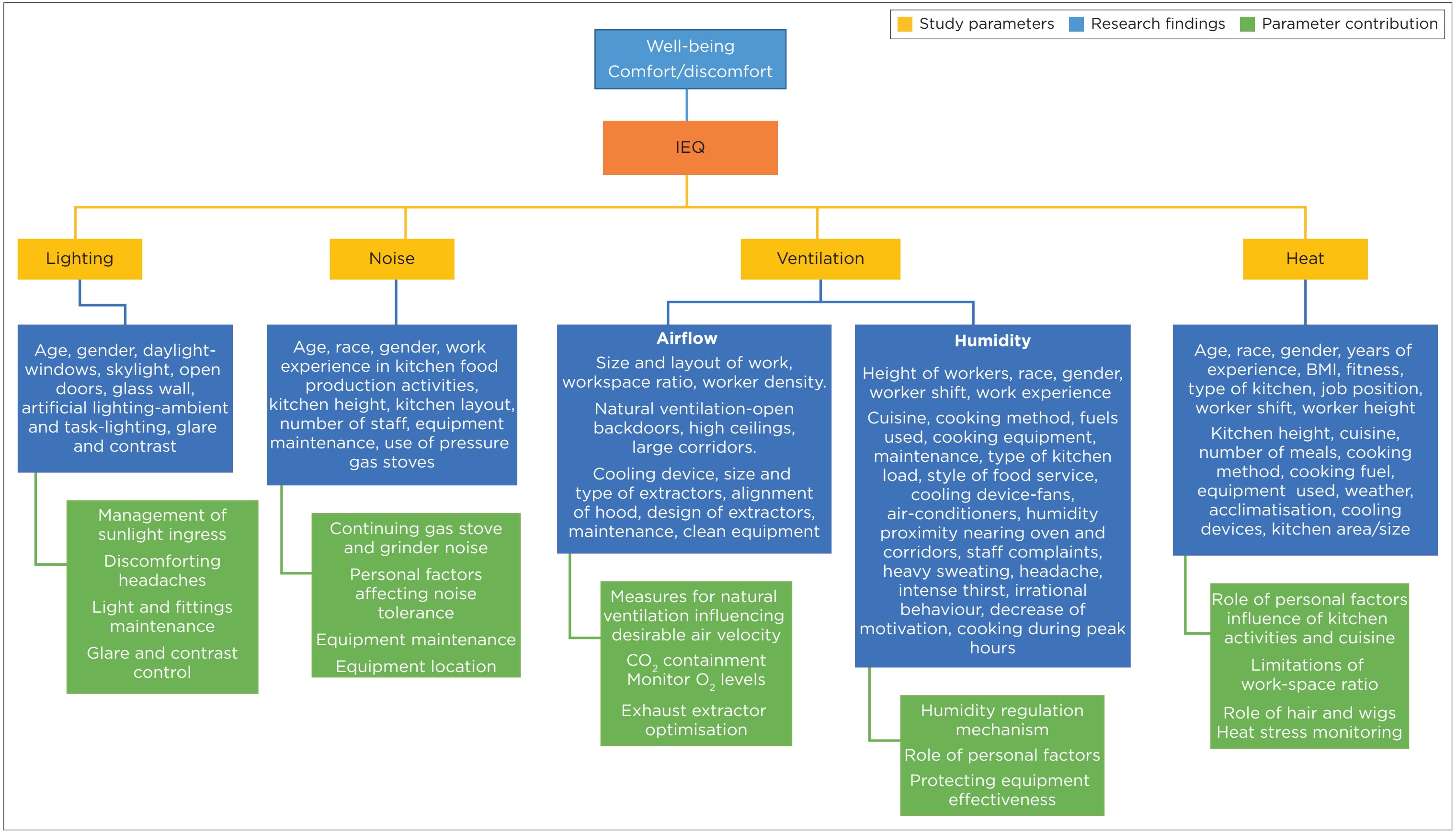
The framework advanced in Yang and Moon (2019) on optimal IEQ is performed in controlled chambers. The initial working framework in Figure 1.2 consists of three comfort attributes under steady-state thermal conditions. The impact of acoustics on indoor environmental comfort is the greatest amongst the three factors, namely thermal, light and acoustics, tested in their study. This old framework finds that thermal comfort is affected by thermal factors, acoustics and illumination factors. Ventilation is lacking in the original framework. Regarding the light parameter, the initial framework finds 500 lux to be optimal with a reported optimal of 35 dBA.

The empirical work in this study shed light on the actual working kitchen environment, specifically in food preparation and production areas. Consequently, a new framework (Figure 11.1) emerged that highpoints the significance of kitchen environment, physical layout, fittings and fixtures. In this research, five elements indicate misalignment from optimal conditions. This study reports that heat has maximum influence on the indoor environmental comfort of Durban kitchens, with food-service workers changing behaviours to cope with heat stress. In the new framework, personal factors, kitchen activities and cuisine, workspace ratio, hair and wigs, and heat stress monitoring impacts temperature in these kitchens, whereas factors such as air velocity, CO_2 containment, exhaust extractor optimisation, humidity regulation, personal factors and equipment effectiveness control ventilation in kitchens. Ventilation is essential in providing safe and efficient working conditions for food-service workers while also protecting their health. Kitchen ventilation is necessary for controlling air contaminants, humidity and temperature generated by cooking processes.

The new framework highlights the physiological and psychological influences of five parameters. The five parameters account for human demographics such as age, gender and race. Hairstyles, uniforms and skin colour are shown to also affect thermal comfort and hence human well-being in the kitchen. The relevance of the initial framework is restricted to age, gender and BMI, with an age range from 19 years to 25 years, whereas the age range of this study varies from 18 years to 61 years. The outcomes of the initial framework ignore the influence of race, hairstyles, clothes or uniform and skin colour that could influence comfort from the heat.

The variables are controlled, and reactions are noted in the initial framework, whereas the variation in parameters occurred because of the food production process in a natural setting. The temperatures increase by 5 °C (20 °C, 25 °C and 30 °C), whereas the temperature (preparation areas) ranged from 28.97 °C to 33.70 °C, and 27.56 °C to 30.85 °C in an East Asian cuisine kitchen. These temperature ranges are affected by menu, cuisine, food production system, volume of cooking, staff–space ratio, layout, NV and mechanical ventilation-influenced heat experience.

However, this framework reports that multiple factors influence light comfort, namely management of sunlight ingress, discomfort (headaches), fixtures and fittings maintenance, contrast and glare control. The outcomes in the new framework are derived from the noise range of 59 dBA–96 dBA



Key: IEQ, indoor environmental quality; BMI, body-mass index; CO_2, carbon dioxide.

FIGURE 11.1: Kitchen IEQ framework.

TABLE 11.1: Summary of influences on initial and revised framework.

No.	Comparison	Original framework	Newly developed framework
		Yang and Moon's study (2019)	**Researcher's study (2021)**
1.	Environment	Controlled chambers	Food production kitchens
2.	Parameters	Three comfort attributes under steady-state thermal conditions	Five elements indicate misalignment from optimal conditions Physiological and psychological influences of all five parameters
3.	Participants	60	Kitchen workers, 170 Head chefs or kitchen managers, 33
4.	Demographic similarities	Age, gender and BMI	Age, gender and BMI
5.	Age	Young university students' age varies narrowly from 19–25-years-old	Large variation in kitchen workers' ages, varying from 18–61-years-old
6.	Variables	Clothing ensemble of nearly 0.75 clo as per ASHRAE Standard 55-2004	Various types of uniform Race, skin colour, hairstyles
7.	Physical parameters influencing comfort	Test laboratory	Physical layout, fittings and fixtures in operational kitchens
8.	Light	500 lux as optimal	Individual management of sunlight ingress, discomfort (headaches), light fixtures and fittings maintenance, and contrast and glare control
9.	Noise	35 dBA as optimal	Individually planning and controlling noise from cooking processes, personal factors, equipment maintenance and location
10.	Heat	Thermal comfort affected by thermal factors, acoustic and illumination factors	Adds personal factors, kitchen activities and cuisine, workspace ratio, hair and wigs, heat stress monitoring
11.	Ventilation	Not part of the study	Accounts for the influence of air velocity, CO_2 containment, exhaust extractor optimisation, humidity regulation, personal factors and equipment effectiveness

(preparation area) to control noise from cooking process, personal factors, equipment maintenance and location.

In conclusion, this book will help scholars and practitioners to expand a repertoire of actions and responses towards an optimal combination of approaches that best fits individuals. The study has demonstrated that the exploration and assessment of interpretations entail a transdisciplinary approach, including methodical resolutions, a blend of provincially suitable expertise incorporated with human privileges and ecofriendly sustainability.

The overall human comfort experience in kitchens is catalysed by several environmental factors simultaneously including heat, humidity, ventilation, acoustics and light. However, procedural standards and design strategies typically focus on a single environmental factor separately. This exploratory study provides an orientation for additional explorations with better perception, modelling or extrapolation amongst numerous workplace surroundings and human well-being in kitchens. It continues to be necessary for such research to embrace an all-inclusive outlook, as the links between indoor environmental parameters are likely to influence behavioural adaptation.

Appendices[3]

TABLE A1: Uniform worn by kitchen workers.

Uniform	Frequency	Percentage (%)
White chef's jacket	33	19.41
Navy blue chef's jacket	4	2.30
Black chef's jacket	4	2.30
Grey chef's jacket	4	2.30
Purple chef's jacket	3	7.76
Blue chef's jacket	2	1.17
Yellow chef's jacket	1	0.58
Housecoat	6	3.50
T-shirt (all colours)	66	38.80
Golf shirt	20	11.76
Purple T-shirt	10	5.88
Formal shirt	6	3.50
Casual wear	11	6.40
Total	**170**	**-**

TABLE A2: Body stature and somatotypes among kitchen workers.

		Phenotype and genotype of kitchen staff					
Ethnicity	***n***	**isiZulu**	**isiXhosa**	**Other Africans**	**Indian**	**White (Caucasians)**	**Coloured (Mixed-race)**
Male	65	49	1	2	9	1	0
Female	109	83	4	1	5	0	1
Body stature	-	Lean	Normal	Obese	Morbidly obese	-	-
Male	65	12	40	15	1	-	-
Female	109	7	34	60	8	-	-
Body type	-	Ectomorph	Mesomorph	Endomorph	-	-	-
Male	65	12	40	10	-	-	-
Female	109	7	34	60	-	-	-

3. Tables generated by author.

TABLE A3: Hair styles among kitchen workers.

Staff hair styles	Percentage (%)
Clean shaven	12.8
Dreadlocks	13.6
Extension	13.6
Natural hair	45
Weave	15

TABLE A4: Skin colour among kitchen workers.

Skin tone	Frequency	Percentage (%)
Very fair	5.0	2.9
Fair	10	5.8
Medium fair	22	12.94
Medium brown	93	54.7
Medium dark	11	6.47
Dark	24	14.11
Black	5	2.9

TABLE A5: Type of nose among kitchen workers.

Type of nose	Frequency	Percentage (%)
Big/large	9	5.2
Button	3	1.8
Droopy	6	3.5
Funnel	109	64.4
Greuan	1	0.5
Hooked	2	1.1
Medium-normal	10	5.9
Small	3	1.8
Snub	14	8.2
Straight	4	2.3
Upturned	7	4.1

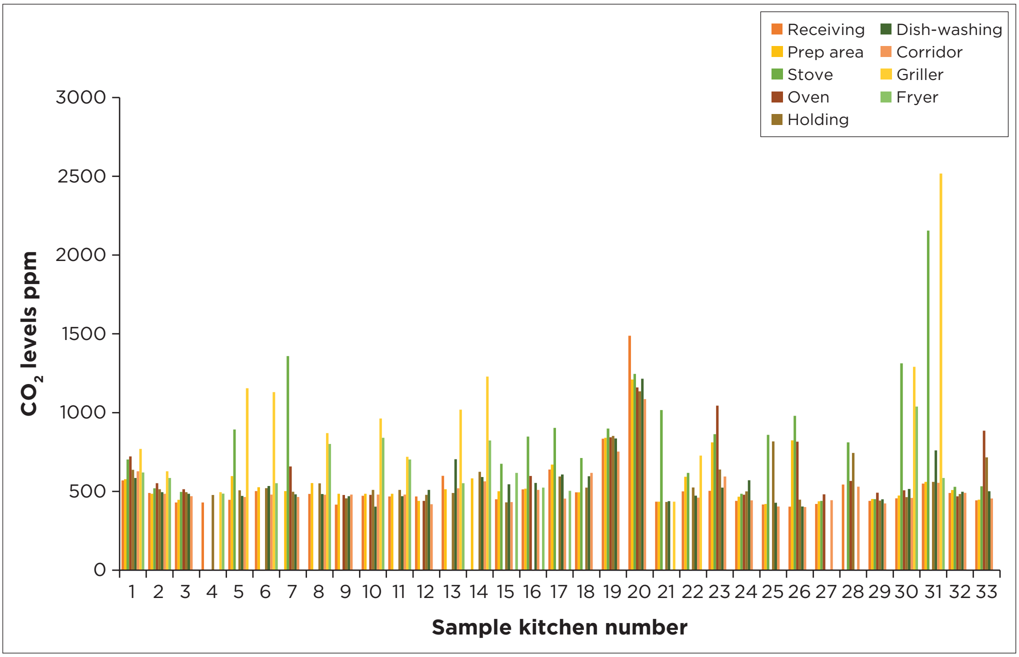


FIGURE A1: Mean CO_2 levels in kitchens.

TABLE A6: Association between food service variables.

Style of service	Type of kitchen load	Cuisine	Test	Value	dF	Asymptotic significance (2-sided)
Q13.6=Quick service	Medium-duty	-	Fisher's Exact	9.265	1	0.013
Q13.1=Family restaurant	Heavy-duty	Indian	Pearson Chi-Square	4.202	1	0.04
Q13.1=Family restaurant	Extra-heavy duty	Indian	Pearson Chi-Square	4.00	1	0.046
Q13.7=Fine dining	Extra-heavy duty	Indian	Pearson Chi-Square	4.00	1	0.046
Q13.1=Family restaurant	Extra-heavy duty	Italian	Pearson Chi-Square	4.00	1	0.046
Q13.7=Fine dining	Extra-heavy duty	Italian	Pearson Chi-Square	4.00	1	0.046
Q13.4=Coffee shop	Heavy-duty	Fusion	Pearson Chi-Square	5.775	1	0.016
Q13.7=Fine dining	Heavy-duty	Fusion	Pearson Chi-Square	5.324	1	0.021
Q13.5=Cafeteria style	Medium-duty	Continental	Pearson Chi-Square	5.00	1	0.025
Q13.7=Fine dining	Heavy-duty	Oriental/Thai	Pearson Chi-Square	3.850	1	0.05

TABLE A7: Head chef ranking of equipment noise.

Equipment	Weighted mean
HVAC & fans	2.2
Refrigeration	2.9
Swivelling doors	3.1
Grinders and blenders	3.5
Boilers and steamers	3.7
Gas stoves	3.8
Fryers	3.8
Trolleys	4.0
Dishwasher	4.1
Air-conditioner	4.5
Ovens	4.6

TABLE A8: Spearman's correlation of oberservation schedule with observation schedule.

		Adequate lighting on dish-washing areas	Lights protected from breakage	Adequate artificial light at night	Adequate light during load-shedding at night	Presence of task-lighting	Presence of infra-red lighting	Presence of UV light-keeping food hot	Presence of natural light	Presence of skylight	Sufficient shielded lights to prevent shadows/ dark areas	Presence of direct glare	Presence of indirect glare	Presence of flickering lights	Presence of contrast in kitchen
Adequate lighting on food preparation areas	Correlation Coefficient	.553**	0.182	.597**	.428*	0.391	−0.025	0.345	0.290	0.148	.632**	0.273	0.180	.544**	.544**
	Sig. (2-tailed)	0.001	0.328	0.001	0.033	0.080	0.934	0.161	0.135	0.533	0.000	0.186	0.349	0.002	0.002
	n	32	31	30	25	21	14	18	28	20	29	25	29	29	29
Adequate lighting on cooking areas	Correlation Coefficient	.661**	.411*	.439*	0.395	.499*	0.361	0.251	0.242	0.216	.425*	0.217	0.041	.466*	.466*
	Sig. (2-tailed)	0.000	0.022	0.015	0.050	0.021	0.205	0.316	0.214	0.361	0.022	0.296	0.834	0.011	0.011
	n	32	31	30	25	21	14	18	28	20	29	25	29	29	29
Adequate lighting on dish-washing areas	Correlation Coefficient	1.000	.537**	.418*	0.153	.553**	0.268	0.144	.400*	0.232	.441*	0.162	0.193	.418*	.418*
	Sig. (2-tailed)		0.002	0.022	0.466	0.009	0.354	0.568	0.035	0.325	0.017	0.439	0.317	0.024	0.024
	n	32	31	30	25	21	14	18	28	20	29	25	29	29	29
Lights protected from breakage	Correlation Coefficient	.537**	1.000	.401*	0.200	.480*	0.475	0.183	0.074	−0.059	.396*	0.169	−0.208	0.237	0.237
	Sig. (2-tailed)	0.002		0.026	0.328	0.024	0.074	0.452	0.702	0.799	0.030	0.410	0.271	0.207	0.207
	n	31	32	31	26	22	15	19	29	21	30	26	30	30	30
Adequate artificial light at night	Correlation Coefficient	.418*	.401*	1.000	.753**	.450*	0.021	.615**	0.093	−0.394	0.313	0.247	−0.075	0.266	0.266
	Sig. (2-tailed)	0.022	0.026		0.000	0.036	0.941	0.005	0.637	0.086	0.098	0.233	0.698	0.164	0.164
	n	30	31	31	26	22	15	19	28	20	29	25	29	29	29
Adequate light during load-shedding at night	Correlation Coefficient	0.153	0.200	.753**	1.000	.482*	0.119	0.427	−0.147	−0.375	−0.045	−0.076	−0.343	−0.025	−0.025
	Sig. (2-tailed)	0.466	0.328	0.000		0.027	0.672	0.087	0.492	0.138	0.835	0.743	0.093	0.907	0.907
	n	25	26	26	26	21	15	17	24	17	24	21	25	25	25
Presence of task-lighting	Correlation Coefficient	.553**	.480*	.450*	.482*	1.000	.899**	0.485	−0.097	−0.160	0.315	0.254	−0.227	0.261	0.261
	Sig. (2-tailed)	0.009	0.024	0.036	0.027		0.000	0.057	0.684	0.570	0.165	0.325	0.322	0.253	0.253
	n	21	22	22	21	22	14	16	20	15	21	17	21	21	21
Presence of infra-red lighting	Correlation Coefficient	0.268	0.475	0.021	0.119	.899**	1.000	0.365	−0.225		0.228	0.145	−0.161	−0.184	−0.184
	Sig. (2-tailed)	0.354	0.074	0.941	0.672	0.000		0.243	0.440		0.434	0.621	0.566	0.529	0.529
	n	14	15	15	15	14	15	12	14	11	14	14	15	14	14

Table A8 continues on the next page →

TABLE A8 (cont.): Spearman's correlation of oberservation schedule with observation schedule.

		Adequate lighting on dish-washing areas	Lights protected from breakage	Adequate artificial light at night	Adequate light during load-shedding at night	Presence of task-lighting	Presence of infra-red lighting	Presence of UV light-keeping food hot	Presence of natural light	Presence of skylight	Sufficient shielded lights to prevent shadows/ dark areas	Presence of direct glare	Presence of indirect glare	Presence of flickering lights	Presence of contrast in kitchen
Presence of UV light keeping food hot	Correlation Coefficient	0.144	0.183	.615**	0.427	0.485	0.365	1.000	−0.015		0.104	0.078	−0.343	0.053	0.053
	Sig. (2-tailed)	0.568	0.452	0.005	0.087	0.057	0.243		0.954		0.673	0.775	0.151	0.834	0.834
	n	18	19	19	17	16	12	19	17	15	19	16	19	18	18
Presence of natural light	Correlation Coefficient	.400*	0.074	0.093	−0.147	−0.097	−0.225	−0.015	1.000	0.352	0.241	0.326	.434*	0.215	0.215
	Sig. (2–tailed)	0.035	0.702	0.637	0.492	0.684	0.440	0.954		0.128	0.217	0.120	0.024	0.282	0.282
	n	28	29	28	24	20	14	17	29	20	28	24	27	27	27
Presence of skylight	Correlation Coefficient	0.232	−0.059	−0.394	−0.375	−0.160			0.352	1.000	0.233	0.102	0.271	0.148	0.148
	Sig. (2–tailed)	0.325	0.799	0.086	0.138	0.570			0.128		0.309	0.679	0.234	0.534	0.534
	n	20	21	20	17	15	11	15	20	21	21	19	21	20	20
Sufficient shielded lights to prevent shadows/ dark areas	Correlation Coefficient	.441*	.396*	0.313	−0.045	0.315	0.228	0.104	0.241	0.233	1.000	0.391	.452*	.687**	.687**
	Sig. (2-tailed)	0.017	0.030	0.098	0.835	0.165	0.434	0.673	0.217	0.309		0.054	0.016	0.000	0.000
	n	29	30	29	24	21	14	19	28	21	30	25	28	28	28
Presence of direct glare	Correlation Coefficient	0.162	0.169	0.247	−0.076	0.254	0.145	0.078	0.326	0.102	0.391	1.000	0.212	0.202	0.202
	Sig. (2-tailed)	0.439	0.410	0.233	0.743	0.325	0.621	0.775	0.120	0.679	0.054		0.299	0.334	0.334
	n	25	26	25	21	17	14	16	24	19	25	26	26	25	25
Presence of indirect glare	Correlation Coefficient	0.193	−0.208	−0.075	−0.343	−0.227	−0.161	−0.343	.434*	0.271	.452*	0.212	1.000	.375*	.375*
	Sig. (2-tailed)	0.317	0.271	0.698	0.093	0.322	0.566	0.151	0.024	0.234	0.016	0.299		0.045	0.045
	n	29	30	29	25	21	15	19	27	21	28	26	30	29	29
Presence of flickering lights	Correlation Coefficient	0.084	0.090	.468*	0.304	0.202	−.674*	0.336	0.165	0.056	0.209	.469*	0.223	.435*	.435*
	Sig. (2-tailed)	0.676	0.648	0.014	0.158	0.406	0.016	0.203	0.432	0.821	0.305	0.021	0.263	0.021	0.021
	n	27	28	27	23	19	12	16	25	19	26	24	27	28	28
Presence of contrast in the kitchen	Correlation Coefficient	.418*	0.237	0.266	−0.025	0.261	−0.184	0.053	0.215	0.148	.687**	0.202	.375*	1.000	1.000
	Sig. (2-tailed)	0.024	0.207	0.164	0.907	0.253	0.529	0.834	0.282	0.534	0.000	0.334	0.045		
	n	29	30	29	25	21	14	18	27	20	28	25	29	30	30

Table A8 continues on the next page →

TABLE A8 (cont.): Spearman's correlation of oberservation schedule with observation schedule.

		Adequate lighting on cooking areas	Adequate lighting on dish-washing areas	Lights protected from breakage	Adequate artificial light at night	Adequate light during load-shedding at night	Presence of task-lighting	Presence of infra–red lighting	Presence of UV light-keeping food hot	Presence of natural light	Presence of skylight	Sufficient shielded lights to prevent shadows/ dark areas	Presence of direct glare	Presence of indirect glare	Presence of flickering lights	Presence of contrast in kitchen
Light switches are in reach	Correlation Coefficient															
	Sig. (2–tailed)	.435*	0.322	0.192	.461*	.443*	0.203	0.161	0.331	–0.018	0.072	0.164	0.349	–0.121	0.247	0.146
	n	0.016	0.083	0.301	0.010	0.027	0.377	0.566	0.166	0.929	0.755	0.396	0.080	0.525	0.214	0.449
Dishwashing machine – noise	Correlation Coefficient	30	30	31	30	25	21	15	19	28	21	29	26	30	27	29
	Sig. (2–tailed)	–0.295	–0.217	–.787**	–.781**	–0.187	–0.404	–0.531	–0.642	–.892**		–0.252	–0.196	–0.132	–0.380	–0.128
	n	0.351	0.498	0.004	0.005	0.606	0.247	0.278	0.086	0.001		0.483	0.642	0.717	0.313	0.724
Dishwashing machine heat production	Correlation Coefficient	12	12	11	11	10	10	6	8	9	8	10	8	10	9	10
	Sig. (2–tailed)	0.264	0.115	–0.042	–0.021	–0.061	–0.322	–0.707	–0.183	–0.243		0.293	0.081	–0.020	0.107	–0.092
	n	0.493	0.769	0.922	0.961	0.897	0.481	0.182	0.695	0.600		0.482	0.864	0.963	0.841	0.844
Natural ventilation	Correlation Coefficient	9	9	8	8	7	7	5	7	7	7	8	7	8	6	7
	Sig. (2-tailed)	0.186	0.085	0.031	0.039	–0.159	–0.141	–0.282	–0.133	.455*	0.107	0.375	0.392	0.137	–0.036	0.166
	n	0.352	0.674	0.882	0.854	0.504	0.591	0.400	0.650	0.025	0.683	0.065	0.079	0.522	0.869	0.429
Adjusting thermostatic controls	Correlation Coefficient	27	27	26	25	20	17	11	14	24	17	25	21	24	24	25
	Sig. (2–tailed)	0.166	0.226	0.350	0.293	0.116	0.059	–0.258	–0.194	0.216	–0.108	–0.180	0.214	–0.016	0.161	0.034
	n	0.408	0.257	0.080	0.155	0.606	0.821	0.418	0.506	0.322	0.668	0.400	0.338	0.940	0.443	0.870
Adjusting ventilating equipment	Correlation Coefficient	27	27	26	25	22	17	12	14	23	18	24	22	25	25	26
	Sig. (2-tailed)	0.112	0.103	0.183	0.319	0.116	0.059	–0.258	–0.194	0.034	–0.108	–0.076	0.214	–0.016	0.161	0.034
	n	0.571	0.602	0.361	0.112	0.606	0.821	0.418	0.506	0.875	0.668	0.720	0.338	0.940	0.443	0.870
Adjusting fans	Correlation Coefficient	28	28	27	26	22	17	12	14	24	18	25	22	25	25	26
	Sig. (2-tailed)	–0.108	–0.028	–0.112	0.177	–0.008	–0.124	–0.417	–0.593	0.247	0.246	0.131	.572*	0.412	.580*	0.154
	n	0.669	0.911	0.658	0.496	0.980	0.717	0.352	0.121	0.324	0.441	0.616	0.033	0.101	0.019	0.554
Cleaning air duct	Correlation Coefficient	18	18	18	17	13	11	7	8	18	12	17	14	17	16	17
	Sig. (2-tailed)	–0.057	–0.017	–0.075	0.311	.423*	–0.073	–0.074	0.142	–0.003	–0.148	–0.179	–0.015	–0.060	0.157	–.460*
	n	0.762	0.928	0.690	0.095	0.035	0.754	0.801	0.574	0.986	0.534	0.354	0.943	0.757	0.425	0.011

Table A8 continues on the next page →

TABLE A8 (cont.): Spearman's correlation of oberservation schedule with observation schedule.

		Adequate lighting on cooking areas	Adequate lighting on dish-washing areas	Lights protected from breakage	Adequate artificial light at night	Adequate light during load-shedding at night	Presence of task-lighting	Presence of infra-red lighting	Presence of UV light-keeping food hot	Presence of natural light	Presence of skylight	Sufficient shielded lights to prevent shadows/dark areas	Presence of direct glare	Presence of indirect glare	Presence of flickering lights	Presence of contrast in kitchen
Cleaning fans	Correlation Coefficient	31	31	31	30	25	21	14	18	28	20	29	25	29	28	30
	Sig. (2-tailed)	0.352	0.330	.671*	.594*	0.401	0.000	−0.272	0.125	0.331	0.366	0.398	0.479	−0.094	0.545	0.083
	n	0.238	0.271	0.012	0.041	0.325	1.000	0.728	0.841	0.270	0.333	0.177	0.136	0.772	0.067	0.797
Cleaning lights/bulbs	Correlation Coefficient	13	13	13	12	8	8	4	5	13	9	13	11	12	12	12
	Sig. (2-tailed)	.592**	.411*	.525**	0.270	0.218	0.395	0.464	0.236	0.197	0.193	.456*	.465*	−0.200	0.202	0.156
	n	0.001	0.024	0.003	0.157	0.305	0.076	0.095	0.362	0.325	0.428	0.015	0.022	0.307	0.312	0.418
Cleaning light fixtures	Correlation Coefficient	30	30	30	29	24	21	14	17	27	19	28	24	28	27	29
	Sig. (2-tailed)	.371*	0.200	.554**	.446*	.407*	.507*	.536*	0.422	0.026	−0.380	0.272	0.330	−.393*	0.144	0.025
	n	0.040	0.281	0.001	0.013	0.043	0.019	0.048	0.081	0.895	0.098	0.154	0.107	0.035	0.465	0.896
Mopping floors (clean)	Correlation Coefficient	31	31	31	30	25	21	14	18	28	20	29	25	29	28	30
	Sig. (2-tailed)	.599**	0.297	.359*	0.257	0.121	0.176	0.163	0.037	0.061	−0.042	0.348	−0.010	0.037	0.057	0.244
	n	0.000	0.105	0.048	0.171	0.564	0.445	0.578	0.885	0.756	0.860	0.065	0.963	0.848	0.772	0.194
Gas cylinders stored away from kitchen	Correlation Coefficient	31	31	31	30	25	21	14	18	28	20	29	25	29	28	30
	Sig. (2-tailed)	−0.201	0.026	−0.190	-0.131	−0.171	0.157	0.135	−0.238	0.282	0.063	0.186	.461*	0.357	−0.075	−0.143
	n	0.315	0.896	0.343	0.524	0.459	0.520	0.676	0.392	0.181	0.812	0.362	0.027	0.079	0.721	0.487
Gas stoves in good repair	Correlation Coefficient	27	27	27	26	21	19	12	15	24	17	26	23	25	25	26
	Sig. (2-tailed)	0.354	0.102	0.104	0.154	0.395	0.370	0.119	0.450	−0.081		.465*	0.076	−0.277	−0.035	0.271
	n	0.082	0.626	0.621	0.472	0.094	0.144	0.728	0.106	0.721		0.022	0.744	0.202	0.873	0.201
Ovens and cookers in good repair	Correlation Coefficient	25	25	25	24	19	17	11	14	22	15	24	21	23	23	24
	Sig. (2-tailed)	0.378	0.116	−0.105	0.033	0.082	−0.164	−0.561	0.226	0.399		0.192	0.134	0.000	0.146	0.013
	n	0.069	0.591	0.632	0.884	0.731	0.528	0.073	0.438	0.073		0.404	0.597	0.999	0.528	0.952
Any equipment producing too much soot	Correlation Coefficient	24	24	23	22	20	17	11	14	21	15	21	18	22	21	23
	Sig. (2-tailed)	0.286	0.078	0.103	−0.163	−0.119	0.463		0.074	−0.316	0.286	0.330	−0.082	0.289	0.043	0.336
	n	0.235	0.751	0.685	0.518	0.672	0.130		0.839	0.216	0.343	0.196	0.771	0.260	0.865	0.172

Table A8 continues on the next page →

TABLE A8 (cont.): Spearman's correlation of oberservation schedule with observation schedule.

		Dish-washing machine noise	Dish-washing machine heat production	Natural ventilation	Adjusting thermostatic controls	Adjusting ventilating equipment	Adjusting fans	Cleaning air duct	Cleaning fans	Cleaning lights/ bulbs	Cleaning light fixtures	Mopping floors (clean)	Gas cylinders stored away from kitchen	Gas stoves in good repair	Ovens and cookers in good repair	Any equipment producing too much soot
Adequate lighting on food preparation areas	Correlation Coefficient															
	Sig. (2-tailed)	−0.213	0.115	0.167	0.033	0.080	0.051	0.122	0.229	.409*	0.267	0.040	−0.136	0.339	0.381	0.091
	n	0.507	0.769	0.406	0.869	0.687	0.841	0.514	0.451	0.025	0.147	0.833	0.500	0.097	0.066	0.712
Adequate lighting on cooking areas	Correlation Coefficient	12	9	27	27	28	18	31	13	30	31	30	27	25	24	19
	Sig. (2-tailed)	−0.295	0.264	0.186	0.166	0.112	−0.108	−0.057	0.352	.592**	.371*	−0.358	−0.201	0.354	0.378	0.286
	n	0.351	0.493	0.352	0.408	0.571	0.669	0.762	0.238	0.001	0.040	0.279	0.315	0.082	0.069	0.235
Adequate lighting on dish-washing areas	Correlation Coefficient	12	9	27	27	28	18	31	13	30	31	11	27	25	24	19
	Sig. (2-tailed)	−0.217	0.115	0.085	0.226	0.103	−0.028	−0.017	0.330	.411*	0.200	0.091	0.026	0.102	0.116	0.078
	n	0.498	0.769	0.674	0.257	0.602	0.911	0.928	0.271	0.024	0.281	0.830	0.896	0.626	0.591	0.751
Lights protected from breakage	Correlation Coefficient	12	9	27	27	28	18	31	13	30	31	8	27	25	24	19
	Sig. (2-tailed)	−.787**	−0.042	0.031	0.350	0.183	−0.112	−0.075	.671*	.525**	.554**	0.159	−0.190	0.104	−0.105	0.103
	n	0.004	0.922	0.882	0.080	0.361	0.658	0.690	0.012	0.003	0.001	0.428	0.343	0.621	0.632	0.685
Adequate artificial light at night	Correlation Coefficient	11	8	26	26	27	18	31	13	30	31	27	27	25	23	18
	Sig. (2-tailed)	−.781**	−0.021	0.039	0.293	0.319	0.177	0.311	.594*	0.270	.446*	0.224	−0.131	0.154	0.033	−0.163
	n	0.005	0.961	0.854	0.155	0.112	0.496	0.095	0.041	0.157	0.013	0.262	0.524	0.472	0.884	0.518
Adequate light during load-shedding at night	Correlation Coefficient	11	8	25	25	26	17	30	12	29	30	27	26	24	22	18
	Sig. (2-tailed)	−0.187	−0.061	−0.159	0.116	0.116	−0.008	.423*	0.401	0.218	.407*	0.292	−0.171	0.395	0.082	−0.119
	n	0.606	0.897	0.504	0.606	0.606	0.980	0.035	0.325	0.305	0.043	0.131	0.459	0.094	0.731	0.672
Presence of task-lighting	Correlation Coefficient	10	7	20	22	22	13	25	8	24	25	28	21	19	20	15
	Sig. (2-tailed)	−0.404	−0.322	−0.141	0.059	0.059	−0.124	−0.073	0.000	0.395	.507*	−0.377	0.157	0.370	−0.164	0.463
	n	0.247	0.481	0.591	0.821	0.821	0.717	0.754	1.000	0.076	0.019	0.123	0.520	0.144	0.528	0.130
Presence of infra-red lighting	Correlation Coefficient	10	7	17	17	17	11	21	8	21	21	18	19	17	17	12
	Sig. (2-tailed)	−0.531	−0.707	−0.282	−0.258	−0.258	−0.417	−0.074	−0.272	0.464	.536*	0.118	0.135	0.119	−0.561	
	n	0.278	0.182	0.400	0.418	0.418	0.352	0.801	0.728	0.095	0.048	0.521	0.676	0.728	0.073	

Table A8 continues on the next page →

TABLE A8 (cont.): Spearman's correlation of oberservation schedule with observation schedule.

		Dish washing machine noise	Dish washing machine heat production	Natural ventilation	Adjusting thermostatic controls	Adjusting ventilating equipment	Adjusting fans	Cleaning air duct	Cleaning fans	Cleaning lights/ bulbs	Cleaning light fixtures	Mopping floors (clean)	Gas cylinders stored away from kitchen	Gas stoves in good repair	Ovens and cookers in good repair	Any equipment producing too much soot
Presence of UV light keeping food hot	Correlation Coefficient	6	5	11	12	12	7	14	4	14	14	32	12	11	11	5
	Sig. (2-tailed)	−0.642	−0.183	−0.133	−0.194	−0.194	−0.593	0.142	0.125	0.236	0.422	0.272	−0.238	0.450	0.226	0.074
	n	0.086	0.695	0.650	0.506	0.506	0.121	0.574	0.841	0.362	0.081	0.368	0.392	0.106	0.438	0.839
Presence of natural light	Correlation Coefficient	8	7	14	14	14	8	18	5	17	18	13	15	14	14	10
	Sig. (2-tailed)	−.892**	−0.243	.455*	0.216	0.034	0.247	−0.003	0.331	0.197	0.026	.383*	0.282	−0.081	0.399	−0.316
	n	0.001	0.600	0.025	0.322	0.875	0.324	0.986	0.270	0.325	0.895	0.033	0.181	0.721	0.073	0.216
Presence of skylight	Correlation Coefficient	9	7	24	23	24	18	28	13	27	28	31	24	22	21	17
	Sig. (2-tailed)			0.107	−0.108	−0.108	0.246	−0.148	0.366	0.193	−0.380	0.347	0.063			0.286
	n			0.683	0.668	0.668	0.441	0.534	0.333	0.428	0.098	0.051	0.812			0.343
Sufficient shielded lights to prevent shadows/ dark areas	Correlation Coefficient	8	7	17	18	18	12	20	9	19	20	32	17	15	15	13
	Sig. (2-tailed)	−0.252	0.293	0.375	−0.180	−0.076	0.131	−0.179	0.398	.456*	0.272	1.000	0.186	.465*	0.192	0.330
	n	0.483	0.482	0.065	0.400	0.720	0.616	0.354	0.177	0.015	0.154		0.362	0.022	0.404	0.196
Presence of direct glare	Correlation Coefficient	10	8	25	24	25	17	29	13	28	29	32	26	24	21	17
	Sig. (2-tailed)	−0.196	0.081	0.392	0.214	0.214	.572*	−0.015	0.479	.465*	0.330	−0.249	.461*	0.076	0.134	−0.082
	n	0.642	0.864	0.079	0.338	0.338	0.033	0.943	0.136	0.022	0.107	0.201	0.027	0.744	0.597	0.771
Presence of indirect glare	Correlation Coefficient	8	7	21	22	22	14	25	11	24	25	28	23	21	18	15
	Sig. (2-tailed)	−0.132	−0.020	0.137	−0.016	−0.016	0.412	−0.060	−0.094	−0.200	−.393*	0.318	0.357	−0.277	0.000	0.289
	n	0.717	0.963	0.522	0.940	0.940	0.101	0.757	0.772	0.307	0.035	0.121	0.079	0.202	0.999	0.260
Presence of flickering lights	Correlation Coefficient	10	8	24	25	25	17	29	12	28	29	25	25	23	22	17
	Sig. (2-tailed)	−0.380	0.107	−0.036	0.161	0.161	.580*	0.157	0.545	0.202	0.144	.559**	−0.075	−0.035	0.146	0.043
	n	0.313	0.841	0.869	0.443	0.443	0.019	0.425	0.067	0.312	0.465	0.005	0.721	0.873	0.528	0.865
Presence of contrast in the kitchen	Correlation Coefficient	9	6	24	25	25	16	28	12	27	28	24	25	23	21	18
	Sig. (2-tailed)	−0.128	−0.092	0.166	0.034	0.034	0.154	−.460*	0.083	0.156	0.025	.535*	−0.143	0.271	0.013	0.336
	n	0.724	0.844	0.429	0.870	0.870	0.554	0.011	0.797	0.418	0.896	0.018	0.487	0.201	0.952	0.172

Table A8 continues on the next page →

TABLE A8 (cont.): Spearman's correlation of oberservation schedule with observation schedule.

		Dishwashing machine - noise	Dishwashing machine heat production	Natural ventilation	Adjusting thermostatic controls	Adjusting ventilating equipment	Adjusting fans	Cleaning air duct	Cleaning fans	Cleaning lights/ bulbs	Cleaning light fixtures	Mopping floors (clean)	Gas stoves in good repair	Ovens and cookers in good repair
Light switches are in reach	Correlation Coefficient													
	Sig. (2-tailed)			0.006	0.161	0.176	−0.043	0.263	0.319	.399*	0.326	0.040	0.162	0.139
	n			0.978	0.443	0.390	0.865	0.160	0.287	0.032	0.079	0.833	0.448	0.537
Dishwashing machine - noise	Correlation Coefficient	10	8	25	25	26	18	30	13	29	30	30	24	22
	Sig. (2-tailed)	1.000	0.543	−0.115	−0.367	−0.367	0.115	−0.034	-1.000	−0.247	−0.568	−0.358	0.000	0.123
	n		0.130	0.769	0.297	0.297	0.854	0.921		0.464	0.068	0.279	1.000	0.736
Dishwashing machine heat production	Correlation Coefficient	12	9	9	10	10	5	11	2	11	11	11	9	10
	Sig. (2-tailed)	0.543	1.000	0.658	−0.331	−0.331	−0.056	0.458	1.000	0.380	0.042	0.091	.907*	.856**
	n	0.130		0.108	0.468	0.468	0.944	0.254		0.353	0.920	0.830	0.013	0.007
Natural ventilation	Correlation Coefficient	9	9	7	7	7	4	8	2	8	8	8	6	8
	Sig. (2-tailed)	−0.115	0.658	1.000	0.097	0.306	−0.020	−0.010	0.466	0.251	0.074	0.159	0.354	0.339
	n	0.769	0.108		0.651	0.137	0.940	0.961	0.148	0.207	0.715	0.428	0.106	0.133
Adjusting thermostatic controls	Correlation Coefficient	9	7	27	24	25	16	27	11	27	27	27	22	21
	Sig. (2-tailed)	−0.367	−0.331	0.097	1.000	1.000**	0.353	0.304	0.553	0.057	0.059	0.224	0.061	0.026
	n	0.297	0.468	0.651			0.198	0.123	0.097	0.782	0.769	0.262	0.792	0.910
Adjusting ventilating equipment	Correlation Coefficient	10	7	24	27	27	15	27	10	26	27	27	21	21
	Sig. (2-tailed)	−0.367	−0.331	0.306	1.000**	1.000	0.410	.390*	.622*	−0.085	−0.038	0.292	0.201	0.026
	n	0.297	0.468	0.137			0.115	0.040	0.041	0.672	0.848	0.131	0.369	0.910
Adjusting fans	Correlation Coefficient	10	7	25	27	28	16	28	11	27	28	28	22	21
	Sig. (2-tailed)	0.115	−0.056	−0.020	0.353	0.410	1.000	0.153	.698**	−0.223	−0.319	−0.377	−0.124	−0.470
	n	0.854	0.944	0.940	0.198	0.115		0.546	0.008	0.390	0.197	0.123	0.688	0.123
Cleaning air ducts	Correlation Coefficient	5	4	16	15	16	18	18	13	17	18	18	13	12
	Sig. (2-tailed)	−0.034	0.458	−0.010	0.304	.390*	0.153	1.000	0.539	0.035	0.130	0.118	0.218	.427*
	n	0.921	0.254	0.961	0.123	0.040	0.546		0.057	0.850	0.479	0.521	0.296	0.038

Table A8 continues on the next page →

TABLE A8 (cont.): Spearman's correlation of oberservation schedule with observation schedule.

		Dishwashing machine - noise	Dishwashing machine heat production	Natural ventilation	Adjusting thermostatic controls	Adjusting ventilating equipment	Adjusting fans	Cleaning air duct	Cleaning fans	Cleaning lights/ bulbs	Cleaning light fixtures	Mopping floors (clean)	Gas stoves in good repair	Ovens and cookers in good repair
Cleaning fans	Correlation Coefficient	11	8	27	27	28	18	32	13	31	32	32	25	24
	Sig. (2-tailed)	−1.000**	1.000**	0.466	0.553	.622*	.698**	0.539	1.000	0.462	0.224	0.272	0.150	−0.015
	n			0.148	0.097	0.041	0.008	0.057		0.131	0.462	0.368	0.660	0.973
Cleaning lights/bulbs	Correlation Coefficient	2	2	11	10	11	13	13	13	12	13	13	11	8
	Sig. (2-tailed)	−0.247	0.380	0.251	0.057	−0.085	−0.223	0.035	0.462	1.000	.829**	.383*	.491*	.443*
	n	0.464	0.353	0.207	0.782	0.672	0.390	0.850	0.131		0.000	0.033	0.013	0.030
Cleaning light fixtures	Correlation Coefficient	11	8	27	26	27	17	31	12	31	31	31	25	24
	Sig. (2-tailed)	−0.568	0.042	0.074	0.059	−0.038	−0.319	0.130	0.224	.829**	1.000	0.347	.475*	0.307
	n	0.068	0.920	0.715	0.769	0.848	0.197	0.479	0.462	0.000		0.051	0.016	0.145
Mopping floors (clean)	Correlation Coefficient	11	8	27	27	28	18	32	13	31	32	32	25	24
	Sig. (2-tailed)	−0.358	0.091	0.159	0.224	0.292	−0.377	0.118	0.272	.383*	0.347	1.000	0.318	.559**
	n	0.279	0.830	0.428	0.262	0.131	0.123	0.521	0.368	0.033	0.051		0.121	0.005
Gas cylinders stored away from kitchen	Correlation Coefficient	11	8	27	27	28	18	32	13	31	32	32	25	24
	Sig. (2-tailed)	−0.062		0.160	0.083	0.093	0.485	0.141		0.222	0.178	−0.249	0.210	
	n	0.865		0.456	0.708	0.665	0.079	0.476		0.255	0.364	0.201	0.314	
Gas stoves in good repair	Correlation Coefficient	10	7	24	23	24	14	28	12	28	28	28	25	21
	Sig. (2-tailed)	0.000	.907*	0.354	0.061	0.201	−0.124	0.218	0.150	.491*	.475*	0.318	1.000	.549*
	n	1.000	0.013	0.106	0.792	0.369	0.688	0.296	0.660	0.013	0.016	0.121		0.012
Ovens and cookers in good repair	Correlation Coefficient	9	6	22	21	22	13	25	11	25	25	25	25	20
	Sig. (2-tailed)	0.123	.856**	0.339	0.026	0.026	−0.470	.427*	−0.015	.443*	0.307	.559**	.549*	1.000
	n	0.736	0.007	0.133	0.910	0.910	0.123	0.038	0.973	0.030	0.145	0.005	0.012	
Any equipment producing too much soot	Correlation Coefficient	10	8	21	21	21	12	24	8	24	24	24	20	24
	Sig. (2-tailed)	0.050	0.500	0.009	−0.344	−0.344	−.704*	−0.265	−0.507	.516*	0.371	.535*	0.401	0.244
	n	0.916	0.391	0.972	0.162	0.162	0.023	0.272	0.199	0.028	0.118	0.018	0.139	0.363

TABLE A9: Correlations between questionnaire with questionnaire.

		Boilers and steamers	Fryers	HVAC & fans	All the kitchen equipment is in good repair	The amount of light in your kitchen is adequate	The staff are happy about adequate lighting in kitchen	The staff complained about glare (difficulty seeing in the presence of bright light such as direct or reflected sunlight) in the kitchen	Given the noise level can you talk to your colleague/neighbour in your kitchen without shouting	The staff complained frequently with regard to noise in the kitchen	The staff complained that they are unable to communicate with co-workers due to noise in the kitchen	The staff complained about blenders/ grinders and/or food processor making too much noise	The staff complained about extractor making too much noise	The staff complained about humidity in the kitchen
Grinders and blenders	Correlation Coefficient	–.547*	–.491*											
	Sig. (2-tailed)	0.035	0.017											
	n	15	23											
Swivelling doors	Correlation Coefficient	–1.000**												
	Sig. (2-tailed)													
	n	2												
Air conditioner	Correlation Coefficient			–.894*										
	Sig. (2-tailed)			0.041										
	n			5										
The amount of light in your kitchen is adequate	Correlation Coefficient				.595**									
	Sig. (2-tailed)				0.000									
	n				34									
The staff are happy about adequate lighting in kitchen	Correlation Coefficient					.551**								
	Sig. (2-tailed)					0.001								
	n					34								
The staff complained about contrast (the difference in brightness or colour that makes an object clear) in kitchen	Correlation Coefficient					–.480**	–.480**	739**						
	Sig. (2-tailed)					0.004	0.004	0.000						
	n					34	34	34						
The staff complained that they are unable to communicate with co-workers due to noise in the kitchen	Correlation Coefficient								–.649**	.504**				
	Sig. (2-tailed)								0.000	0.002				
	n								34	34				

Table A9 continues on the next page →

TABLE A9 (cont.): Correlations between questionnaire with questionnaire.

		Boilers and steamers	**Fryers**	**HVAC & fans**	**All the kitchen equipment is in good repair**	**The amount of light in your kitchen is adequate**	**The staff are happy about adequate lighting in kitchen**	**The staff complained about glare (difficulty seeing in the presence of bright light such as direct or reflected sunlight) in the kitchen**	**Given the noise level can you talk to your colleague/neighbour in your kitchen without shouting**	**The staff complained frequently with regard to noise in the kitchen**	**The staff complained that they are unable to communicate with co-workers due to noise in the kitchen**	**The staff complained about blenders/ grinders and/or food processor making too much noise**	**The staff complained about extractor making too much noise**	**The staff complained about humidity in the kitchen**
The staff complained about blenders/grinders and/or food processor making too much noise	Correlation Coefficient								–.465**	.450**	.742**			
	Sig. (2-tailed)								0.006	0.008	0.000			
	n								34	34	34			
The staff complained about extractor making too much noise	Correlation Coefficient									.523**	.431*	.493**		
	Sig. (2-tailed)									0.002	0.011	0.003		
	n									34	34	34		
The staff complained about stoves and/or ovens making too much noise	Correlation Coefficient								–0.300	.499**	.523**	.623**		
	Sig. (2-tailed)								0.084	0.003	0.002	0.000		
	n								34	34	34	34		
The staff complained about humidity in the kitchen	Correlation Coefficient												.459**	
	Sig. (2-tailed)												0.006	
	n												34	
The staff complained about difficulty in breathing	Correlation Coefficient	–.566**												.561**
	Sig. (2-tailed)	0.009												0.001
	n	20												34
All kitchen equipment is installed as per specification	Correlation Coefficient				.519**									
	Sig. (2-tailed)				0.002									
	n				34									.682**
The staff complained that it is too hot in the kitchen	Correlation Coefficient													0.000
	Sig. (2-tailed)													34
	n													

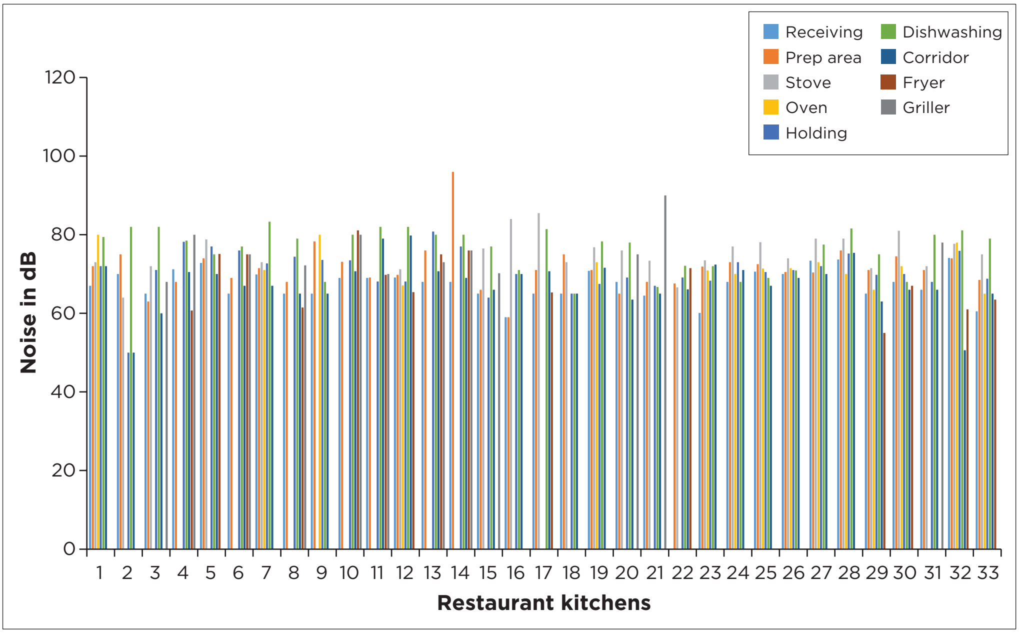


FIGURE A2: Mean lighting levels in sampled kitchens.

Source: Photographs taken by Sasi Gangiah, exact times and dates unspecified, published with appropriate permission from Sasi Gangiah.

FIGURE A3: Photographs of (a & d) pizza ovens, (b) electric and (e) gas cooking equipment and a (c) tandoor and (f) tandoor burner as heat-producing equipment in sampled kitchens.

References

Abdel-Salam, MMM 2022, 'Relationship between residential indoor air quality and socioeconomic factors in two urban areas in Alexandria, Egypt', *Building and Environment*, vol. 207, part A, a108425. https://doi.org/10.1016/j.buildenv.2021.108425

Abdoulaziz, A 2020, 'An assessment of occupational heat stress in a central utility plant', MPH thesis, University of Nebraska, Lincoln.

Abdullahi, KL, Delgado-Saborit, JM & Harrison, RM 2013, 'Emissions and indoor concentrations of particulate matter and its specific chemical components from cooking: A review', *Atmospheric Environment*, vol. 71, pp. 260–294. https://doi.org/10.1016/j.atmosenv.2013.01.061

Abowitz, DA & Toole, TM 2010, 'Mixed method research: Fundamental issues of design, validity, and reliability in construction research', *Journal of Construction Engineering and Management*, vol. 136, no. 1, pp. 108–116. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000026

Abubaker, LI 2010, 'Prediction of playing abilities of athletes and coaching competence of potential coaches in ball games', *The Intuition*, vol. 2010, n.p., s.n., s.l.

Achutan, C 2009, 'Assessment of noise exposure in a hospital kitchen', *Noise and Health*, vol. 11, no. 44, pp. 145–150. https://doi.org/10.4103/1463-1741.53359

Adam, S 2013, *Commercial kitchen ventilation*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Georgia.

Adams, KA & Lawrence, EK 2018, *Research methods, statistics, and applications*, Sage Publications, Thousand Oaks.

Adamu, ZA 2013, 'The feasibility of natural ventilation in healthcare buildings', PhD thesis, Loughborough University, Loughborough.

Adonis, R 2016, 'An empirical investigation into the information management systems at a South African financial institution', MTech thesis, Cape Peninsula University of Technology, Cape Town.

Advanced Control Solutions 2018, *Commercial kitchen ventilation*, Advanced Control Solutions, Marietta, viewed 20 October 2021, https://www.acs-southeast.com/services/ahu-ventilation-services/commercial-kitchen-ventilation/

Ahmed, A, Alomari, A, Alfgih, M & Almalky, A 2020, 'Wet Bulb Globe Temperature (WBGT) among Solid Waste Collection Workers at Al Leith Municipal', *IOSR Journal of Environmental Science Toxicology and Food Technology*, vol. 14, no. 11, pp. 28–36. http://dx.doi.org/10.9790/2402-1411022836

Ahola, M, Säteri, J & Sariola, L 2019, 'Revised Finnish classification of indoor climate 2018', *paper presented at the E3S Web of Conferences*, Milan, 13–15 February.

Air and Odour Management 2015, *Commercial kitchen ventilation design guide*, Air and Odour Management, Kingsgrove.

AirClean 2018, *Electrostatic precipitator kitchen grease and smoke particle removal*, Airclean, Kent, viewed 18 June 2019, https://www.airclean.co.uk/kitchen-extract-odour-control-solutions/electrostatic-precipitator/

Airtècnics 2020, *What is an air curtain?*, Airtècnics, Madrid, viewed n.d., https://www.airtecnics.com/technology/what-is-an-air-curtain

Akbar-Khanzadeh, F, Tan, Y, Brown, EN & Akbar-Khanzadeh, M 2002, 'An evaluation of ventilation system flow rates and levels of carbon dioxide, ambient temperature, and relative humidity in restaurants', *Applied Occupational and Environmental Hygiene*, vol. 17, no. 9, pp. 640–647. https://doi.org/10.1080/10473220290095989

Akbari, J, Dehghan, H, Azmoon, H & Forouharmajd, F 2013, 'Relationship between lighting and noise levels and productivity of the occupants in automotive assembly industry', *Journal of Environmental and Public Health*, vol. 2013, a527078. https://doi.org/10.1155/2013/527078

Akinwande, MO, Dikko, HG & Samson, A 2015, 'Variance inflation factor: As a condition for the inclusion of suppressor variable(s) in regression analysis', *Open Journal of Statistics*, vol. 5, no. 7, pp. 754–767. https://doi.org/10.4236/ojs.2015.57075

Al-Horr, Y, Arif, M, Katafygiotou, M, Mazroei, A, Kaushik, A & Elsarrag, E 2016, 'Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature', *International Journal of Sustainable Built Environment*, vol. 5, no. 1, pp. 1–11. https://doi.org/10.1016/j.ijsbe.2016.03.006

Al-Obaidi, KM, Ismail, M & Rahman, AMA 2014, 'A review of the potential of attic ventilation by passive and active turbine ventilators in tropical Malaysia', *Sustainable Cities and Society*, vol. 10, pp. 232–240. https://doi.org/10.1016/j.scs.2013.10.001

Alam, M, Arunachalam, M & Salve, U 2019, 'A pilot study on thermal comfort in Indian Railway pantry car chefs', *Journal of Physics: Conference Series*, vol. 1240, a012033. https://doi.org/10.1088/1742-6596/1240/1/012033

Alam, MS & Salve, UR 2021, 'Enhancement of thermal comfort inside the kitchen of non-airconditioned railway pantry car', *Journal Homepage*, vol. 39, no. 1, pp. 275–291. https://doi.org/10.18280/ijht.390131

Alam, S, Sharma, M & Salve, UR 2022, 'Assessment of thermal comfort in a hot and humid indoor built environment of a kitchen at a university canteen', Work, vol. 72, no. 1, pp. 189-199. https://doi.org/10.3233/wor-205174

Alexandrova, A 2009, 'Extract and cleaning of contaminated air in commercial kitchens: Ultraviolet technology', Bachelor's disertation, Mikkeli University of Applied Sciences, Mikkeli.

Alexandru, DP, Vartires, A & Angel, D 2016, 'An overview of current methods for thermal comfort assessment in vehicle cabin', *Energy Procedia*, vol. 85, pp. 162–169. https://doi.org/10.1016/j.egypro.2015.12.322

Alfano, F, Olesen, BW, Palella, BI & Riccio, G 2014, 'Thermal comfort: Design and assessment for energy saving', *Energy and Buildings*, vol. 81, pp. 326–336. https://doi.org/10.1016/j.enbuild.2014.06.033

Allan, AC, Hansen, VG, Isoardi, G & Smith, SS 2019, 'Subjective assessments of lighting quality: A measurement review', *Leukos*, vol. 15, no. 2–3, pp. 115–126. https://doi.org/10.1080/15502724.2018.1531017

Allen, D 2014, 'Restaurant ventilation: Best practices', *FSR*, viewed 18 June 2019, https://www.foodnewsfeed.com/fsr/vendor-bylines/restaurant-ventilation-best-practices

Alonso, AD & O'Neill, MA 2010, 'Exploring consumers' images of open restaurant kitchen design', *Journal of Retail & Leisure Property*, vol. 9, pp. 247–259. https://doi.org/10.1057/rlp.2010.5

Alpert, J 2018, *7 Ways a restaurant architect can help make your dream a reality*, LinkedIn article, 12 july, viewed 15 March 2020, https://www.linkedin.com/pulse/7-ways-restaurant-architect-can-help-make-your-dream-justin?trk=read_related_article-card_title

Alshaikh, AM & Alhefnawi, MAM 2020, 'Thermal comfort and gender: A practical study in the eastern province of Saudi Arabia', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 381–392.

Altomonte, S, Allen, J, Bluyssen, PM, Brager, G, Heschong, L, Loder, A et al. 2020, 'Ten questions concerning well-being in the built environment', *Building and Environment*, vol. 180, a106949. https://doi.org/10.1016/j.buildenv.2020.106949

Aluline Group, 2019, 'Guidelines for the safe design of a commercial kitchen', Aluline Group, Runcorn, viewed 30 January 2020, http://www.alulinegms.com/sitedata/files/Kitchen_Design_Guide.pdf

Alves, AJ, Paiva, NF, Silva, TL & Remoaldo, P 2020, 'Low-frequency noise and its main effects on human health – A review of the literature between 2016 and 2019', *Applied Sciences*, vol. 10, no. 15, a5205. https://doi.org/10.3390/app10155205

American Optometric Association, 2020, *Senior vision: Over 60 years of age*, American Optometric Association, Saint Louis, MO, viewed 16 November 2020, https://www.aoa.org/healthy-eyes/eye-health-for-life/senior-vision

Amsbary, R 2012, 'Instrument accuracy checks and calibration', *QA Magazine*, viewed 06 May 2021, https://www.qualityassurancemag.com/article/aib0612-instrument-calibration-program/

Andersen, RV, Toftum, J, Andersen, KK & Olesen, BW 2009, 'Survey of occupant behaviour and control of indoor environment in Danish dwellings', *Energy and Buildings*, vol. 41, no. 1, pp. 11–16. https://doi.org/10.1016/j.enbuild.2008.07.004

Anderson, CA, Stewart, IB, Stewart, KL, Linnane, DM, Patterson, MJ & Hunt, AP 2022, 'Sex-based differences in body core temperature response across repeat work bouts in the heat', *Applied Ergonomics*, vol. 98, a103586. https://doi.org/10.1016/j.apergo.2021.103586

André, M, Vecchi, RD & Lamberts, R 2020, 'Feasibility of using personal fans for increasing thermal comfort in mixed- mode shared work spaces in Brazil: A field study', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 990–1004.

Anguera, MT, Portell, M, Chacón-Moscoso, S & Sanduvete-Chaves, S 2018, 'Indirect observation in everyday contexts: Concepts and methodological guidelines within a mixed methods framework', *Frontiers in Psychology*, vol. 9, pp. 1–20. https://doi.org/10.3389/fpsyg.2018.00013

American National Standards Institute (ANSI) & American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 2010, *Standard 55-2010: Thermal environmental conditions for human occupancy*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.

Archtoolbox, 2021, 'Recommended lighting levels in buildings', Archtoolbox, Boston, viewed 01 May 2021, https://www.archtoolbox.com/materials-systems/electrical/recommended-lighting-levels-in-buildings.html

Arens, E, Heinzerling, D, Liu, S, Paliaga, G, Pande, A, Schiavon, S et al. 2020, 'Advances to ASHRAE Standard 55 to encourage more effective building practice', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 510–528.

Arezes, PM, Bernardo, C & Mateus, OA 2012, 'Measurement strategies for occupational noise exposure assessment: A comparison study in different industrial environments', *International Journal of Industrial Ergonomics*, vol. 42, pp. 172–177. https://doi.org/10.1016/j.ergon.2011.10.005

Aries, M 2005, *Human lighting demands – Healthy lighting in an office environment*, Technische Universiteit Eindhoven, Eindhoven.

Aries, MB, Aarts, MP & Van Hoof, J 2015, 'Daylight and health: A review of the evidence and consequences for the built environment', *Lighting Research & Technology*, vol. 47, no. 1, pp. 6–27. https://doi.org/10.1177/1477153513509258

Aries, MB, Veitch, JA & Newsham, GR 2010, 'Windows, view, and office characteristics predict physical and psychological discomfort', *Journal of Environmental Psychology*, vol. 30, no. 4, pp. 533–541. https://doi.org/10.1016/j.jenvp.2009.12.004

Armstrong, JR 2020, 'Systems engineering evidence in commercial kitchens', *INCOSE International Symposium (Virtual)*, s.l. pp. 1354–1367.

Asfour, OS 2015, 'Natural ventilation in buildings: An overview', in OT Haynes (ed.) *Natural ventilation: Strategies, health implications and impacts on the environment*, Nova Science Publishers Inc, New York, pp. 1–26.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2020, *Thermal environmental conditions for human occupancy*, American National Standards Institute, New York.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 2019, *Ventilation for acceptable indoor air quality*, ASHRAE, Atlanta, GA, viewed 10 July 2020, https://www.ashrae.org/File%20Library/Technical%20Resources/Standards%20and%20Guidelines/Standards%20Addenda/62_1_2016_t_20191018.pdf

Astolfi, A & Filippi, M 2004, 'Good acoustical quality in restaurants: A compromise between speech intelligibility and privacy', *18th International Congresses on Acoustics*, Kyoto, pp. 1201–1204.

Atkinson, J, Chartier, Y, Silva, CLP, Jensen, P, Li, Y & Seto, WH 2009, *Natural ventilation for infection control in health-care settings*, World Health Organization, Geneva.

Ayodeji, JI, 2017, 'Workspace utilization, maintenance practice and lecturers' satisfaction with indoor environmental quality in selected Nigerian universities', PhD thesis, University of Lagos, Lagos.

Babu, P & Suthar, G 2020, 'Indoor air quality and thermal comfort in green building: A study for measurement, problem and solution', *Indoor Environmental Quality: Select Proceedings of the 1st ACIEQ*, vol. 60, pp. 139–146. https://doi.org/10.1007/978-981-15-1334-3_15

Banwell, C, Dixon, J, Bambrick, H, Edwards, F & Kjellstrom, T 2012, 'Socio-cultural reflections on heat in Australia with implications for health and climate change adaptation', *Global Health Action*, vol. 5, no. 1, a19277. https://doi.org/10.3402/gha.v5i0.19277

Bare Metal Standard, 2020, *Prepare for a commercial kitchen health and fire safety inspection*, Bare Metal Standard, Washington, DC, viewed 17 January 2020, https://www.baremetalstandard.com/prepare-commercial-kitchen-health-fire-safety-inspection/

Barnes, B, Mathee, A, Thomas, E & Bruce, N 2009, 'Household energy, indoor air pollution and child respiratory health in South Africa', *Journal of Energy in Southern Africa*, vol. 20, no. 1, pp. 4–13.

Barthelmes, VM, Karmann, C, Licina, D, Andersen, M & Khovalyg, D 2020, 'A multi-domain data collection strategy for capturing relationships between occupant behaviour, comfort, indoor environment, and energy use in offices', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 309–322.

Bates, GP & Schneider, J 2008, 'Hydration status and physiological workload of UAE construction workers: A prospective longitudinal observational study', *Journal of Occupational Medicine and Toxicology*, vol. 3, a21. https://doi.org/10.1186/1745-6673-3-21

Beheshti, MH, Boroumand Nejad, E, Bahalgerdy, B, Mehrafshan, F & Zamani Arimy, A 2015, 'Performance loss among workers due to heat stress in high-temperature workplaces', *Journal of Occupational Health and Epidemiology*, vol. 4, no. 2, pp. 116–124. https://doi.org/10.18869/acadpub.johe.4.2.116

Bellingham, C, Davies, G & Human, A 2009, 'Energy efficiency guideline', in *Greening Durban 2010*, Ethekwini Municipality, Durban.

Ben-Gal, I 2005, 'Outlier detection', in *Data mining and knowledge discovery handbook*, pp. 131–146, Springer, Boston.

Berquist, J, Ouf, MM & O'Brien, W 2019, 'A method to conduct longitudinal studies on indoor environmental quality and perceived occupant comfort', *Building and Environment*, vol. 150, pp. 88–89. https://doi.org/10.1016/j.buildenv.2018.12.064

Best Ceiling Fans.Net., n.d., 'Kitchen ceiling fans', Best Ceiling Fans.Net, viewed 03 March 2020, https://www.bestceilingfans.net/kitchen-ceiling-fans/

Better Health Channel 2020, 'Heat stress - preventing heatstroke', Better Health Channel, Victoria, viewed 01 November 2019, https://www.betterhealth.vic.gov.au/health/healthyliving/heat-stress-preventing-heatstroke

Bhatia, A 2012, 'Fundamentals of kitchen ventilation', PDHOnline, viewed 13 July 2020, https://www.pdhonline.com/courses/m228/m228content.pdf

Bierwirth, PN 2018, 'Carbon dioxide toxicity and climate change: A serious unapprehended risk for human health', Grapevine, Victoria, viewed 22 October 2021, http://grapevine.com.au/~pbierwirth/co2toxicity.pdf. https://doi.org/10.13140/RG.2.2.16787.48168

Bindu, ESH & Reddy, MV 2013, 'Indoor air quality in commercial kitchens', *International Journal of Science and Research*, vol. 5, no. 10, pp. 1337–1340. https://www.ijsr.net/get_abstract.php?paper_id=ART20162453

Bindu, ESH & Reddy, MV 2016, 'Perception on work environment stress by cooks in commercial kitchens', *International Journal of Science and Research*, vol. 5, no. 10, pp. 1320–1323. https://www.ijsr.net/get_abstract.php?paper_id=ART20162480

Black & Decker 2009, *The complete guide to kitchens*, Creative Publishing International Inc., Minneapolis.

Black, M 2019, 'The best way to keep a restaurant kitchen cool', *Chron*, viewed 01 November 2019, https://smallbusiness.chron.com/way-keep-restaurant-kitchen-cool-34955.html

Blackwell, DL, Lucas, JW & Clarke, TC 2014, 'Summary health statistics for US adults: National health interview survey, 2012', in *Vital and health statistics. Series 10, Data from the National Health Survey*, Centers for Disease Control and Prevention, Atlanta, viewed n.d., https://www.cdc.gov/nchs/products/series/series10.htm

Blitzer, D & Mackay, T 2015, *Kitchen and bath lighting: Concept, design, light*, John Wiley & Sons, Hoboken.

Bluyssen, PM 2019, 'Towards an integrated analysis of the indoor environmental factors and its effects on occupants', *Intelligent Buildings International*, vol. 12, no. 3, pp. 199–207. https://doi.org/10.1080/17508975.2019.1599318

Bluyssen, PM, Janssen, S, Van den Brink, LH & De Kluizenaar, Y 2011, 'Assessment of wellbeing in an indoor office environment', *Building and Environment*, vol. 46, no. 12, pp. 2632–2640. https://doi.org/10.1016/j.buildenv.2011.06.026

Boduch, M & Fincher, W 2009, 'Standards of human comfort: Relative and absolute', *UTSoA-seminar in sustainable architecture*, Austin, pp. 1–9.

Bonnell, EK, Huggins, CE, Huggins, CT, Mccaffrey, TA, Palermo, C & Bonham, MP 2017, 'Influences on dietary choices during day versus night shift in shift workers: A mixed methods study', *Nutrients*, vol. 9, no. 3, p. 193. https://doi.org/10.3390/nu9030193

Borisuit, A, Linhart, F, Kämpf, JH, Scartezzini, J & Münch, M 2011, 'Comparison of objective and subjective visual comfort and associations with non-visual functions in young subjects', *CISBAT 2011 Conference*, Lausanne, pp. 1–5.

Boyce, PR, Veitch, JA, Newsham, GR, Jones, CC, Heerwagen, J, Myer, M et al. 2006, 'Lighting quality and office work: two field simulation experiments', *Lighting Research & Technology*, vol. 38, no. 3, pp. 191–223. https://doi.org/10.1191%2F1365782806lrt161oa

Breathing Buildings, 2021, 'Breathing Buildings Catalogue', *Breathing Buildings*, viewed 01 May 2021, https://www.breathingbuildings.com/wp-content/uploads/2021/07/Breathing-Buildings-Catalogue.pdf

British Columbia Campus 2020, *Basic kitchen and food service management*, BCcampus Open Publishing, viewed 19 January 2020, https://opentextbc.ca/basickitchenandfoodservicemanagement/chapter/factors-affecting-working-performance/

Bryman, A 2006, 'Integrating quantitative and qualitative research: How is it done?', *Qualitative Research*, vol. 6, no. 1, pp. 97–113. https://doi.org/10.1177/1468794106058877

Bryman, A & Bell, E 2011, *Business research methods*, Oxford University Press, Oxford.

Buonocore, C, André, M, Ramos, G, De Vecchi, R, Candido, C & Lamberts, R 2020, 'Exploring the Brazilian Thermal Comfort Database: An overview on the main contributions', in *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 1052–1064.

Burt, C 2017, 'How often should you clean your restaurant kitchen exhaust hood?', *Quora*, viewed 01 November 2019, https://www.quora.com/How-often-should-you-clean-your-restaurant-kitchen-exhaust-hood

California Energy Commission 2003, 'Design guide: Improving commercial kitchen ventilation system performance', California Energy Commission, Sacremento, viewed 18 June 2019, http://www.espair.co.in/download/commercial-kitchen-ventilation/CKV_Design_Guide_0.pdf

Cameron, S & Vila, B 2020, '5 Easy ideas for better kitchen ventilation', bobvila, viewed 01 November 2020, https://www.bobvila.com/articles/kitchen-ventilation/

Cao, G, Awbi, H, Yao, R, Fan, Y, Sirén, K, Kosonen, R et al. 2014, 'A review of the performance of different ventilation and airflow distribution systems in buildings', *Building and Environment*, vol. 73, no. 16, pp. 171–186. https://doi.org/10.1016/j.buildenv.2013.12.009

Caple 2018, 'Extraction and ventilation guide', Caple, Bristol, viewed 05 November 2020, https://www.caple.co.uk/wp-content/uploads/2018/05/Extraction-Guide-2021.pdf

Carter, R, Cheuvront, SN, Williams, JO, Kolka, MA, Stephenson, LA, Sawka, MN et al. 2005, *Epidemiology of hospitalizations and deaths from heat illness in soldiers*, Army Research Institute of Environmental Medicine, Natick.

Casteel, A & Bridier, N 2021, 'Describing populations and samples in doctoral student research', *International Journal of Doctoral Studies*, vol. 16, pp. 339–362. https://doi.org/10.28945/4766

Castle, E 2018, '6 Questions to ask when preparing data for analysis', Sisense, Tel Aviv, viewed 02 November 2019, https://www.sisense.com/blog/6-questions-to-ask-when-preparing-data-analysis/

CBMC Lighting Solutions 2017, 'How to choose the best modern kitchen lighting for large kitchens', CBMC Lighting Solutions, viewed 01 May 2019, https://lightingsolutionsanddesign.tumblr.com/post/160882512643/how-to-choose-the-best-modern-kitchen-lighting-for

Chakraborty, D, Mukhopadhyay, K, Mitra, P & Mondal, NK 2022, 'Optimization of household ventilation with improved cookstove: an amicable approach to strengthen indoor air quality and public health', in *Indoor Air Quality Assessment for Smart Environments*, IOS Press Amsterdam.

Chan, APC, Yi, W & Wong, FKW 2016, 'Evaluating the effectiveness and practicality of a cooling vest across four industries in Hong Kong', *Facilities*, vol. 34, pp. 511–534. https://doi.org/10.1108/F-12-2014-0104

Chandler, N 2019, 'Time to vent: Why you need to turn on the kitchen exhaust fan?', HowStuffWorks, viewed 01 July 2020, https://home.howstuffworks.com/kitchen-exhaust-fan.htm

Chang, HS, Capuozzo, B, Okumus, B & Cho, M 2021, 'Why cleaning the invisible in restaurants is important during COVID-19: A case study of indoor air quality of an open-kitchen restaurant', *International Journal of Hospitality Management*, vol. 94, a102854. https://doi.org/10.1016/j.ijhm.2020.102854

Charan, J & Biswas, T 2013, 'How to calculate sample size for different study designs in medical research?', *Indian Journal of Psychological Medicine*, vol. 35, no. 2, pp. 121–126. https://doi.org/10.4103/0253-7176.116232

Charlotte, S 2017, 'Is office lighting affecting your vision?', Blink, viewed 31 July 2019, https://blinkcharlotte.com/newsletter-library/is-office-lighting-affecting-your-vision/

Chef Services Group 2020, 'Cook chill production', Chef Services Group, Placida, viewed 01 May 2020, https://chefservicesgroup.com/services/cook-chill-production/

Chellappa, SL, Steiner, R, Oelhafen, P & Cajochen, C 2017, 'Sex differences in light sensitivity impact on brightness perception, vigilant attention and sleep in humans', *Scientific Reports*, vol. 7, a14215. https://doi.org/10.1038/s41598-017-13973-1

Chen, K, Su, S & Chen, K 2020, 'An overview of occupational noise-induced hearing loss among workers: Epidemiology, pathogenesis, and preventive measures', *Environmental Health and Preventive Medicine*, vol. 25, no. 1, pp. 1–10. https://doi.org/10.1186/s12199-020-00906-0

Cheung, T, Schiavon, S & Graham, KL 2020, 'Post-occupancy evaluation of occupants' satisfaction with the indoor environment in five commercial buildings in Singapore', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 774–784.

Chevin, LM & Hoffmann, AA 2017, 'Evolution of phenotypic plasticity in extreme environments', *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol. 372, no. 1723, pp. 1–12. https://doi.org/10.1098/rstb.2016.0138

Choi, K, Shin, C, Kim, T, Chung, HJ & Suk, H 2019, 'Awakening effects of blue-enriched morning light exposure on university students' physiological and subjective responses', *Scientific Reports*, vol. 9, a345. https://doi.org/10.1038/s41598-018-36791-5

Christie, R 2019, 'Three ways to use your wood-burning stove correctly', *Which?*, viewed 25 January 2019, https://www.which.co.uk/news/2019/01/three-ways-to-use-your-wood-burning-stove-correctly/

Chu, J 2018, 'See-through film rejects 70 per cent of incoming solar heat', Massachusetts Institute of Technology, viewed 11 September 2019, http://news.mit.edu/2018/see-through-film-rejects-incoming-solar-heat-1108

City of Durban 2020, *Provincial Notice No. 627 of 1950*, City of Durban, Durban.

City of Milwaukee 2020, 'Chapter 275- building maintenance', City of Milwaukee, Milwaukee, viewed n.d., from https://city.milwaukee.gov/ImageLibrary/Groups/ccClerk/Ordinances/Volume-2/CH275.pdf

City of Penticton 2013, *Building permit-kitchen exhaust for food service operations*, Development Services Department, Building Permitting and Bylaw, Penticton.

City of Tshwane 2004, *City of Tshwane noise management policy*, City of Tshwane Metropolitan Municipality, Pretoria.

Clark, JA 2009, 'Solving kitchen ventilation problems', *ASHRAE Journal*, vol. 51, no. 7, pp. 20–24, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.

Clark, JA 2012, 'Design considerations for commercial kitchen ventilation', *ASHRAE Journal*, vol. 54, p. 54, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.

Clements, N, Zhang, R, Jamrozik, A, Campanella, C & Bauer, B 2019, 'The spatial and temporal variability of the indoor environmental quality during three simulated office studies at a living lab', *Buildings*, vol. 9, no. 3, p. 62. https://doi.org/10.3390/buildings9030062

Cois, A & Day, C 2015, 'Obesity trends and risk factors in the South African adult population', *BioMed Central Obesity*, vol. 2, a42. https://doi.org/10.1186/s40608-015-0072-2

Colin, E 2011, 'Ergonomics kitchen design', Ergonoomics-Info.com, viewed 16 April 2020, https://ergonomics-info.com/ergonomics-kitchen-design/

Community Toolbox 2019, 'A framework for program evaluation: A gateway to tools', CommunityToolBox, viewed 09 November 2021, https://ctb.ku.edu/en/table-of-contents/evaluate/evaluation/framework-for-evaluation/main

Comrey, AL & Lee, HB 2013, *A first course in factor analysis*, Psychology Press, New York.

Conradie, DCU 2012, 'South Africa's climatic zones: Today, tomorrow', *International Green Building Conference and Exhibition*, Sandton, n.p.

ContekPro 2021, 'Commercial kitchen design: The 6 Design Principles You Should Know', ContekPro, Portland, viewed 19 November 2020, https://www.contekpro.com/blog/commercial-kitchen-design-principles

Costanzo, V, Evola, G, Marletta, L & Pistone Nascone, F 2018, 'Application of climate based daylight modelling to the refurbishment of a school building in Sicily', *Sustainability*, vol. 10, no. 8, pp. 1–19. https://doi.org/10.3390/su10082653

Costello, AB & Osborne, JW 2005, 'Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis', *Practical Assessment, Research and Evaluation*, vol. 10, no. 7, pp. 1–9. https://doi.org/10.7275/jyj1-4868

Crandell, C, Mills, TL & Gauthier, R 2004, 'Knowledge, behaviors, and attitudes about hearing loss and hearing protection among racial/ethnically diverse young adults', *Journal of the National Medical Association*, vol. 96, no. 2, p. 176. http://www.ncbi.nlm.nih.gov/pmc/articles/pmc2594952/

Creswell, JW 2013, *Qualitative inquiry and research design: Choosing among five approaches*, Sage, Thousand Oaks.

Crewsswell, JW, Klassen, AC, Plano Clark, VL & Clegg Smith, K 2011, *Best Practices for Mixed Methods Research in the Health Sciences*, Office of Behavioral and Social Sciences Research, Bethesda.

Cronin-De-Chavez, A 2011, *Cultural beliefs and thermal care of infants: Protecting South Asian and white British infants in Bradford from heat and cold*, Durham University, Durham.

Cypress, BS 2017, ‘Rigor or reliability and validity in qualitative research: Perspectives, strategies, reconceptualization, and recommendations’, *Dimensions of Critical Care Nursing*, vol. 36, no. 4, pp. 253–263. https://doi.org/10.1097/DCC.0000000000000253

D’Souza, MJ, Walls, KE, Rojas, C, Everett, LM & Wentzien, DE 2015, ‘Effect of gender and lifestyle behaviors on BMI trends in a sample of the first state’s undergraduate population’, *American Journal of Health Sciences*, vol. 6, no. 1, pp. 59–74. https://doi.org/10.19030/ajhs.v6i1.9270

Daaboul, J, Ghali, K & Ghaddar, N 2018, ‘Mixed-mode ventilation and air-conditioning as alternative for energy savings: A case study in Beirut current and future climate’, *Energy Efficiency*, vol. 11, no. 1, pp. 13–30. https://doi.org/10.1007/s12053-017-9546-z

Dai, W, Zhong, H, Li, L, Cao, J, Huang, Y, Shen, M et al. 2018, ‘Characterization and health risk assessment of airborne pollutants in commercial restaurants in northwestern China: Under a low ventilation condition in wintertime’, *Science of the Total Environment*, vol. 633, pp. 308–316. https://doi.org/10.1016/j.scitotenv.2018.03.124

David, M 2019, ‘What is the difference between anonymity and confidentiality?’, Statistics Solutions, viewed 02 November 2019, https://www.statisticssolutions.com/what-is-the-difference-between-anonymity-and-confidentiality/

David, M & Sutton, CD 2011, *Social research: An introduction*, Sage Publications, London.

Dawe, M 2019, ‘Field evaluation of occupant satisfaction and energy performance in eight LEED-certified buildings using radiant systems’, MS thesis, University of California, Los Angeles.

Day, JK, Moore, Z & Ruiz, S 2020, ‘Snuggies at work: Case study examples of thermal [dis]comfort, behaviors, and environmental satisfaction in the workplace’, in *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 463–477.

De Alzaa, F, Guillaume, C & Ravetti, L 2018, ‘Evaluation of chemical and physical changes in different commercial oils during heating’, *Acta Scientific Nutritional Health*, vol. 2, no. 6, pp. 2–11.

De Dear, R 2004, ‘Thermal comfort in practice’, *Indoor Air*, vol. 14, suppl. 7, pp. 32–39. https://doi.org/10.1111/j.1600-0668.2004.00270.x

De Kort, Y & Smolders, K 2010, ‘Effects of dynamic lighting on office workers: First results of a field study with monthly alternating settings’, *Lighting Research & Technology*, vol. 42, no. 3, pp. 345–360. https://doi.org/10.1177/1477153510378150

De Vecchi, R, Candido, C, De Dear, R & Lamberts, R 2017, ‘Thermal comfort in office buildings: Findings from a field study in mixed-mode and fully-air-conditioning environments under humid subtropical conditions’, *Building and Environment*, vol. 123, pp. 672–683. https://doi.org/10.1016/j.buildenv.2017.07.029

Decker, F 2019, *Restaurant kitchen-to-dining area ratio*, AZCentral, viewed 13 July 2021, https://yourbusiness.azcentral.com/restaurant-kitchentodining-area-ratio-14065.html

Deepthi, Y, Nagendra, SS & Gummadi, SN 2020, ‘Characteristics of PM from different South Indian cooking methods and implications in health effects’, in A Sharma, R Goyal & R Mittal (eds.), *Indoor environmental quality*, Springer, Singapore, pp. 35–44.

Denscombe, M 2014, *The good research guide: For small-scale social research projects*, McGraw-Hill Education, London.

Devlin, H., 2017, ‘Why women secretly turn up the heating?’, *The Guardian*, viewed 28 July 2020, https://www.theguardian.com/science/shortcuts/2017/oct/11/why-women-sewcretly-turn-up-the-heating

Die-Pat 2016a, ‘Commercial kitchen design principles’, Die-Pat, Northamptonshire, viewed 20 October 2021, http://www.die-pat.co.uk/commercial-kitchen-design-principles

Die-Pat 2016b, ‘Commercial kitchen lighting requirements and LED lighting’, Die-Pat, Northamptonshire, viewed 31 October 2021, https://www.die-pat.co.uk/commercial-kitchen-lighting-requirements-and-led-lighting

Dinnen, J 2014, *Phase #2: Clearly define your research strategy*, MacKenzie Corporation, viewed 02 November 2019, https://www.mackenziecorp.com/phase-2-clearly-define-research-strategy/

Distefano, C, Zhu, M & Mindrila, D 2009, 'Understanding and using factor scores: Considerations for the applied researcher', *Practical Assessment, Research & Evaluation*, vol. 14, pp. 1–11.

Djongyang, N, Tchinda, R & Njomo, D 2010, 'Thermal comfort: A review paper. *Renewable and Sustainable Energy Reviews*, vol. 14, no. 9, pp. 2626–2640. https://doi.org/10.1016/j.rser.2010.07.040

Dobbin, NA, Sun, L, Wallace, L, Kulka, R, You, H, Shin, T et al. 2018, 'The benefit of kitchen exhaust fan use after cooking – An experimental assessment', *Building and Environment*, vol. 135, pp. 286–296. https://doi.org/10.1016/j.buildenv.2018.02.039

Draper, S 2019, *Effect size*, document uploaded and managed by Steve Draper, Department of Psychology, University of Glasgow, Glasgow, viewed 13 November 2019, http://www.psy.gla.ac.uk/~steve/best/effect.html

Du, Z, Guo, W, Li, W & Gao, X 2022, 'A study on the optimization of wind environment of existing villa buildings in Lingnan area: a case study of Jiangmen's "Yunshan Poetic" Moon Island Houses', *Buildings*, vol. 12, no. 9, a1304. https://doi.org/10.3390/buildings12091304

Du, W, Wang, J, Wang, Z, Lei, Y, Huang, Y, Liu, S et al. 2021, 'Influence of COVID-19 lockdown overlapping Chinese Spring Festival on household $PM_{2.5}$ in rural Chinese homes', *Chemosphere*, vol. 278, a130406. https://doi.org/10.1016/j.chemosphere.2021.130406

Dunaief, J 2018, 'Are bright lights damaging to the eye?', BrightFocus Foundation, viewed 31 October 2020, https://www.brightfocus.org/macular/article/are-bright-lights-damaging-eye

Dunne, JP, Stouffer, RJ & John, JG 2013, 'Reductions in labour capacity from heat stress under climate warming', *Nature Climate Change*, vol. 3, p. 563. https://doi.org/10.1038/nclimate1827

Duravent 2020, *Type 1 vs. Type 2 exhaust hoods*, Duravent, Albany, NY, viewed 21 October 2021, https://duravent.com/wp-content/uploads/2020/03/Type-1-vs-Type-2-Kitchen-Exhaust-Hoods-SFPE.pdf

Dzhambov, A & Dimitrova, D 2014, 'Neighborhood noise pollution as a determinant of displaced aggression: A pilot study', *Noise and Health*, vol. 16, no. 69, p. 95. https://doi.org/10.4103/1463-1741.132090

Eaaswarkhanth, M, Pavlidis, P & Gokcumen, O 2014, 'Geographic distribution and adaptive significance of genomic structural variants: An anthropological genetics perspective', *Human Biology*, vol. 86, no. 4, pp. 260–275. https://doi.org/10.13110/humanbiology.86.4.0260

Eagles, A & Stedmon, AW 2004, 'Are you cooking comfortably? Ergonomics in the restaurant kitchen', in PT Mccabe (ed.), *Contemporary ergonomics*, CRC Press, London.

Eartheasy 2020, 'Energy efficient lighting', *EarthEasy*, viewed 07 May 2020, from https://learn.eartheasy.com/guides/energy-efficient-lighting/

EASHW 2008a, 'E-fact 27 – Hot environments in HORECA', European Agency for Safety and Health at Work, Luxembourg, viewed 27 October 2021, https://osha.europa.eu/en/publications/e-fact-27-hot-environments-horeca/view

EASHW 2008b, *Working environment information- protecting workers in hotels, restaurants and catering*, European Agency for Safety and Health at Work, Luxembourg.

EASHW 2017, *Annual activity report 2016*, European Agency for Safety and Health at Work, Luxembourg.

Ecophon 2010, *Noise reduction in the food industry*, Ecophon, Hyllinge, viewed 01 May 2019, https://www.ecophon.com/globalassets/old-structure/01.ecophon-master/nhys/uk_nyhs_food-industry.pdf

Edwards, AL, Dekker, JJ, Franz, RM, Van Dyk, T & Banyini, A 2011, 'Profiles of noise exposure levels in South African mining', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 111, no. 5, pp. 315–322.

Eichwald, J, Murphy, WJ & Scinicariello, F 2022, 'Study shows noisy restaurants pose health risks', *The Hearing Journal*, vol. 75, no. 1, pp. 8-12. doi: https://doi.org/10.1097/01.HJ.0000812704.31321.cd

El-Sharkawy, MF & Javed, W 2018, 'Study of indoor air quality level in various restaurants in Saudi Arabia', *Environmental Progress & Sustainable Energy*, vol. 37, no. 5, pp. 1713–1721. https://doi.org/10.1002/ep.12859

Electrical Encounter 2019, 'Your guide to IP ratings', Electrical Encounter, Kent, viewed 13 November 2019, https://www.electricalcounter.co.uk/ip-rating.

Electricians Forums 2017, 'Won't install new cooker without new extraction?', Electricians Forums, viewed 03 March 2020, https://www.electriciansforums.net/threads/wont-install-new-cooker-without-new-extraction.119593/page-2

Electrical Knowhow 2013, 'Artificial lighting types and design', Electrical Knowhow, viewed n.d., http://www.electrical-knowhow.com/2012/03/artificial-lighting-types-and-design.html

EN ISO 7730 2005, *Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*, Technical Committee, Geneva.

Energy ACE CODE 2013, 'Building energy efficiency standards – Reference ace', Energy Code Ace, California, viewed 01 July 2020, https://energycodeace.com/site/custom/public/reference-ace-2013/index.html#!Documents/43ventilationrequirements.htm

Engelbrecht, F, Adegoke, J, Bopape, M, Naidoo, M, Garland, R, Thatcher, M et al. 2015, 'Projections of rapidly rising surface temperatures over Africa under low mitigation', *Environmental Research Letters*, vol. 10, no. 8, a085004. https://doi.org/10.1088/1748-9326/10/8/085004

The Engineering Toolbox 2004, 'Illuminance – Recommended light level', The Engineering Toolbox, viewed 09 February 2020, https://www.engineeringtoolbox.com/light-level-rooms-d_708.html

Environmental Protection Agency 2017, 'Why and where mold grows', United States Environmental Protection Agency, Washington DC, viewed 25 October 2021, https://www.epa.gov/mold/mold-course-chapter-2

Enviro FWA, 2019, 'The importance of cleaning kitchen extract ventilation systems', Enviro FWA, Warrenpoint, viewed 30 April 2022, https://web.archive.org/web/20210420153313/https://envirofwa.com/2019/06/05/importance-cleaning-kitchen-extract-ventilation-systems/

Epstein, Y & Moran, DS 2006, 'Thermal comfort and the heat stress indices', *Industrial Health*, vol. 44, no. 3, pp. 388–398. https://doi.org/10.2486/indhealth.44.388

Esfarjani, F, Khoshtinat, K, Zargaraan, A, Mohammadi-Nasrabadi, F, Salmani, Y, Saghafi, Z et al. 2019, 'Evaluating the rancidity and quality of discarded oils in fast food restaurants', *Food Science & Nutrition*, vol. 7, no. 7, pp. 2302–2311. https://doi.org/10.1002/fsn3.1072

Esther 2008, *Should a bald food handler wear a hairnet?*, Forum topic, International Food Safety and Quality Network, viewed 02 November 2019, https://www.ifsqn.com/forum/index.php/topic/10323-should-a-bald-food-handler-wear-a-hairnet/

eThekwini Municipality 2015a, 'City clamps down on nuisance behavior in public places', Top Business Portfolio, viewed 26 January 2020, https://kzntopbusiness.co.za/site/ethekwini-municipality/view/5662/2792/2015/09/21/eThekwini_Municipality__City_clamps_down_on_nuisance_behavior_in_public_places/

eThekwini Municipality 2015b, 'Legal services', eThekwini Municipality, Durban, viewed from 13 October 2019, https://web.archive.org/web/20180402134406/http://www.durban.gov.za/City_Government/Administration/city_manager/LegalServices/Pages/default.aspx

European Standards 2021, *BS EN 17037:2018 Daylight in buildings*, European Standards, viewed 01 May 2020, https://www.en-standard.eu/bs-en-17037-2018-daylight-in-buildings/?gclid=Cj0KCQjwt-6LBhDlARIsAIPRQcJ8zo7uc5xA2Dlsnf4pcFAatjwE0B-PSGPUOVq-Zy4Ml_JuBp39DqsaAoa0EALw_wcB

Everyday Health 2017, 'Gas vs. electric stove: Which do you need?', Everyday Health, viewed 11 April 2020, https://www.everydayhealth.com/healthy-living/healthy-home/gas-vs-electric-stove-which-you-need/

Ezani, E, Brimblecombe, P, Asha'ari, ZH, Fazil, AA, Ismail, SNS, Ramly, ZTA et al. 2021, 'Indoor and outdoor exposure to $PM_{2.5}$ during covid-19 lockdown in suburban Malaysia', *Aerosol and Air Quality Research*, vol. 21, a200476. https://doi.org/10.4209/aaqr.2020.07.0476

Ezzati, M & Kammen, DM, 2002, 'The health impacts of exposure to indoor air pollution from solid fuels in developing countries: Knowledge, gaps, and data needs', *Environmental Health Perspectives*, vol. 110, no. 11, a1057. https://doi.org/10.1289/ehp.021101057

Fameli, K, Kladakis, A & Assimakopoulos, VD 2022, 'Inventory of commercial cooking cctivities and emissions in a typical urban area in Greece', *Atmosphere*, vol. 13, no. 5, a792. https://doi.org/10.3390/atmos13050792

Fan, M, Su, M, Tan, Y, Liu, Q, Ren, Y, Li, L et al. 2015, 'Gender, age, and education level modify the association between body mass index and physical activity: A cross-sectional study in Hangzhou, China', *PloS One*, vol. 10, a0125534. https://doi.org/10.1371/journal.pone.0125534

Fanger, PO 1970, *Thermal comfort. Analysis and applications in environmental engineering*, Danish Technical Press, Copenhagen.

Fantech 2019, 'Kitchen ventilation', Fantech, Victoria, viewed 02 November 2019, https://www.fantech.com.au/FanApplication.aspx?AppID=D1#null

Farber, GS & Wang, LM 2017, 'Analyses of crowd-sourced sound levels of restaurants and bars in New York City', *Meetings on Acoustics*, Acoustical Society of America, New Orleans, pp. 1–16.

Farnell, GS, Pierce, KE, Collinsworth, TA, Murray, LK, Demes, RN, Juvancic-Heltzel, JA et al. 2008, 'The influence of ethnicity on thermoregulation after acute cold exposure', *Wilderness & Environmental Medicine*, vol. 19, no. 4, pp. 238–244. https://doi.org/10.1580/07-WEME-OR-138.1

Fauzan, MF, Zakariab, IA, Hasanb, NH, Anuar, FS & Ghazali, ND, 2014, 'Thermodynamic analysis of human heat and mass transfer and their impact on thermal comfort – A review', viewed 02 November 2019, https://www.researchgate.net/publication/263866314

FCSI, 2006, 'Commercial kitchen ventilation-best practice', Mexico Documents, viewed 22 October 2021, https://vdocuments.mx/commercial-kitchen-ventilation-white-paperpdf-fcsi-ckv-white-paper-.html

Fedoronko, K 2020, *Building our health: Optimizing human health in architectural design*, Ball State University, Muncie.

Felderman, K 2017, *How lighting affects the productivity of your workers*, Kenan-Flagler Business School, viewed 16 March 2020, https://onlinemba.unc.edu/news/how-lighting-affects-productivity/

Field, A 2013, *Discovering statistics using IBM SPSS statistics*, 4th edn., Sage, London.

Fischer, M, Spessert, B & Emmerich, E 2014, 'Noise reduction measures of noisy kitchen devices and evidence of their improvement by an objective analysis of spontaneous EEG measurements', *Inter-Noise and Noise Congress and Conference Proceedings*, Institute of Noise Control Engineering, Melbourne, pp. 340–347.

Fisher, D, Swierczyna, R & Karas, A 2015, 'Commercial kitchen ventilation exhaust hoods', *ASHRAE Journal*, vol. 57, pp. 26–37, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.

Flick, U 2015, *Introducing research methodology: A beginner's guide to doing a research project*, Sage Publications, London.

Flick, U 2019, *An introduction to qualitative research*, Sage Publications, London.

Fligor, BJ, Levey, S & Levey, T 2014, 'Cultural and demographic factors influencing noise exposure estimates from use of portable listening devices in an urban environment', *Journal of Speech, Language, and Hearing Research*, vol. 57, no. 4, pp. 1535–1547. https://doi.org/10.1044/2014_JSLHR-H-12-0420

Flouris, AD, Dinas, PC, Ioannou, LG, Nybo, L, Havenith, G, Kenny, GP et al. 2018, 'Workers' health and productivity under occupational heat strain: A systematic review and meta-analysis', *The Lancet Planetary Health*, vol. 2, no. 12, pp. 521–531. https://doi.org/10.1016/S2542-5196(18)30237-7

Foley, B 2018, 'What is regression analysis and why should I use it?', Survey Gizmo, viewed 02 November 2019, https://www.surveygizmo.com/resources/blog/regression-analysis/

Forcada, N & Tejedor, B 2020, 'Evaluation of thermal comfort in elderly care centres (ECC)r', in *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 200–215.

Forouharmajd, F & Shabab, M 2015, 'Noise pollution status in a metal melting industry and the map of its isosonic curve', *Jundishapur Journal of Health Sciences*, vol. 7, no. 4, pp. 46–50. https://doi.org/10.17795/jjhs-30366

Fostervold, K & Nersveen, J 2008, 'Proportions of direct and indirect indoor lighting – The effect on health, well-being and cognitive performance of office workers', *Lighting Research & Technology*, vol. 40, no. 4, pp. 175–200. https://doi.org/10.1177/1477153508090917

Fotios, S & Johansson, M 2019, 'Appraising the intention of other people: Ecological validity and procedures for investigating effects of lighting for pedestrians', *Lighting Research & Technology*, vol. 51, no. 1, pp. 111–130. https://doi.org/10.1177/1477153517737345

Fox, S 2019, 'Noise level chart', *Noise Help*, viewed 31 October 2019, https://web.archive.org/web/20210326121648/https://www.noisehelp.com/noise-level-chart.html

Frimpong, K 2015, 'An appraisal of experiences of climate change and adaptive response to heat stress by farmers in rural Ghana', PhD thesis, Edith Cowan University.

Frontczak, M, Schiavon, S, Goins, J, Arens, E, Zhang, H & Wargocki, P, 2012, 'Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design', *Indoor Air*, vol. 22, no. 2, pp. 119–131. https://doi.org/10.1111/j.1600-0668.2011.00745.x

Frontczak, M & Wargocki, P 2011, 'Literature survey on how different factors influence human comfort in indoor environments', *Building and Environment*, vol. 46, no. 4, pp. 922–937. https://doi.org/10.1016/j.buildenv.2010.10.021

Gabel, V, Maire, M, Reichert, C, Chellappa, S, Schmidt, C, Hommes, V et al. 2013, 'Effects of artificial dawn and morning blue light on daytime cognitive performance, well-being, cortisol and melatonin levels', *The Journal of Biological and Medical Rhythm Researc*, vol. 30, no. 8, pp. 988–997. https://doi.org/10.3109/07420528.2013.793196

Galarza, D 2015, 'Cooks have the third worst job in America, study finds', *Eater*, viewed 13 November 2019, https://www.eater.com/2015/4/14/8415113/cook-third-worst-job-america-study-career-cast

Gangiah, S 2021, 'Behavioural adaptation: A review of adaptation to workplace heat exposure of kitchen workers with reference to gender differences in Durban', *HTS Theological Studies*, vol. 77, no. 2, a6823. https://doi.org/10.4102/hts.v77i2.6823

Gangiah, S & Naidoo, KM 2021, 'An exploration of environmental ergonomics: A case of restaurant kitchens in Durban', PhD thesis, Durban University of Technology, Durban.

Ganguly, SK 2013, 'Yogic practices applied to physical education and sports', *International Journal of Yoga and Allied Sciences*, vol. 2, no. 1, pp. 49–53.

Gao, C, Kuklane, K, Östergren, P & Kjellstrom, T 2018, 'Occupational heat stress assessment and protective strategies in the context of climate change', *International Journal of Biometeorology*, vol. 62, no. 3, pp. 359–371. https://doi.org/10.1007/s00484-017-1352-y

Gardner, D, Laird, I, Dickinson, P, Legg, S, Mcbride, D & Mclaren, S 2014, 'Safety climate, attitudes to noise management and exposure to noise in small and medium sized workplaces in New Zealand', *Small Enterprise Research*, vol. 21, no. 2, pp. 190–201. https://doi.org/10.1080/13215906.2014.11082087

Gauer, R & Meyers, BK 2019, 'Heat-related illnesses', *American Family Physician*, vol. 99, no. 8, pp. 482–489.

Gauthier, S & Bourikas, L 2020, 'Investigating dependencies between indoor environmental parameters: Thermal, air quality and acoustic perception', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 323–330.

Gaydos, M, Bhatia, R, Morales, A, Lee, PT, Liu, SS, Chang, C et al. 2011, 'Promoting health and safety in San Francisco's Chinatown restaurants: Findings and lessons learned from a pilot observational checklist', *Public Health Reports*, vol. 126, Suppl. 3, pp. 62–69. https://doi.org/10.1177/00333549111260S311

Green building Council South Africa (GBCSA), 2017, *About GBCSA*, viewed 10 May 2020, https://gbcsa.org.za/about-gbcsa/

Ghaffarianhoseini, A, Alwaer, H, Omrany, H, Ghaffarianhoseini, A, Alalouch, C, Clements-Croome, D et al. 2018, 'Sick building syndrome: Are we doing enough?', *Architectural Science Review*, vol. 61, no. 3, pp. 99–121. https://doi.org/10.1080/00038628.2018.1461060

Ghasemkhani, M & Naseri, F 2008, 'Comparison of indoor air quality in restaurant kitchens in Tehran with ambient air quality', *Journal of Environmental Health Science & Engineering*, vol. 5, no. 1, pp. 59–64.

Giarma, C, Tsikaloudaki, K & Aravantinos, D 2017, 'Daylighting and Visual Comfort in Buildings' Environmental Performance Assessment Tools: A Critical Review', *Procedia Environmental Sciences*, vol. 38, pp. 522–529. https://doi.org/10.1016/j.proenv.2017.03.116

Gibson, R 2013, 'How to bring natural light into your dark kitchen', *Decoist*, viewed 22 May 2020, https://www.decoist.com/2013-02-06/how-to-bring-in-natural-light-to-your-dark-kitchen/?chrome=1

GIFActive Vent 2021, *Brilliant solutions for commercial kitchens*, GIFActive Vent, Freiburg, viewed 20 October 2021, https://eftech.ie/wp-content/uploads/2021/03/GIF_IB_EN.pdf

Gigstad, J 2002, 'Ergonomic analysis of production cooks at XYZ high school', MSc, University of Wisconsin-Stout, Menomonie.

Girard, S, Leroux, T, Courteau, M, Picard, M, Turcotte, F & Richer, O 2015, 'Occupational noise exposure and noise-induced hearing loss are associated with work-related injuries leading to admission to hospital', *Injury Prevention*, vol. 21, no. e1, pp. 88–92. https://doi.org/10.1136/injuryprev-2013-040828

Giwa, SO, Nwaokocha, CN & Sharifpur, M 2022, 'An appraisal of air quality, thermal comfort, acoustic, and health risk of household kitchens in a developing country', *Environmental Science and Pollution Research*, vol. 29, no. 18, pp. 26202-26213. https://doi.org/10.1007/s11356-021-17788-6

Gladieux, D 2015, 'Characterization of noise exposure for high-volume restaurant workers', MSc, University of South Florida, Tampa.

Glamox 2017, 'Canteens and kitchens', Glamox, Oslo, viewed 03 November 2019, https://glamox.com/uk/solutions/school-kitchen

Glickman, G 2019, *Novel lighting strategies for optimizing circadian health and alertness in shiftworkers (new project)*, U.S. Department of Energy, University of California, San Diego.

Göçer, Ö, Candido, C, Thomas, L & Göçer, K 2019, 'Differences in occupants' satisfaction and perceived productivity in high-and low-performance offices', *Buildings*, vol. 9, no. 9, p. 199. https://doi.org/10.3390/buildings9090199

Goines, L & Hagler, L 2007, 'Noise pollution: A modern plague', *Southern Medical Journal-Birmingham Alabama*, vol. 100, p. 287. https://doi.org/10.1097/SMJ.0b013e3180318be5

Golbazi, M, El Danaf, A & Aktas, CB 2020, 'Willingness to pay for green buildings: A survey on students' perception in higher education', *Energy and Buildings*, vol. 216, a109956. https://doi.org/10.1016/j.enbuild.2020.109956

Goldman, GJ 2014, 'How human culture influences our genetics', *BBC*, viewed 14 November 2020, https://www.bbc.com/future/article/20140410-can-we-drive-our-own-evolution

Goldsmith, M 2013, 'The quiet house', Quiet Mark, viewed 21 November 2020, https://www.realwire.com/writeitfiles/Quiet-Mark-Quiet-House-IHS-Stats-and-Facts-FINAL.pdf

Gordon, KB & Zeigler, B 2017, 'How to reinvent open kitchens', *Restaurant and Hospitality*, viewed 03 November 2019, https://www.restaurant-hospitality.com/design/how-reinvent-open-kitchens

Gough, HL, Luo, Z, Halios, CH, King, M, Noakes, CJ, Grimmond, CSB et al. 2018, 'Field measurement of natural ventilation rate in an idealised full-scale building located in a staggered urban array: Comparison between tracer gas and pressure-based methods', *Building and Environment*, vol. 137, pp. 246–256. https://doi.org/10.1016/j.buildenv.2018.03.055

Graydon, K, Waterworth, C, Miller, H & Gunasekera, H 2019, 'Global burden of hearing impairment and ear disease', *The Journal of Laryngology & Otology*, vol. 133, pp. 18–25. https://doi.org/10.1017/S0022215118001275

Grease Cycle 2018, *Your guide to restaurant equipment maintenance*, Grease Cycle, Raleigh, viewed 03 November 2019, http://www.grease-cycle.com/blog2/restaurant-equipment-maintenance/

Green, DR & Anthony, TR 2015, 'Occupational noise exposure of employees at locally-owned restaurants in a college town', *Journal of Occupational and Environmental Hygiene*, vol. 12, pp. 489–499. https://doi.org/10.1080/15459624.2015.1018517

Greenberg, M 2017, 'Flick of a switch: How lighting affects productivity and mood', *Business.com*, viewed n.d., https://www.business.com/articles/flick-of-a-switch-how-lighting-affects-productivity-and-mood/

Greenheck 2020, *Kitchen ventilation system-application and design guide*, Geenheck Corporation, Schofield, viewed 05 November 2020, from https://greenheck-cms-prod.azureedge.net/atg-cms-prod/docs/default-source/pdf-downloads/catalogs/kvshoods_catalog.pdf?sfvrsn=4c39ad92_6

Greenplan 2015, 'Natural ventilation', Greenplan, Somerset West, viewed 30 January 2020, https://www.greenplan.co.za/consulting/natural-ventilation/

Green Seal 2014, *GS-55: Green Seal™ standard for restaurants and food services*, Green Seal Inc., Washington DC.

Greiner, TH 2020, 'Carbon monoxide poisoning: Gas-fired kitchen ranges', Iowa State University, viewed 16 January 2020, https://www.abe.iastate.edu/extension-and-outreach/carbon-monoxide-poisoning-gas-fired-kitchen-ranges-aen-205/

Gronlund, CJ 2014, 'Racial and socioeconomic disparities in heat-related health effects and their mechanisms: A review', *Current Epidemiology Reports*, vol. 1, no. 3, pp. 165–173. https://doi.org/10.1007/s40471-014-0014-4

Gu, JK, Charles, LE, Bang, KM, Ma, CC, Andrew, ME, Violanti, JM et al. 2014, 'Prevalence of obesity by occupation among US workers: The National Health Interview Survey 2004–2011', *Journal of Occupational and Environmental Medicine/American College of Occupational and Environmental Medicine*, vol. 56, no. 5, p. 516. https://doi.org/10.1097/JOM.0000000000000133

Guadagnoli, E & Velicer, WF 1988, 'Relation of sample size to the stability of component patterns', *Psychological Bulletin*, vol. 103, no. 2, p. 265. https://pubmed.ncbi.nlm.nih.gov/3363047/

Gubernot, DM, Anderson, GB & Hunting, KL 2014, 'The epidemiology of occupational heat exposure in the United States: A review of the literature and assessment of research needs in a changing climate', *International Journal of Biometeorology*, vol. 58, no. 8, pp. 1779–1788. https://doi.org/10.1007/s00484-013-0752-x

Guevara, G, Soriano, G & Rodriguez, IM 2020, 'Thermal comfort assessment in university classrooms in the tropics', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 236–251.

Haberl, J, Davies, H, Owens, B & Hunn, B 2008, 'ASHRAE's new performance measurement protocols for commercial buildings', *Proceedings of the Eighth International Conference for Enhanced Building Operations*, Energy Systems Laboratory, Berlin, viewed 29 April 2022, https://hdl.handle.net/1969.1/90789

Habibi, P, Momeni, R & Dehghan, H 2016, 'The effect of body weight on heat strain indices in hot and dry climatic conditions', *Jundishapur Journal of Health Sciences*, vol. 8, p. 8. https://doi.org/10.17795/jjhs-34303

Halton 2007, *Halton design guide for indoor air climate in commercial kitchens*, Halton Foodservice, Pulttikatu.

Halton 2020, 'Ventilated ceiling system', Halton Foodservice, Pulttikatu, viewed 20 October 2020, https://www.halton.com/wp-content/uploads/2020/08/Halton_Ventilated_Ceiling_Brochure_BR-006.pdf

Hammer, R & Holzer, P 2020, 'Indoor daylight supply – A must have for all climates', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 980–983.

Han, O, Li, A, & Kosonen, R 2019, 'Hood performance and capture efficiency of kitchens: A review: Building and environment', Kundoc, viewed 29 April 2022, https://coek.info/pdf-hood-performance-and-capture-efficiency-of-kitchens-a-review-.html

Handzlik, D 2018, 'Why do different races often have physical differences besides skin color?', *Quora*, viewed 05 May 2019, https://www.quora.com/Why-do-different-races-often-have-physical-differences-besides-skin-color/answer/David-Handzlik

Hanna, E & Tait, P 2015, 'Limitations to thermoregulation and acclimatization challenge human adaptation to global warming', *International Journal of Environmental Research and Public Health*, vol. 12, no. 7, pp. 8034–8074. https://doi.org/10.3390/ijerph120708034

Hansen, A, Bi, L, Saniotis, A & Nitschke, M 2013, 'Vulnerability to extreme heat and climate change: Is ethnicity a factor?', *Global Health Action*, vol. 6, a21364. https://doi.org/10.3402/gha.v6i0.21364

Hansen, A, Bi, P, Nitschke, M, Pisaniello, D, Newbury, J & Kitson, A 2011,' Perceptions of heat-susceptibility in older persons: Barriers to adaptation', *International Journal of Environmental Research and Public Health*, vol. 8, no. 12, pp. 4714–4728. https://doi.org/10.3390/ijerph8124714

Hansen, A, Pisaniello, D, Varghese, B, Rowett, S, Hanson-Easey, S, Bi, P et al. 2018, 'What can we learn about workplace heat stress management from a safety regulator complaints database?', *International Journal of Environmental Research and Public Health*, vol. 15, no. 3, a459. https://doi.org/10.3390/ijerph15030459

Hansia, MR & Dickinson, D 2010, 'Hearing protection device usage at a South African gold mine', *Occupational Medicine*, vol. 60, pp. 72–74. https://doi.org/10.1093/occmed/kqp114

Haruyama, Y, Muto, T, Matsuzuki, H, Ito, A, Tomita, S, Muto, S et al. 2010, 'Evaluation of subjective thermal strain in different kitchen working environments using subjective judgment scales', *Industrial Health*, vol. 48, no. 2, pp. 135–144. https://doi.org/10.2486/indhealth.48.135

Hatchuel, M 2018, 'Noisy, nuisance neighbours? Know your rights', *Private Property*, viewed 03 November 2019, https://www.privateproperty.co.za/advice/property/articles/noisy-nuisance-neighbours-know-your-rights/3273

Havenith, G & Fiala, D 2016, 'Thermal indices and thermophysiological modeling for heat stress', *Comprehensive Physiology*, vol. 6, no. 1, pp. 255–302. https://doi.org/10.1002/cphy.c140051

Hayashi, P, Abib, G & Hoppen, N 2019, 'Validity in qualitative research: A processual approach', *The Qualitative Report*, vol. 24, no. 1, pp. 98–112. https://doi.org/10.46743/2160-3715/2019.3443

Heale, R & Twycross, A 2015, 'Validity and reliability in quantitative research', *The British Medical Journal*, vol. 18, pp. 66–67. http://dx.doi.org/10.1136/eb-2015-102129

Health and Safety Executive UK 2013, *Heat stress in the workplace – A brief guide*, Health and Safety Executive UK, Edinburgh, pp. 1–4.

Hedge, A & Nou, D 2018, 'Effects of electrochromic glass on computer vision syndrome', in *Human Factors and Ergonomics Society Annual Meeting*, Sage Publications, Los Angeles, pp. 378–382.

Heggie, V 2019, 'Blood, race and indigenous peoples in twentieth century extreme physiology', *History and Philosophy of the Life Sciences*, vol 41, p. 26. https://doi.org/10.1007/s40656-019-0264-z

Heinonen, J 1997, 'Indoor climate in commercial kitchens and possibilities to improve it', Master's thesis, Helsinki University of Technology, Helsinki.

Heinzerling, D, Webster, T, Schiavon, S, Anwar, G & Dickerhoff, D 2013, 'A prototype toolkit for evaluating indoor environmental quality in commercial buildings', *eScholarship*, viewed 03 November 2019, https://escholarship.org/uc/item/7jh9h72t

Hellwig, RT, Despoina, T, Schweiker, M, Choi, J, Lee, JM, Mora, R et al. 2020, 'Guideline to bridge the gap between adaptive thermal comfort theory and building design and operation practice', *Windsor Conference 2020: Resilient Comfort*, Ecohouse Initiative Ltd, Witney, pp. 529–545.

Hillis, J, 2018, 'BMI vs. body fat per centage', *LiveStrong.com*, viewed 03 November 2019, https://www.livestrong.com/article/77106-bmi-vs.-body-fat-percentage/

Ho, SSH, Yu, JZ, Chu, KW & Yeung, LL 2006, 'Carbonyl emissions from commercial cooking sources in Hong Kong', *Journal of the Air & Waste Management Association*, vol. 56, pp. 1091–1098. https://doi.org/10.1080/10473289.2006.10464532

Holzer, P & Stuckey, D 2020, 'Balanced heating & cooling with radiative surfaces: Resilient answers to upcoming cooling needs, with new questions for the comfort community', in *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 1039–1045.

Honeywell 2017, 'Indoor air quality checklist', Honeywell International Inc, Charlotte, viewed 03 November 2019, https://buildings.honeywell.com/content/dam/hbtbt/en/documents/downloads/IAQ%20Checklist%20PDF-Digital.pdf

Hood Products 2020, 'NFPA 96: Standard for ventilation control and fire protection of commercial cooking operations', Hood Filters, viewed 17 Jaunary 2020, https://www.hoodfilters.com/nfpa/

Hossain, MS & Majumder, AK 2017, 'Investigation of customers'comfort perception in the hot humid region's restaurants', *EPRA International Journal of Research and Development*, vol. 2, no. 10, pp. 1–7.

Houzz 2019, 'CRI vs Lumens – Which is most important?', *Lighting*, viewed 26 March 2020, from https://www.houzz.com/discussions/3581603/cri-vs-lumens-which-is-most-important

Health and Safety Executive (HSE) 1997, *Lighting at work*, Health and Safety Executive, Bootle, viewed n.d., http://www.hse.gov.uk/pubns/priced/hsg38.pdf

Huang, L, Cheng, H, Ma, S, He, R, Gong, J, Li, G et al. 2021, 'The exposures and health effects of benzene, toluene and naphthalene for Chinese chefs in multiple cooking styles of kitchens', *Environment International*, vol. 156, pp. 52–55. https://doi.org/10.1016/j.envint.2021.106721

Hubbard, B 2020, 'The 10 best laser measuring tools', *The Architect's Guide*, viewed n.d., https://www.thearchitectsguide.com/blog/best-laser-measuring-tools

Hueda, RA 2020, 'Key factors and problems in the performance of kitchen ventilation systems', MSc thesis, University of Gävle, Gävle.

Hwang, T & Kim, JT 2011, 'Effects of indoor lighting on occupants' visual comfort and eye health in a green building', *Indoor and Built Environment*, vol. 20, no. 1, pp. 75–90. https://doi.org/10.1177/1420326X10392017

Idang, GE 2015, 'African culture and values', *Phronimon*, vol. 16, no. 2, pp. 97–111. https://journals.co.za/doi/pdf/10.10520/EJC189182

International Mechanical Code (IMC) 2015, *Washington state building code*, I.C. Council (ed.), International Mechanical Code, Washington DC.

International Mechanical Code (IMC) 2018, *International mechanical code – Chapter 5 exhaust system*, International Code Council, Washington DC, viewed 24 October 2021, from https://codes.iccsafe.org/s/IMC2018/chapter-5-exhaust-systems/IMC2018-Ch05-Sec502.1

Institution of Gas Engineers and Managers (IGEM) 2015, *Guidance for gas engineers to the application of relevant sections of IGEM/UP/19 in catering establishments*, Institution of Gas Engineers and Managers, Kegworth, viewed 03 November 2019, https://www.igem.org.uk/_resources/assets/attachment/full/0/2303.pdf

International Agency for Research on Cancer (IARC) 2010, *Household use of solid fuels and high-temperature frying*, IARC Press, International Agency for Research on Cancer, Lyon.

International Labour Organisation (ILO) 2017, *Why is lighting in the workplace important?* International Labour Organisation, Geneva, viewed 01 November 2021, https://www.ilo.org/wcmsp5/groups/public/---americas/---ro-lima/---sro-port_of_spain/documents/presentation/wcms_250198.pdf

Jagarnath, M, Thambiran, T & Gebreslasie, M 2020, 'Heat stress risk and vulnerability under climate change in Durban metropolitan, South Africa – Identifying urban planning priorities for adaptation', *Climatic Change*, vol. 163, no. 2, pp. 807–829. https://doi.org/10.1007/s10584-020-02908-x

James, GD 2010, 'Climate-related morphological variation and physiological adaptations in homo sapiens', in CS Larsen (ed.), *A companion to biological anthropology*, Wiley-Blackwell, Chichester, pp. 153–166.

Juslén, H, Wouters, M & Tenner, A 2007, 'The influence of controllable task-lighting on productivity: a field study in a factory', *Applied Ergonomics*, vol. 38, no. 1, pp. 39–44. https://doi.org/10.1016/j.apergo.2006.01.005

Modern Data Management 2018, '10 Best practices in data preparation "data profiling and data quality analysis best practices"', *Import.io*, viewed 30 April 2022, https://www.import.io/post/10-best-practices-data-preparation/

Index Mundi 2020, 'South Africa country profile 2018', *Index Mundi*, viewed 01 November 2021, https://www.indexmundi.com/south_africa/

Indraganti, M 2020, 'Differences in thermal comfort and satisfaction in offices based on gender', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 829–841.

Intelligent Cooling Solutions 2019, 'Portable air cooling', Intelligent Cooling Solutions, Kilkenny, viewed 05 October 2020, https://coolingsolutions.ie/

Iwata, T, Shinohara, N, Kaiho, K & Nakao, R 2016, 'Performance and visual comfort of light duct system adopted in a fast food restaurant', *AIJ Journal of Technology and Design*, vol. 22, pp. 579–584. https://doi.org/10.3130/aijt.22.579

Jacklitsch, B, Williams, WJ, Musolin, K, Coca, A, Kim, JH & Turner, N 2016, *Criteria for a recommended standard occupational exposure to heat and hot environments*, Department of Health and Human Services, Atlanta.

Jacoby, C 2018, 'How to reduce scalp sweating', *Health Guidance*, viewed 16 November 2019, https://www.healthguidance.org/entry/14386/1/how-to-reduce-scalp-sweating.html

Jadhav, GK, Ghanegaonkar, P & Garg, S 2016, 'Experimental and CFD analysis of turbo ventilator', *Journal of Building Engineering*, vol. 6, pp. 196–202. https://doi.org/10.1016/j.jobe.2016.04.001

Jagarnath, M, Thambiran, T & Gebreslasie, M 2020, 'Heat stress risk and vulnerability under climate change in Durban metropolitan, South Africa – Identifying urban planning priorities for adaptation', *Climatic Change*, vol. 163, no. 2, pp. 807–829. https://doi.org/10.1007/s10584-020-02908-x

Jakubiec, JA, Srisamranrungruang, T, Kong, Z, Quek, G & Talami, R 2019, *Subjective and measured evidence for residential lighting metrics in the tropics*, Building Simulation, Rome.

Jariwala, HJ, Syed, HS, Pandya, MJ & Gajera, YM 2017, 'Noise pollution & human health: A review', *Indoor and Built Environment,* vol. 26, pp. 1–4.

Jeng, Y, Lin, S, Hu, H, Lee, OK & Kuo, L 2018, 'Osteoporosis and dry eye syndrome: A previously unappreciated association that may alert active prevention of fall', *PLoS One*, vol. 13, no. 11, a0207008. https://doi.org/10.1371/journal.pone.0207008

Jensen, A 2019, 'How office lighting affects productivity', *Andrew Jensen*, blog post, 27 June, viewed 04 November 2019, https://www.andrewjensen.net/how-office-lighting-affects-productivity/

Jeong, S, Kwon, H, Ahn, S & Yang, J 2016, 'A study on the improvement of ventilation rate using air-flow inducing local exhaust ventilation system', *Journal of Asian Architecture and Building Engineering*, vol. 15, no. 1, pp. 119–126. https://doi.org/10.3130/jaabe.15.119

Jiang, C, Chau, KT, Leung, YY, Liu, C, Lee, HT & Han, W 2019, 'Design and analysis of wireless ballastless fluorescent lighting', *IEEE Transactions on Industrial Electronics*, vol. 66, pp. 4065–4074. https://doi.org/10.1109/TIE.2017.2784345

Jiang, DH, Wang, ZH, Shi, FE & Ren, RS 2012, 'Numerical and experimental analysis on indoor thermal environment in commercial kitchen', in *Advanced materials research*, Trans Tech Publications Ltd., Wollerau, pp. 4435–4438.

Jiang, XH & Wang, CH 2008, 'Investigation on the noise pollution in kitchens', *Journal of Environmental & Occupational Medicine*, vol. 1, n.p.

Jimoh, IA 2017, 'Workspace utilisation, maintenance practice and lecturers' satisfaction with indoor environmental quality in selected Nigerian universities', PhD thesis, University of Lagos, Lagos.

Joachim, D & Schloss, A 2017, 'The science of cooktops', *Fine Cooking*, viewed 04 July 2020, https://www.finecooking.com/article/the-science-of-cooktops

Jobtips 2020, 'Noise level', *do2Learn*, viewed 03 April 2020, https://do2learn.com/JobTIPS/DeterminingInterests/EnvironmentalDemands/NoiseLevel.html

John, D & Liu, S 2020, 'Air diffusion performance index method update', *ASHRAE Journal*, vol. 62, pp. 20–26, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.

Johnson, F, Zabrowski, D, Zhivov, AM & Fisher, D 2019, *Energy and water efficiency improvements for dishrooms in military dining facilities*, Gas Technology Institute, Des Plaines.

Kabir, A 2019, 'How we will promote safe cook in kitchen?', *CPQ Medicine*, vol. 7, pp. 1–5.

Kane International 2020, 'What are safe levels of CO and CO_2 in rooms?', Kane International Ltd, Welwyn Garden City, viewed 19 October 2020, https://www.kane.co.uk/knowledge-centre/what-are-safe-levels-of-co-and-co2-in-rooms

Kapur, R 2018, *Research methodology: Methods and strategies*, University of Delhi, Delhi, viewed 04 November 2019, https://cmapspublic2.ihmc.us/rid=1SG69305X-1FN0PGW-TK/Kapur%20-%20Research%20methodology%20Methods%20and%20strategies.pdf

Karyono, K, Abdullah, BM, Cotgrave, AJ, Bras, A & Cullen, J 2022, 'Human-centred approach in industry 4.0: lighting comfort in the workplace', in *Global Congress on Manufacturing and Management*, Springer, Cham, pp. 533–546.

KAUL, N., KHANDELWAL, S. & SUTHAR, G. 2022. Health Aspects of Indoor Environmental Quality. *Biotechnological Innovations for Environmental Bioremediation*. Springer, Cham.

Keil, CB, Kassa, H & Fent, K 2004, 'Kitchen hood performance in food service operations', *Journal of Environmental Health*, vol. 67, no. 5, p. 25.

Kerns, E, Masterson, EA, Themann, CL & Calvert, GM 2018, 'Cardiovascular conditions, hearing difficulty, and occupational noise exposure within US industries and occupations', *American Journal of Industrial Medicine*, vol. 61, no. 6, pp. 477–491. https://onlinelibrary.wiley.com/doi/10.1002/ajim.22833

Keuter, M 2008, *National Building Regulations and Building Standards Act No. 103 of 1977*, Government Printers, Pretoria, pp. 1–127.

Khovalyg, D, Chatterjee, A & Lichtenbelt, WVM 2020, 'Living in extremes: Dynamic indoor environment and thermal performance of traditional nomadic yurts', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 546–557.

Kim, H 2012, 'Field-Test of the New ASHRAE/CIBSE/USGBC Performance Measurement Protocols for Commercial Buildings: Basic Level', *Atlanta*, vol. 118, pp. 135–142.

Kim, J & De Daar, R 2012, 'Nonlinear relationships between individual IEQ factors and overall workspace satisfaction', *Building and Environment*, vol. 49, pp. 33–40. https://doi.org/10.1016/j.buildenv.2011.09.022

Kim, H & Haberl, J 2018, 'Field-test of the ASHRAE/CIBSE/USGBC performance measurement protocols: Part I intermediate level energy protocols', *Science and Technology for the Built Environment*, vol. 24, no. 3, pp. 281–297. https://doi.org/10.1080/23744731.2017.1368836

Kim, NK, Kang, DH, Lee, W & Kang, HW 2022, 'Removal efficiency of PM_{10} via ventilation with residential exhaust hood and conditions for reducing human intake fraction', *Environmental Modeling & Assessment*, vol. 27, pp. 461–472. http://dx.doi.org/10.1007/s10666-022-09827-4

Kim, G, Lim, HS, Lim, TS, Shaefer, L & Kim, JT 2012, 'Comparative advantage of an exterior shading device in thermal performance for residential buildings', *Energy and Buildings*, vol. 46, pp. 105–111. https://doi.org/10.1016/j.enbuild.2011.10.040

Kim, J, De Dear, R, Candido, C, Zhang, H & Arens, E 2013, 'Gender differences in office occupant perception of indoor environmental quality (IEQ)', *Building and Environment*, vol. 70, pp. 245–256. https://doi.org/10.1016/j.buildenv.2013.08.022

Kim, K, Pandey, SK, Kabir, E, Susaya, J & Brown, RJ 2011, 'The modern paradox of unregulated cooking activities and indoor air quality', *Journal of Hazardous Materials*, vol. 195, pp. 1–10. https://doi.org/10.1016/j.jhazmat.2011.08.037

Kim, YS, Walker, IS & Delp, WW 2018, 'Development of a standard capture efficiency test method for residential kitchen ventilation', *Science and Technology for the Built Environment*, vol. 24, no. 2, pp. 176–187. https://doi.org/10.1080/23744731.2017.1416171

Kjellstrom, T, Lemke, B, Hyatt, O & Otto, M 2014, 'Climate change and occupational health: A South African perspective', *South African Medical Journal*, vol. 104, no. 8, pp. 1–5. https://doi.org/10.7196/SAMJ.8646

Kjellstrom, T, Lemke, B & Otto, M 2013, 'Mapping occupational heat exposure and effects in South-East Asia: Ongoing time trends 1980–2011 and future estimates to 2050', *Industrial Health*, vol. 51, no. 1, pp. 56–67. https://doi.org/10.2486/indhealth.2012-0174

Knoop, M, Stefani, O, Bueno, B, Matusiak, B, Hobday, R, Wirz-Justice, A et al. 2020, 'Daylight: What makes the difference?', *Lighting Research & Technology*, vol. 52, no. 3, pp. 423–442. https://doi.org/10.1177/1477153519869758

Kong, M & Zhang, J 2016, 'Life-cycle cost and benefit analysis of utilizing hoods for light-duty cooking appliances in commercial kitchens (RP-1631, part 2)', *Science and Technology for the Built Environment*, vol. 22, no. 6, pp. 866–882. https://doi.org/10.1080/23744731.2016.1197750

Konig, H 2019, 'Avoid fines, imprisonment for acts of "public nuisance"', *South Coast Sun*, 03 August, viewed 22 November 2020, https://southcoastsun.co.za/99902/avoid-fines-imprisonment-acts-public-nuisance/

Kosonen, R 2002, 'Displacement ventilation for room air moisture control in hot and humid climate', in *Roomvent*, Citeseer, Copenhagen, pp. 241–244.

Kosonen, R 2005, 'The meaning of efficiency on the requested air flow rate in commercial kitchens', Risto Kosonen, article upload, viewed 13 November 2020, https://www.researchgate.net/profile/R_Kosonen/publication/237405870_the_meaning_of_efficiency_on_the_requested_air_flow_rate_in_commercial_kitchens/links/5416dbc00cf2fa878ad42fe3/the-meaning-of-efficiency-on-the-requested-air-flow-rate-in-commercial-kitchens.pdf

Kosonen, R 2006, 'Literature review on health and productivity factors in kitchens', *Yumpu*, viewed 11 September 2021, https://www.yumpu.com/en/document/read/5538531/literature-review-on-health-and-productivity-factors-in-kitchens

Kosonen, R 2010, 'Displacement ventilation for room air moisture control in hot and humid climate air distribution techniques (air distribution techniques 5)', in *HVAC handbook-displacement ventilation in hot and humid climate*, Industrial Press Inc., New York, pp. 1–4.

Kosonen, R, Koskela, H & Saarinen, P 2006, 'Thermal plumes of kitchen appliances: Cooking mode', *Energy and Buildings*, vol. 38, no. 10, pp. 1141–1148. https://doi.org/10.1016/j.enbuild.2006.01.003

Kralikova, R & Wessely, E 2017, 'Lighting quality, productivity and human health', *Proceedings of the 27th DAAAM International Symposium*, Vienna, pp. 59–66.

Krishnamurthy, M, Ramalingam, P, Perumal, K, Kamalakannan, LP, Chinnadurai, J, Shanmugam, R et al. 2017, 'Occupational heat stress impacts on health and productivity in a steel industry in southern India', *Safety and Health at Work*, vol. 8, no. 1, pp. 99–104. https://doi.org/10.1016/j.shaw.2016.08.005

Kruisselbrink, T, Dangol, R & Rosemann, A 2018, 'Photometric measurements of lighting quality: An overview', *Building and Environment*, vol. 138, pp. 42–52. https://doi.org/10.1016/j.buildenv.2018.04.028

Kue, J, Szalacha, LA, Happ, MB, Crisp, AL & Menon, U 2018, 'Culturally relevant human subjects protection training: A case study in community-engaged research in the United States', *Journal of Immigrant and Minority Health*, vol. 20, no. 1, pp. 107–114. https://doi.org/10.1007/s10903-017-0548-x

Kuehn, TH 2009, 'Characterization of cooking effluent from seven commercial kitchen appliances and representative food products', *ASHRAE Transactions*, vol. 115, pp. 360–365, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.

Küller, R, Ballal, S, Laike, T, Mikellides, B & Tonello, G 2006, 'The impact of light and colour on psychological mood: A cross-cultural study of indoor work environments', *Ergonomics*, vol. 49, no. 14, pp. 1496–1507. https://doi.org/10.1080/00140130600858142

Kulve, M, Hellwig, R, Dijken, FV & Boerstra, A 2020, 'What about children? Implications from their subjective perception and the risk of overheating in schools', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 216–223.

Kulve, M, Loomans, M, Boerstra, A & Schrock, D 2022, 'Exploring $PM_{2.5}$ Exposure of Chefs in Professional Kitchens', *ASHRAE Journal*, vol. 64, no. 9, 16-26.

Kumar, A 2015, 'Review of the steps for development of quantitative research tools', *Journal of Advanced Practices in Nursing*, vol. 1, pp. 1–4, Hilaris Publishing SRL, Brussels.

Kumar, P, Hama, S, Abbass, RA, Nogueira, T, Brand, VS, Wu, H, Abulude, FO, Adelodun, AA, De Fatima Andrade, M & Asfaw, A 2022, 'CO_2 exposure, ventilation, thermal comfort and health risks in low-income home kitchens of twelve global cities', *Journal of Building Engineering*, vol. 61, a105254. https://doi.org/10.1016/j.jobe.2022.105254

Kumar, P & Sharma, A 2022, 'Assessing the outdoor thermal comfort conditions of exercising people in the semi-arid region of India', *Sustainable Cities and Society*, vol. 76, no. 6, a103366. https://doi.org/10.1016/j.scs.2021.103366

Kumar, R 2011, *Research methodology-a step-by-step guide for beginners*, 3rd edn., Sage Publications, New Delhi.

Kumar, S, Jain, N & Mathur, J 2020, 'Experimental investigation of ISHRAE IEQ Standard focusing on implementation aspects through', *Indoor Environmental Quality: Select Proceedings of the 1st ACIEQ*, vol. 60, pp. 167–182. https://doi.org/10.1007/978-981-15-1334-3_17

Kumie, A & Zeru, K 2007, 'Sanitary conditions of food establishments in Mekelle town, Tigray, north Ethiopia', *Ethiopian Journal of Health Development*, vol. 21, no. 1, pp. 3–11. https://doi.org/10.4314/ejhd.v21i1.10025

Kunduraci, AC 2017, 'Lighting design for the aging eyes', *Matter: International Journal of Science and Technology*, vol. 3, no. 3, pp. 185–193. https://doi.org/10.20319/mijst.2017.33.185194

Kundu, S, Alam, S & Salve, UR 2022, 'Development of a methodology for investigating thermal comfort and quality of air inside Indian railway pantry car', *Productivity with Health, Safety, and Environment*, Springer, Cham.

Lachin, JM 2004, 'The role of measurement reliability in clinical trials', *Clinical Trials*, vol. 1, no. 6, pp. 553–566. https://doi.org/10.1191/1740774504cn057oa

Läikkö-Roto, T & Nevas, M 2014, 'Restaurant business operators' knowledge of food hygiene and their attitudes toward official food control affect the hygiene in their restaurants', *Food Control*, vol. 43, pp. 65–73. https://doi.org/10.1016/j.foodcont.2014.02.043

Laiskonis, M 2016, 'Evidence of a life in the kitchen-chef scars', *Diced*, viewed 08 November 2019, https://www.ice.edu/blog/evidence-life-kitchen

Lam, RW 2009, 'Light therapy for nonseasonal depression: Status report society for light treatment and biological rhythms', Society for Light Treatment and Biological Rhythms, 21st Annual Meeting, 24th– 27th June, Berlin.

Lambert, H 1992, 'The cultural logic of Indian medicine: Prognosis and etiology in Rajasthani popular therapeutics', *Social Science & Medicine*, vol. 34, no. 10, pp. 1069–1076. https://doi.org/10.1016/0277-9536(92)90280-4

Lambert, MI, Mann, T & Dugas, JP 2008, 'Ethnicity and temperature regulation', in FE Marino (ed.), *Thermoregulation and human performance*, Karger Publishers, Basel, Switzerland, pp. 104–120.

Lan, L, Lian, Z, Liu, W & Liu, Y 2008, 'Investigation of gender difference in thermal comfort for Chinese people', *European Journal of Applied Physiology*, vol. 102, no. 4, pp. 471–480. https://doi.org/10.1007/s00421-007-0609-2

Lao, XQ, Yu, ITS, Au, DKK, Chiu, YL, Wong, CCY & Wai, T 2013, 'Noise exposure and hearing impairment among Chinese restaurant workers and entertainment employees in Hong Kong', *PLoS One*, vol 8, no. 8, pp. 1–9. https://doi.org/10.1371/journal.pone.0070674

Lau, SSY, Li, FM, Leung, DKC, Tang, GWKAL, Ye, AL, Ye, B et al. 2006, ‘Compromising building regulations and user expectations in the design of high-rise domestic kitchens’, *Structural Survey*, vol. 24, no. 3, pp. 212–229. https://doi.org/10.1108/02630800610678869

Laurìa, A, Secchi, S & Vessella, L 2020, ‘Acoustic comfort as a salutogenic resource in learning environments – A proposal for the design of a system to improve the acoustic quality of classrooms’, *Sustainability*, vol. 12, no. 22, a9733. https://doi.org/10.3390/su12229733

Lee, E 2019, ‘Indoor environmental quality (IEQ) of LEED-certified home: Importance-performance analysis (IPA)’, *Building and Environment*, vol. 149, no. 2, pp. 571–581. https://doi.org/10.1016/j.buildenv.2018.12.038

Lee, E, Park, N & Han, JH 2013, ‘Gender difference in environmental attitude and behaviors in adoption of energy-efficient lighting at home’, *Journal of Sustainable Development*, vol. 6, no. 9, a36. https://doi.org/10.5539/jsd.v6n9p36

Lee, H & Lee, E 2021, ‘Effects of coloured lighting on pleasure and arousal in relation to cultural differences’, *Lighting Research & Technology*, vol. 54, no. 2, pp. 145–162. https://doi.org/10.1177/1477153521999592

Lee, S 2012, ‘CO_2-based demand-controlled ventilation and its implications for interior design’, *Journal of Interior Design*, vol. 37, no. 2, pp. 19–36. https://doi.org/10.1111/j.1939-1668.2012.01073.x

Lee, SC, Li, W & Chan, LY 2001, ‘Indoor air quality at restaurants with different styles of cooking in metropolitan Hong Kong’, *Science of the Total Environment*, vol. 279, no. 1–3, pp. 181–193. https://doi.org/10.1016/S0048-9697(01)00765-3

Lee, T & Gany, F 2013, ‘Cooking oil fumes and lung cancer: A review of the literature in the context of the US population’, *Journal of Immigrant and Minority Health*, vol. 15, no. 3, pp. 646–652. https://doi.org/10.1007/s10903-012-9651-1

Lester, MC 2021, ‘Tips for managing humidity in your commercial kitchen or bakery’, *Quill*, viewed 01 May 2021, https://www.quill.com/content/index/restaurant/commercial-kitchen-ventilation-air-conditioning/

Levison, S 2019, ‘3 Basic types of lighting & when to use them’, The Lightbulb Company, viewed 31 October 2019, https://www.thelightbulb.co.uk/resources/3-basic-types-lighting-when-to-use/

Li, A, Hou, Y & Yang, J 2019, ‘Attached ventilation based on a curved surface wall’, in *Building simulation*, Springer, Boston, pp. 505–515.

Li, A & Kosonen, R 2019, *Kitchen pollutants control and ventilation*, Springer, Singapore.

Li, A, Zhao, Y, Jiang, D & Hou, X 2012, ‘Measurement of temperature, relative humidity, concentration distribution and flow field in four typical Chinese commercial kitchens’, *Building and Environment*, vol. 56, pp. 139–150. https://doi.org/10.1016/j.buildenv.2012.03.001

Liao, S, Cai, H, Tian, P, Zhang, B & Li, Y 2022, ‘Combined impacts of the abnormal and urban heat island effect in Guiyang, a typical Karst Mountain City in China’, *Urban Climate*, vol. 41, a101014. https://doi.org/10.1016/j.uclim.2021.101014

Licina, VF, Cheung, T, Zhang, H, De Dear, R, Parkinson, T, Arens, E et al. 2018, ‘Development of the ASHRAE global thermal comfort database II’, *Building and Environment*, vol. 142, pp. 502–512.

Lightology 2018, ‘Kitchen lighting: Tips from a designer’, Lightology, Chicago, viewed 04 February 2020, https://www.lightology.com/index.php?module=how_to&sub=kitchen-lighting

Lin, BM, Wang, M, Stankovic, KM, Eavey, R, Mckenna, MJ, Curhan, GC et al. 2020, ‘Cigarette smoking, smoking cessation, and risk of hearing loss in women’, *The American Journal of Medicine*, vol. 133, no. 10, pp. 1180–1186. https://doi.org/10.1016/j.amjmed.2020.03.049

Lin, FR, Maas, P, Chien, W, Carey, JP, Ferrucci, L & Thorpe, R 2012, ‘Association of skin color, race/ethnicity, and hearing loss among adults in the USA’, *Journal of the Association for Research in Otolaryngology*, vol. 13, no. 1, pp. 109–117. https://doi.org/10.1007/s10162-011-0298-8

Lin, KH, Su, CC, Chen, YY & Chu, PC 2019, ‘The effects of lighting problems on eye symptoms among cleanroom microscope workers’, *International Journal of Environmental Research and Public Health*, vol. 16, no. 1, pp. 1–9. https://doi.org/10.3390/ijerph16010101

Lin, Z 2014, 'Stratum ventilation – A solution to meet challenges to contemporary air distribution', *REHVA Journal*, vol. 51, no. 4, pp. 40–43, Federation of European Heating, Ventilation and Air-Conditioning Associations, Brussels.

Lin, Z & Deng, S 2008, 'A study on the thermal comfort in sleeping environments in the subtropics-developing a thermal comfort model for sleeping environments', *Building and Environment*, vol. 43, pp. 70–81. https://doi.org/10.1016/j.buildenv.2006.11.026

Lipczynska, A, Mishra, A & Schiavon, S 2020, 'Experimental evaluation of the effect of body mass on thermal comfort perception', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 411–423.

Lisman, P, Kazman, JB, O'Connor, FG, Heled, Y & Deuster, PA 2014, 'Heat tolerance testing: Association between heat intolerance and anthropometric and fitness measurements', *Military Medicine*, vol. 179, no. 11, pp. 1339–1346. https://doi.org/10.7205/MILMED-D-14-00169

Liu, S, Cao, Q, Zhao, X, Lu, Z, Deng, Z, Dong, J et al. 2020, 'Improving indoor air quality and thermal comfort in residential kitchens with a new ventilation system', *Building and Environment*, vol. 180, a107016. https://doi.org/10.1016/j.buildenv.2020.107016

Livchak, A, Schrock, D & Sun, Z 2005, 'The effect of supply air systems on kitchen thermal environment', *ASHRAE Transactions*, vol. 111, no. 1, pp. 748–754, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.

Logeswari, S & Mrunalini, A 2017, 'Heat stress among large kitchen workers in hostel', *International Journal of Pure and Applied Bioscience*, vol. 5, pp. 607–610. https://doi.org/10.18782/2320-7051.5177

Los Alamos National Laboratory 2018, 'Chapter 5: Lighting, HVAC, and plumbing', in *Los Alamos National Laboratory Sustainable Design Guide*, Los Alamos National Laboratory, Santa Fe, viewed 01 August 2020, https://www.energy.gov/sites/prod/files/2013/12/f5/sustainable_guide_ch5.pdf

Lotfabadi, P & Hançer, P 2019, 'A comparative study of traditional and contemporary building envelope construction techniques in terms of thermal comfort and energy efficiency in hot and humid climates', *Sustainability*, vol. 11, no. 13, a3582. https://doi.org/10.3390/su11133582

Lucas, RA, Epstein, Y & Kjellstrom, T 2014, 'Excessive occupational heat exposure: A significant ergonomic challenge and health risk for current and future workers', *Extreme Physiology & Medicine*, vol. 3, pp. 1–14. https://doi.org/10.1186/2046-7648-3-14

Lumens 2020, 'Understanding color rendering index', Lumens, Sacremento, viewed 28 January 2020, https://www.lumens.com/light-bulb-facts/color-rendering-index.html

Lundgren-Kownacki, K 2018, 'The heat is on: Evaluation of workplace heat stress under a changing climate', PhD thesis, Lund University, Lund.

Lundgren-Kownacki, K, Gao, C, Kuklane, K & Wierzbicka, A 2019, 'Heat stress in indoor environments of Scandinavian urban areas: A literature review', *International Journal of Environmental Research and Public Health*, vol. 16, no. 4, pp. 1–18. https://doi.org/10.3390/ijerph16040560

Lundgren, K & Holmér, I 2013, 'Climate change and occupational health-populations exposed and the sustainability of methods to avoid excessive heat in workplaces', in JD Cotter, JEL Samuel & T Mündel (eds.), *15th International Conference on Environmental Ergonomics*, Queenstown, pp. 20–21.

Lundgren, K, Kuklane, K, Gao, C & Holmér, I 2013, 'Effects of heat stress on working populations when facing climate change', *Industrial Health*, vol. 51, no. 1, pp. 3–15. https://doi.org/10.2486/indhealth.2012-0089

Luo, M, Cao, B, Ji, W, Ouyang, Q, Lin, B & Zhu, Y 2016, 'The underlying linkage between personal control and thermal comfort: Psychological or physical effects?', *Energy and Buildings*, vol. 111, pp. 56–63. https://doi.org/10.1016/j.enbuild.2015.11.004

Lynch, ED & Kil, J 2005, 'Compounds for the prevention and treatment of noise-induced hearing loss', *Drug Discovery Today*, vol. 10, no. 19, pp. 1291–1298. https://doi.org/10.1016/S1359-6446(05)03561-0

Maher, JM, Markey, JC & Ebert-May, D 2013, 'The other half of the story: Effect size analysis in quantitative research', *CBE – Life Sciences Education*, vol. 12, no. 3, pp. 345–351. https://doi.org/10.1187/cbe.13-04-0082

Maierova, L, Borisuit, A, Scartezzini, JL, Jaeggi, SM, Schmidt, C & Münch, M 2016, 'Diurnal variations of hormonal secretion, alertness and cognition in extreme chronotypes under different lighting conditions', *Scientific Reports*, vol. 6, a33591. https://doi.org/10.1038/srep33591

Malgoyre, A, Siracusa, J, Tardo-Dino, PE, Garcia-Vicencio, S, Koulmann, N, Epstein, Y et al. 2020, 'Four-month operational heat acclimatization positively affects the level of heat tolerance 6 months later', *Scientific Reports*, vol. 10, pp. 1–9. https://doi.org/10.1038/s41598-020-77358-7

Malkawi, M, Al-Yousf, B & Mandil, A 2021, 'Air quality and health impacts in the Eastern Mediterranean Region: An eye on COVID-19', *Eastern Mediterranean Health Journal*, vol. 27, no. 1, pp. 3–4. https://doi.org/10.26719/2021.27.1.3

Mandal, J, Acharya, S & Parija, SC 2011, 'Ethics in human research', *Tropical Parasitology*, vol. 1, no. 1, pp. 2–3. https://doi.org/10.4103/2229-5070.129140

Mandal, P, Nagesh, MS & Mandal, A 2020, 'Status of carbonaceous aerosol at indoor environment of a cafeteria in Delhi, India – A case study', in A Sharma, R Goyal & R Mittal (eds.), *Indoor environmental quality*, Springer, Singapore, pp. 9–17.

Maniscalco, J, Hoffmeyer, F, Monsé, C, Jettkant, B, Marek, E, Brüning, T et al. 2021, 'Physiological responses, self-reported health effects, and cognitive performance during exposure to carbon dioxide at 20 000 ppm', *Indoor Air*, vol. 32, no. 1, pp. 1–15. https://doi.org/10.1111/ina.12939

Manshoor, B, Zaman, I, Asmuin, N, Ramlan, F & Khalid, A 2014, 'Optimizing of make up air performance for commercial kitchen ventilation improvement', *MATEC Web of Conferences*, EDP Sciences, Langkawi, n.p.

Manu, BR 2019, 'What is the average size of a commercial kitchen?', *Sam Tell Companies*, viewed 20 July 2020, https://www.samtell.com/blog/average-commercial-kitchen-size

Manuel, JP 2021, 'How hot is too hot for humans? Understanding wet-bulb temperatures', *CBC*, viewed 06 July 2021, https://www.cbc.ca/news/science/how-hot-is-too-hot-for-humans-understanding-wet-bulb-temperatures-1.6088415

Marć, M, Śmiełowska, M, Namieśnik, J & Zabiegała, B 2018, 'Indoor air quality of everyday use spaces dedicated to specific purposes – A review', *Environmental Science and Pollution Research*, vol. 25, pp. 2065–2082. https://doi.org/10.1007/s11356-017-0839-8

Marcheso-Moreno, E 2019, 'The importance of natural light to office design and employee satisfaction', St. Cloud Window, Inc, Sauk Rapids, viewed 29 October 2021, https://stcloudwindow.com/news/the-importance-of-natural-light-to-office-design-and-employee-satisfaction/

Mardaljevic, J 2008, *Climate-based daylight analysis for residential buildings*, Institute of Energy and Sustainable Development, Leicester, pp. 1–91.

Marshall, J 2014, 'Biological benefits to curly and coily hair', *Natural Hair Mag*, viewed 05 May 2019, https://www.naturalhairmag.com/biological-benefits-curly-coily-hair/

Maruthi, YA, Hossain, K & Hari, BS 2013, 'Potential health problems among workers of food parlors due to exposure to LPG, electric and biomass fuel-based stoves', *Journal of Pharmaceutical and Biosciences*, vol. 1, pp. 4–6.

Master Builders 2021, *Green building dynamics*, Master Builders Association, Westville, viewed 23 April 2021, https://www.masterbuilders.co.za/index.php/building-services/green-building/green-building-dynamics

Masuda, YJ, Castro, B, Aggraeni, I, Wolff, NH, Ebi, K, Garg, T et al. 2019, 'How are healthy, working populations affected by increasing temperatures in the tropics? Implications for climate change adaptation policies', *Global Environmental Change*, vol. 56, pp. 29–40. https://doi.org/10.1016/j.gloenvcha.2019.03.005

Matheney, T 2019, How much office space do I need?, Aquila, viewed 05 November 2020, https://aquilacommercial.com/learning-center/how-much-office-space-need-calculator-per-person/

Matsuzuki, H, Haruyama, Y, Muto, T, Aikawa, K, Ito, A & Katamoto, S, 2013, 'Workers' load and job-related stress after a reform and work system change in a hospital kitchen in Japan', *Environmental Health and Preventive Medicine*, vol. 18, no. 2, pp. 171–176. https://doi.org/10.1007/s12199-012-0291-9

Matsuzuki, H, Ito, A, Ayabe, M, Haruyama, Y, Tomita, S, Katamoto, S et al. 2011, 'The effects of work environments on thermal strain on workers in commercial kitchens', *Industrial Health*, vol. 49, no. 5, pp. 605–613. https://doi.org/10.2486/indhealth.MS1219

Mccullough, JM 1973, 'Human ecology, heat adaptation, and belief systems: The hot-cold syndrome of Yucatan', *Journal of Anthropological Research*, vol. 29, no. 1, pp. 32–36. https://doi.org/10.1086/jar.29.1.3629623

Mcgowan, S 2009, *When it's too hot in the kitchen*, AIRAH, Melbourne.

Mcleod, SA 2013, 'What is reliability?', *Simply Psychology*, viewed 09 June 2019, https://www.simplypsychology.org/reliability.html

Mcnulty, D 2003, 'Range hood's "capture area"', *Remodeling*, viewed 17 January 2020, https://www.remodeling.hw.net/business/range-hoods-capture-area

Mealey, L 2019, 'The Basic Layout of a Commercial Kitchen', *The balance: Small business*, viewed 23 March 2020, https://www.thebalancesmb.com/basics-of-commercial-ovens-and-cooking-equipment-2888872

MedCalc 2020, *Logistic regression*, MedCalc Software Ltd, Ostend, viewed 04 April 2020, https://www.medcalc.org/features/logisticregression.php

MedlinePlus 2019, 'Aging changes in the senses', *MedlinePlus*, viewed 15 March 2020, https://medlineplus.gov/ency/article/004013.htm

Medved, S 2022, 'Visual comfort and architectural lighting', in *Building physics*, Springer, Cham, pp. 251–330.

Meese, G, Kok, R, Lewis, M & Wyon, D 1984, 'A laboratory study of the effects of moderate thermal stress on the performance of factory workers', *Ergonomics*, vol. 27, no. 1, pp. 19–43.

Mehta, K 2019, 'Redefining fenestrations', *Happo*, viewed 08 November 2019, https://happho.com/types-fenestration-need-role-fenestration/

Melanson, EL, Ritchie, HK, Dear, TB, Catenacci, V, Shea, K, Connick, E et al. 2018, 'Daytime bright light exposure, metabolism, and individual differences in wake and sleep energy expenditure during circadian entrainment and misalignment', *Neurobiology of Sleep and Circadian Rhythms*, vol. 4, pp. 49–56. https://doi.org/10.1016/j.nbscr.2017.12.002

MESHGuides 2021, 'Most Recent Guides', MESHGuides, Leicester, viewed n.d., http://www.meshguides.org/most-recent/

Messeri, A, Morabito, M, Bonafede, M, Bugani, M, Levi, M, Baldasseroni, A et al. 2019, 'Heat stress perception among native and migrant workers in Italian industries-case studies from the construction and agricultural sectors', *International Journal of Environmental Research and Public Health*, vol. 16, no. 7, a1090. https://doi.org/10.3390/ijerph16071090

Mikeska, T & Fan, J 2015, 'Full scale measurements and CFD simulations of diffuse ceiling inlet for ventilation and cooling of densely occupied rooms', *Energy and Buildings*, vol. 107, pp. 59–67. https://doi.org/10.1016/j.enbuild.2015.06.070

Mikulka, M 2018, 'The ultimate guide to light measurement', *Lumitex*, viewed 08 November 2019, https://www.lumitex.com/blog/light-measurement

Miles, M & Huberman, A 1994, 'Within-case displays: Exploring and describing', in *Qualitative Data Analysis: An Expanded Sourcebook*, 2nd edn., Sage Publications Inc, Thousand Oaks, pp. 90–142.

Miller, V, Bates, G, Schneider, JD & Thomsen, J 2011, 'Self-pacing as a protective mechanism against the effects of heat stress', *Annals of Occupational Hygiene*, vol. 55, no. 5, pp. 548–555. https://doi.org/10.1093/annhyg/mer012

Millett, C 2014, 'Explainer: What is seasonal affective disorder?', *The Conversation*, viewed 13 November 2019, https://theconversation.com/explainer-what-is-seasonal-affective-disorder-31887

Minnon, T 2019, 'The benefits of natural daylighting', Tubelite, Walker, viewed 08 November 2019, https://www.tubeliteinc.com/benefits-of-natural-daylighting-part-1.

Mohajan, HK 2017, 'Two criteria for good measurements in research: Validity and reliability', *Annals of Spiru Haret University. Economic Series*, vol. 17, no. 4, pp. 59–82. https://doi.org/10.26458/1746

Montazami, A & Lunn, C 2020, 'Office workers' stress level; the impact of IEQ, control and personal factors', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, n.p.

Morton, J 2016, 'Facility Teams Get Swapped for Better Buildings Challenge', *Buildings*, viewed n.d., https://www.buildings.com/feature/article/10187092/facility-teams-get-swapped-for-better-buildings-challenge

Moumen, K & Delporte, N 2022, 'Kitchen ventilation system design and its effect on restaurant IAQ', *REHVA 14th HVAC World Congress, CLIMA, Rotterdam*, pp. 1–8. https://doi.org/10.34641/clima.2022.90

Moya, TA, Van den Dobbelsteen, A, Ottelé, M & Bluyssen, PM 2019, 'A review of green systems within the indoor environment', *Indoor and Built Environment*, vol. 28, no. 3, pp. 298–309. https://doi.org/10.1177/1420326X18783042

Muhsin, F, Mohammad Yusoff, W, Mohamed, M & Sapian, A 2016, 'The effects of void on natural ventilation performance in multi-storey housing', *Buildings*, vol. 6, no. 3, a35. https://doi.org/10.3390/buildings6030035

Mujeebu, MA 2019, 'Introductory chapter: Indoor environmental quality', in *Indoor environmental quality*, IntechOpen, London, pp. 1–13.

Münch, M, Wirz-Justice, A, Brown, SA, Kantermann, T, Martiny, K, Stefani, O et al. 2020, 'The role of daylight for humans: Gaps in current knowledge', *Clocks & Sleep*, vol. 2, no. 1, pp. 61–85. https://doi.org/10.3390/clockssleep2010008

Munters 2004, *Dehumidification: Restaurant humidity control design guide*, Munters, Cape Town, viewed 15 November 2020, https://www.munters.com/globalassets/documents/airt/applications-guide/application-and-product-guide--restaurant.pdf

Münzel, T, Gori, T, Babisch, W & Basner, M 2014, 'Cardiovascular effects of environmental noise exposure', *European Heart Journal*, vol. 35, pp. 829–836. https://doi.org/10.1093/eurheartj/ehu030

Nag, PK 2019, 'Sick building syndrome and other building-related illnesses', in *Office buildings*, Springer, Singapore, pp. 53–103.

Najafi, F, Soltani, S, Matin, BK, Karyani, AK, Rezaei, S, Soofi, M et al. 2020, 'Socioeconomic-related inequalities in overweight and obesity: Findings from the PERSIAN cohort study', *BMC Public Health*, vol. 20, pp. 1–13. https://doi.org/10.1186/s12889-020-8322-8

Najjar, RP, Wolf, L, Taillard, J, Schlangen, LJM, Salem, A, Cajochen, C et al. 2014, 'Chronic artificial blue-enriched white light is an effective countermeasure to delayed circadian phase and neurobehavioral decrements', *PLoS One*, vol. 9, no. 7, a102827. https://doi.org/10.1371/journal.pone.0102827

Nana, M, Coetzer, K & Vogel, C 2019, 'Facing the heat: Initial probing of the City of Johannesburg's heat-health planning', *South African Geographical Journal*, vol. 101, no. 2, pp. 253–268. https://doi.org/10.1080/03736245.2019.1599412

Naravane, S., 2009, 'Effect of industrial noise on occupational skill performance capability', MSc thesis, State University of New York Binghamton, Binghampton.

Nassiri, P, Monazam, M, Dehaghi, BF, Abadi, LIG, Zakerian, S & Azam, K 2013, 'The effect of noise on human performance: A clinical trial', *The International Journal of Occupational and Environmental Medicine*, vol., 4, no. 2, pp. 87–95.

National Academy of Sciences 2019, *Control of hazardous noise*, National Academies Press, Washington DC.

National Cancer Institute 2017, 'Chemicals in meat cooked at high temperatures and cancer risk', National Cancer Institute, Bethesda, viewed 06 March 2020, https://www.cancer.gov/about-cancer/causes-prevention/risk/diet/cooked-meats-fact-sheet

National Regulator for Compulsory Specifications, 2018, *Home*, National Regulator for Compulsory Specifications, Pretoria, viewed n.d., https://www.nrcs.org.za/

Nayek, S & Padhy, PK 2020, 'Personal exposure to VOCs (BTX) and women health risk assessment in rural kitchen from solid biofuel burning during cooking in West Bengal, India', *Chemosphere*, vol. 244, a125447. https://doi.org/10.1016/j.chemosphere.2019.125447

Ncongwane, KP, Botai, JO, Sivakumar, V & Botai, CM, 2021, 'A literature review of the impacts of heat stress on human health across Africa', *Sustainability*, vol. 13, pp. 1–27. https://doi.org/10.3390/su13095312

Nelson, DI, Nelson, RY, Concha-Barrientos, M & Fingerhut, M 2005, 'The global burden of occupational noise-induced hearing loss', *American Journal of Industrial Medicine*, vol. 48, no. 6, pp. 446–458. https://doi.org/10.1002/ajim.20223

New, K, Friday, A, Gormally, A, Tyler, A & Hazas, M 2020, 'Exploring current and future thermal comfort practices in shared workspaces', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 785–801.

Newair 2019, 'Common swamp cooler complaints – How to troubleshoot your evaporative cooler', Newair, viewed 17 January 2020, https://www.newair.com/blogs/learn/common-swamp-cooler-complaints-how-to-troubleshoot-your-evaporative-cooler

Newsham, G, Brand, J, Donnelly, C, Veitch, J, Aries, M & Charles, K 2009, 'Linking indoor environment conditions to job satisfaction: A field study', *Building Research & Information*, vol. 37, no. 2, pp. 129–147. https://doi.org/10.1080/09613210802710298

Nicol, F 2020, 'The shapes of comfort', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 10–19.

Nicol, JF & Roaf, S 2017, 'Rethinking thermal comfort', *Building Research & Information*, vol. 45, no. 7, pp. 711–716. https://doi.org/10.1080/09613218.2017.1301698

Nikolopoulou, M 2011, 'Outdoor thermal comfort', *Frontiers in Bioscience*, vol. 3, no. 4, pp. 1552–1568. https://doi.org/10.2741/245

Nikolopoulou, M & Lykoudis, S 2006, 'Thermal comfort in outdoor urban spaces: Analysis across different European countries', *Building and Environment*, vol. 41, pp. 1455–1470. https://doi.org/10.1016/j.buildenv.2005.05.031

National Institute for Occupational Safety and Health (NIOSH) 2015, 'Indoor environmental quality', Center for Disease Control and Prevention, Atlanta, viewed 18 October 2021, http://www.cdc.gov/niosh/topics/indoorenv/

Nisbets 2019, 'Designing a commercial kitchen', Nisbets, Cork, viewed 13 November 2019, https://www.nisbets.ie/designing-commercial-kitchen

Noakes, TD 2011, 'Time to move beyond a brainless exercise physiology: The evidence for complex regulation of human exercise performance', *Applied Physiology, Nutrition, and Metabolism*, vol. 36, no. 1, pp. 23–35. https://doi.org/10.1139/H10-082

Noise Help 2019, 'Door soundproofing options', *Noise Help*, viewed 16 November 2020, https://web.archive.org/web/20210613145332/https://www.noisehelp.com/door-soundproofing.html

Noise News 2015, 'What are the 4 different types of noise?', *Cirus Research*, viewed 08 November 2019, https://www.cirrusresearch.co.uk/blog/2015/01/4-different-types-noise/

Nolan, LS 2020, 'Age-related hearing loss: Why we need to think about sex as a biological variable', *Journal of Neuroscience Research*, vol. 98, no. 9, pp. 1705–1720. https://doi.org/10.1002/jnr.24647

Notley, SR, Park, J, Tagami, K, Ohnishi, N & Taylor, NA 2017, 'Variations in body morphology explain sex differences in thermoeffector function during compensable heat stress', *Experimental Physiology*, vol. 102, no. 5, pp. 545–562. https://doi.org/10.1113/EP086112

Nyilo, P & Putri, MSP 2019, 'The association of reactive oxygen species levels on noise induced hearing loss of high risk workers in Dr. Soetomo General Hospital Surabaya, Indonesia', *Indian Journal of Otolaryngology and Head & Neck Surgery*, vol. 71, no. 1, pp. 86–89. https://doi.org/10.1007/s12070-018-1460-y

Nylen, P 2017, ‘Sensory ageing – Visual ergonomics and lighting’, in G Aronsson, K Nilsson, M Albin, M Torgén, P Nylen, KP Waye & E Vingård (eds.), *Healthy workplaces for women and men of all ages*, Arbetsmiljöverket, Stockholm.

Okada, D, 2020, ‘Does skin color affect body temperature?’, *Skincare Geeks*, viewed 01 May 2020, https://skincaregeeks.com/does-skin-color-affect-body-temperature/

Okop, KJ, Mukumbang, FC, Mathole, T, Levitt, N & Puoane, T 2016, ‘Perceptions of body size, obesity threat and the willingness to lose weight among black South African adults: A qualitative study’, *BioMed Central (BMC) Public Health*, vol. 16, a365. https://doi.org/10.1186/s12889-016-3028-7

Olesen, BW 2007, ‘The philosophy behind EN15251: Indoor environmental criteria for design and calculation of energy performance of buildings’, *Energy and Buildings*, vol. 39, no. 7, pp. 740–749. https://doi.org/10.1016/j.enbuild.2007.02.011

Olesen, BW 2015, ‘Indoor environmental input parameters for the design and assessment of energy performance of buildings’, *REHVA Journal*,vol. 52, no. 1, pp. 17–23, Federation of European Heating, Ventilation and Air-Conditioning Associations, Brussels.

Olesen, BW 2020, ‘ASHRAE’s history with thermal comfort’, *ASHRAE Journal*, vol. 62, no. 11, 32–39, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.

Omidiandost, A, Sohrabi, Y, Poursadeghiyan, M, Yarmohammadi, H & Mosavi, A 2015, ‘Evaluation of general and local lighting as an environmental ergonomics factor in different parts of a hospital in the city of Kermanshah in 2015’, *Technical Journal of Engineering and Applied Sciences*, vol. 3, pp. 255–259.

Oropeza-Perez, I 2019, ‘Fundamentals of natural ventilation design within dwellings’, *Different strategies of housing design*, IntechOpen, London, pp. 1–104.

Osaro, FO, Cookey-Gam, A & Iyerefa, S 2022, ‘Usefulness of building ventilation’, *International Journal of Innovative Environment*, vol. 10, pp. 25–32.

Occupational Safety and Health Administration (OSHA) 1970, *Heat stress guide*, US Department of Labor, Washington DC.

Occupational Safety and Health Administration (OSHA) 1997, ‘Permit-required confined spaces’, in US Department of Labour (ed.), *Occupational safety and health administration*, US Department of Labour, Washington DC.

Occupational Safety and Health Administration (OSHA) 2008, *OSHA technical manual*, US Department of Labor, Washington DC.

Occupational Safety and Health Administration (OSHA) 2014a, *Health hazards*, OSHA, Washington DC.

Occupational Safety and Health Administration (OSHA) 2014b, *Protecting workers from the effects of heat*, OSHA, Washington DC, viewed 01 May 2020, https://www.osha.gov/sites/default/files/publications/heat_stress.pdf

Osawa, T, Kurabuchi, T, Toriumi, Y, Sihwan, L, Shimanuki, Y & Ami, K 2022, ‘Reproduction of thermal plume above commercial cooking gas stove using CFD analysis’, *REHVA 14th HVAC World Congress*, CLIMA, Rotterdam, n.p.

Osibona, O, Solomon, BD & Fecht, D 2021, ‘Lighting in the home and health: A systematic review’, *International Journal of Environmental Research and Public Health*, vol. 18, no. 2, a609. https://doi.org/10.3390/ijerph18020609

Owen, J 2012, *Men and women really do see differently?*, National Geographic Society, Washington DC.

Ozarisoy, B & Altan, H 2021, ‘Regression forecasting of “neutral” adaptive thermal comfort: A field study investigation in the south-eastern Mediterranean climate of Cyprus’, *Building and Environment*, vol. 202, a108013. https://doi.org/10.1016/j.buildenv.2021.108013

Pachito, DV, Eckeli, AL, Desouky, AS, Corbett, MA, Partonen, T, Rajaratnam, SM et al. 2018, ‘Workplace lighting for improving alertness and mood in daytime workers’, *Cochrane Database of Systematic* Reviews, vol. 3, pp. 1–82. https://doi.org/10.1002/14651858.CD012243.pub2

Pahari, S, Biswas, D & Pal, B 2020, 'Impact of health, safety, and welfare on productivity of workers: A study on selected tea estates in Terai region of West Bengal', PhD thesis, Department of Business Administration, Vidyasagar University, Midnapore.

Pairan, MR 2017, 'Fine nozzle characteristics for increasing filtration efficiency in commercial kitchen hood ventilation system', PhD thesis, Universiti Tun Hussein Onn Malaysia, Parit Raja.

Parameswarappa, S & Narayana, J 2014, 'Assessment of heat strain among workers in steel industry a study', *International Journal of Current Microbiology and Applied Sciences*, vol. 2014, pp. 861–870.

Parekh, R 2017, 'Seasonal Affective Disorder (SAD)', American Psychiatric Association, viewed 09 November 2019, https://web.archive.org/web/20220329183542/https://www.psychiatry.org/patients-families/depression/seasonal-affective-disorder

Park, J, Kee, D, Kim, W, Amit, L & Song, Y 2017, 'Survey and analysis of the accident cases of kitchen workers in catering and commercial kitchens', *Applied Ergonomics*, vol. 40, pp. 477–480.

Park, J, Loftness, V & Aziz, A 2018, 'Post-occupancy evaluation and IEQ measurements from 64 office buildings: Critical factors and thresholds for user satisfaction on thermal quality', *Buildings*, vol. 8, no. 11, pp. 1–24. https://doi.org/10.3390/buildings8110156

Parker-Pope, T 2010, 'Do fluorescent lights trigger migraines?', *The New York Times*, 02 September 2010.

Parkinson, T, Raftery, P & Present, E 2020, 'Spatial uniformity of thermal comfort from ceiling fans blowing upwards', *ASHRAE Transactions*, vol. 143, pp. 91–96. https://doi.org/10.3402/gha.v2i0.2057

Parrott, K, Emmel, J & Beamish, J 2003, 'Use of kitchen ventilation: Impact on indoor air quality', *The Forum for Family and Consumer Issues*, vol. 8, no. 1, pp. 1–15.

Parsons, K 2009, 'Maintaining health, comfort and productivity in heat waves', *Global Health Action*, vol. 2, p. 2057. https://doi.org/10.1186/s12992-020-00554-7

Parsons, KC 2001, 'Introduction to thermal comfort standards', in K Mccartney (ed.), *Moving Thermal Comfort Standards into the 21st Century*, Oxford Centre for Sustainable Development, Windsor, pp. 1–12.

Parsons, KC 2011, 'Assessment of heat stress and heat stress indices', *Encyclopedia of occupational health and safety*, viewed 19 January 2019, https://web.archive.org/web/20180128053438/http://www.iloencyclopaedia.org/part-vi-16255/heat-and-cold/76-42-heat-and-cold/assessment-of-heat-stress-and-heat-stress-indicies

Păsculescu, D, Pană, L, Buică, G, Păsculescu, VM & Dobra, R 2019, 'A quality-based approach for improving the lighting design process', *Calitatea*, vol. 20, pp. 287–292.

Passive Design 2018, 'Design of passive ventilation', Level, Porirua, viewed 31 October 2019, http://www.level.org.nz/passive-design/ventilation/design-of-passive-ventilation/

Paterson, SK & Godsmark, CN 2020, 'Heat-health vulnerability in temperate climates: Lessons and response options from Ireland', *Globalization and Health*, vol. 16, pp. 1–17.

Patki, A & Frank-Ito, DO 2016, 'Characterizing human nasal airflow physiologic variables by nasal index', *Respiratory Physiology & Neurobiology*, vol. 232, pp. 66–74. https://doi.org/10.1016/j.resp.2016.07.004

Pawas.Com 2018, 'Allocation of space in a kitchen', Pawas.com, viewed 27 March 2020, https://web.archive.org/web/20210612135629/http://www.pawas.com/allocation-of-space-in-a-kitchen/

Peris, E 2020, *Noise pollution is a major problem, both for human health and the environment*. European Environment Agency, Copenhagen, pp. 1–3.

Perkins, C 2018, 'What is the national average size of a restaurant kitchen?', *Azcentral*, viewed 19 October 2020, https://yourbusiness.azcentral.com/national-average-size-restaurant-kitchen-29446.html

Petty, S 2017, 'Summary of Ashrae's position on carbon dioxide (CO_2) levels in spaces', Energy & Environmental Solutions, viewed 05 November 2020, https://silo.tips/queue/summary-of-ashrae-s-position-on-carbon-dioxide-co-2-levels-in-spaces-stephen-pet?&queue_id=-1&v=1604595409&u=MTk3LjE4NS4xMDYuNzM=

Phipps-Nelson, J, Redman, JR, Dijk, D & Rajaratnam, SM 2003, 'Daytime exposure to bright light, as compared to dim light, decreases sleepiness and improves psychomotor vigilance performance', *Sleep*, vol. 26, no. 6, pp. 695–700. https://doi.org/10.1093/sleep/26.6.695

Picard, M, Girard, SA, Simard, M, Larocque, R, Leroux, T & Turcotte, F 2008, 'Association of work-related accidents with noise exposure in the workplace and noise-induced hearing loss based on the experience of some 240,000 person-years of observation', *Accident Analysis & Prevention*, vol. 40, no. 5, pp. 1644–1652. https://doi.org/10.1016/j.aap.2008.05.013

Pienkowski, M 2021, 'Loud music and leisure noise is a common cause of chronic hearing loss, tinnitus and hyperacusis', *International Journal of Environmental Research and Public Health*, vol. 18, no. 8, a4236. https://doi.org/10.3390/ijerph18084236

Pimenta, ADS, Teixeira, CF, Silva, VMD, Almeida, BDGPD & Lima, MLLTD 2019, 'Logical operating model of the hearing conservation program for workers', *Revista Cefac*, vol. 21, no. 3, a16018. http://dx.doi.org/10.1590/1982-0216/201921316018

Pochepan, J 2017, *Bad mood in the workplace? Try changing the lights*, Strong Project, New York.

Pompei, L, Blaso, L, Fumagalli, S & Bisegna, F 2022, 'The impact of key parameters on the energy requirements for artificial lighting in Italian buildings based on standard EN 15193-1: 2017', *Energy and Buildings*, vol. 263, a112025. https://doi.org/10.1016/j.enbuild.2022.112025

Pool, R 1987, 'Hot and cold as an explanatory model: The example of Bharuch district in Gujarat, India', *Social Science and Medicine*, vol. 25, no. 4, pp. 389–399. https://doi.org/10.1016/0277-9536(87)90277-2

Porritt, MT 2015, *Performance of number of factors procedures in small sample sizes*, Linda Loma University: The Scholars Repository, Loma Linda.

Powell, V 2017, 'Can black people blush?', *Quora*, viewed 13 November 2019, https://www.quora.com/Can-black-people-blush

Prashanth, KVM & Sridhar, V 2008, 'The relationship between noise frequency components and physical, physiological and psychological effects of industrial workers', *Noise and Health*, vol. 10, no. 40, pp. 90–98. https://doi.org/10.4103/1463-1741.44347

Present, E, Raftery, P, Brager, G & Graham, LT 2019, 'Ceiling fans in commercial buildings: In situ airspeeds & practitioner experience', *Building and Environment*, vol. 147, pp. 241–257. https://doi.org/10.1016/j.buildenv.2018.10.012

Pryor, JL, Johnson, EC, Roberts, WO & Pryor, RR 2019, 'Application of evidence-based recommendations for heat acclimation: Individual and team sport perspectives', *Temperature*, vol. 6, no. 1, pp. 37–49. https://doi.org/10.1080/23328940.2018.1516537

Pucci, S 2014, 'Check oxidation in fats and oils by testing p-Anisidine value', *Foodlab*, viewed 31 October 2019, https://www.cdrfoodlab.com/news-topics/p-anisidine-anisidine-value/

Qiu, Y, Hodder, S & Havenith, G 2020, 'Ethnic differences in preferred air flow temperature', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 984–989.

Queensland Food Safety and Public Health Working Group 2019, *Food premises – Design, construction and fit-out guide*, State of Queensland, Brisbane, pp. 1–42.

Quest, 2020, *Humidity issues in kitchens*, Quest Dehumidifiers, Madison, viewed 21 November 2020, https://www.questclimate.com/humidity-issues-in-kitchens/

Rabeiy, R 2019, 'Evaluation of indoor heat stress on workers of bakeries at Assiut City, Egypt', *International Journal of Environmental Science and Technology*, vol. 16, pp. 2637–2642. https://doi.org/10.1007/s13762-018-1839-z

Rahaghi, F, Varasteh, A, Memarpour, R & Tashtoush, B 2016, 'Teppanyaki/hibachi pneumonitis: An exotic cause of exogenous lipoid pneumonia', *Case Reports in Pulmonology*, vol. 2016, pp. 1–5. https://doi.org/10.1155/2016/1035601

Rahmillah, FI, Tumanggor, AHU & Sari, AD 2017, 'The analysis of thermal comfort in kitchen', *IOP Conference Series: Materials Science and Engineering*, IOP Publishing, Bali, pp. 1–8.

Rajasekar, E & Ramachandraiah, A 2010, 'Adaptive comfort and thermal expectations – A subjective evaluation in hot humid climate', in SN (eds.), *Network for comfort and energy use in buildings*, NCEUB, London, pp. 1–15.

Ramasamy, R & Mukhopadhyay, K 2022, 'Implementing a ventilation index for assessing indoor air $PM_{2.5}$ concentrations in biomass-using households', *Environmental Monitoring and Assessment*, vol. 194, pp. 1–11. https://doi.org/10.1007/s10661-021-09718-3

Ramesh, C & Manikandan, MA 2015, 'Thermal analysis for the ergonomics design of hotel kitchen environment', *International Journal of Applied Engineering Research*, 10, no. 85, pp. 472–477.

Rankin, S 2019, 'Which commercial kitchen layout is right for your restaurant?', *Lightspeed*, blog post, viewed 23 April 2021, https://www.lightspeedhq.com/blog/commercial-kitchen-layout/

Rasmussen, B 2014, 'International proposal for an acoustic classification scheme for dwellings: Background and perspectives', in *Inter-noise*, Australian Acoustical Society, Melbourne, p. 9.

Rasmussen, B 2015, 'Employment density projections', *Sizztech*, viewed 20 October 2021, https://sizztech.com/?p=121

Ravindra, K, Kaur-Sidhu, M & Mor, S 2020, 'Air pollution in rural households due to solid biomass fuel use and its health impacts', in A Sharma, R Goyal & R Mittal (eds.), *Indoor environmental quality*, Springer, Singapore, pp. 27–33.

Ravindra, U 2015, 'Social temperature sensing', MSc, Delft University of Technology, Delft.

Ray, S 2015, '7 Regression techniques you should know', *Analytics Vidhya*, viewed 18 November 2019, https://www.analyticsvidhya.com/blog/2015/08/comprehensive-guide-regression/

Rea, MS & Figueiro, MG 2018, 'Light as a circadian stimulus for architectural lighting', *Lighting Research & Technology*, vol. 50, no. 4, pp. 497–510. https://doi.org/10.1177/1477153516682368

Reggev, K 2017, 'An honest guide to the benefits and drawbacks of skylights', *Dwell*, viewed 28 July 2020, https://www.dwell.com/article/skylights-pros-and-cons-d6cbd5a7

Revit 2018, 'Stack ventilation and Bernoulli's principle part-1', Autodesk, viewed 19 October 2021, https://knowledge.autodesk.com/support/revit/getting-started/caas/simplecontent/content/stack-ventilation-and-bernoullis-principle-part-1.html

Richter, K, Acker, J, Adam, S & Niklewski, G 2016, 'Prevention of fatigue and insomnia in shift workers – A review of non-pharmacological measures', *EPMA Journal*, vol. 7, no. 1, pp. 1–11. https://doi.org/10.1186/s13167-016-0064-4

Riege, AM 2003, 'Validity and reliability tests in case study research: A literature review with "hands-on" applications for each research phase', *Qualitative Market Research: An International Journal*, vol. 6, no. 2, pp. 75–86. https://doi.org/10.1108/13522750310470055

Rijal, HB, Humphreys, MA & Fergus Nicol, JF 2020, 'Adaptive model and the adaptive mechanisms for thermal comfort in Japanese offices', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 759–773.

Rim, D, Wallace, L, Nabinger, S & Persily, A 2012, 'Reduction of exposure to ultrafine particles by kitchen exhaust hoods: The effects of exhaust flow rates, particle size, and burner position', *Science of the Total Environment*, vol. 432, 350–356. https://doi.org/10.1016/j.scitotenv.2012.06.015

Ring, B 2018, 'Ergonomy in commercial kitchens – Challenges of kitchen technology in 2018', MSc, University of Applied Sciences, Budapest.

Rissetto, R, Schweiker, M & Wagner, A 2020, 'The effects of occupants' expectations on thermal comfort under summer conditions', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 252–268.

Roaf, S 2020, 'The Windsor conferences: Past, present and future', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 1096–1114.

Rodríguez-Morilla, B, Madrid, JA, Molina, E, Pérez-Navarro, J & Correa, Á 2018, 'Blue-enriched light enhances alertness but impairs accurate performance in evening chronotypes driving in the morning', *Frontiers in Psychology*, vol. 9, a688. https://doi.org/10.3389/fpsyg.2018.00688

Roomaney, R & Coetzee, B 2018, 'Introduction to and application of mixed methods research designs', PsySSA, viewed 19 November 2019, https://www.psyssa.com/wp-content/uploads/2018/10/ORIM-Chapter-4-Introduction-to-and-application-of-mixed-methods-research-designs_by-Roomaney-Coetzee.pdf

Rosone, MC 2016, 'Humidity control in your restaurant kitchen', *Aristair*, blog post, viewed 13 November 2019 https://aristair.com/blog/humidity-control-in-your-restaurant-kitchen/

Rossi, M 2019, 'Circadian lighting design in the LED era', in *Research for development*, 1st edn., Springer, Cambridge, pp. 257–277.

Ruger, M, Gordijn, MC, Beersma, DG, De Vries, B & Daan, S 2006, 'Time-of-day-dependent effects of bright light exposure on human psychophysiology: Comparison of daytime and nighttime exposure', *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, vol. 290, no. 5, pp. 1413–1420. https://doi.org/10.1152/ajpregu.00121.2005

Rupp, RF, Toftum, J & Ghisi, E 2020, 'Investigating occupant's thermal disposition in mixed-mode offices: A field study on thermal comfort in a Brazilian subtropical climate', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 802–814.

Rupp, RF, Vásquez, NG & Lamberts, R 2015, 'A review of human thermal comfort in the built environment', *Energy and Buildings*, vol. 105, pp. 178–205. https://doi.org/10.1016/j.enbuild.2015.07.047

Rusnock, CF & Bush, PM 2012, 'Case study: An evaluation of restaurant noise levels and contributing factors', *Journal of Occupational and Environmental Hygiene*, vol. 9, no. 6, pp. 108–113. https://doi.org/10.1080/15459624.2012.683716

Sada, GKA & Salih, TWM 2019, 'Enhancing indoor air quality for residential building in hot-arid regions', in *Sustainable building for a cleaner environment*, Springer, Cham, pp. 255–264.

Saif Eldin, A, Radwan, N & Khalifa, E 2022, 'Evaluation of occupational indoor heat stress impact on health and kidney functions among kitchen workers', *Egyptian Journal of Occupational Medicine*, vol. 46, no. 3, pp. 93–108. https://dx.doi.org/10.21608/ejom.2022.118594.1263

Saha, S, Guha, A & Roy, S 2012, 'Experimental and computational investigation of indoor air quality inside several community kitchens in a large campus', *Building and Environment*, vol. 52, pp. 177–190. https://doi.org/10.1016/j.buildenv.2011.10.015

Saint-Gobain 2010, 'Acoustic comfort', Saint-Gobain, viewed 16 November 2020, https://multicomfort.saint-gobain.com/comforts-and-solutions/acoustic-comfort

Sajedifar, J, Mirzaei, R, Teimori, GH, Mehri, A, Azadbakht, F, Choupani, A & Taheri, MR 2017, 'Evaluation of Thermal Comfort in an Iranian Educational Hospital Using PMV- PPD Model', *Biotech Health Science*, vol. 2017, n.p.

Sandberg, M, Kabanshi, A & Wigö, H 2020, 'Is building ventilation a process of diluting contaminants or delivering clean air?', *Indoor and Built Environment*, vol. 29, no. 6, pp. 768–774. https://doi.org/10.1177/1420326X19837340

Sanjog, J, Patel, T & Karmakar, S 2013, 'Indoor physical work environment: An ergonomics perspective', *International Journal of Science, Engineering and Technology Research*, vol. 2, no. 3, pp. 507–513.

Sankhyan, S, Zabinski, K, O'brien, RE, Coyan, S, Patel, S & Vance, ME 2022, 'Aerosol emissions and their volatility from heating different cooking oils at multiple temperatures', *Environmental Science: Atmospheres*, vol. 2022, n.p. https://doi.org/10.1039/D2EA00099G

SANS10400 2017, 'Dimensions', SANS10400 Building regulations, viewed 24 October 2021, https://www.sans10400.co.za/size-dimensions-room-height/

Sansaniwal, SK, Tewari, P, Kumar, S, Mathur, S & Mathur, J 2020, 'Impact assessment of air velocity on thermal comfort in composite climate of India', *Science and Technology for the Built Environment*, vol. 26, no. 9, pp. 1301–1320. https://doi.org/10.1080/23744731.2020.1793640

Saunders, MNK, Thornbill, A & Lewis, P 2009, *Research methods for business students*, Pearson Education, London.

Sayapathi, BS, Su, A & Koh, D 2013, 'The effectiveness of applying different permissible exposure limits in preserving the hearing threshold level: A systematic review', *Journal of Occupational Health*, vol. 56, no. 1, pp. 1–11. https://doi.org/10.1539/joh.13-0135-RA

Schiavon, S & Altomonte, S 2014, 'Influence of factors unrelated to environmental quality on occupant satisfaction in LEED and non-LEED certified buildings', *Building and Environment*, vol. 77, pp. 148–159. https://doi.org/10.1016/j.buildenv.2014.03.028

Schneider, SM 2016, 'Heat acclimation: Gold mines and genes', *Temperature*, vol. 3, no. 4, pp. 527–538. https://doi.org/10.1080/23328940.2016.1240749

Schulte, PA & Chun, H 2009, 'Climate change and occupational safety and health: Establishing a preliminary framework', *Journal of Occupational and Environmental Hygiene*, vol. 6, no. 9, pp. 542–554. https://doi.org/10.1080/15459620903066008

Schuster, C, Honold, J, Lauf, S & Lakes, T 2017, 'Urban heat stress: Novel survey suggests health and fitness as future avenue for research and adaptation strategies', *Environmental Research Letters*, vol. 12, a044021. https://doi.org/10.1088/1748-9326/aa5f35

Schweiker, M, Fuchs, X, Becker, S, Shukuya, M, Dovjak, M, Hawighorst, M et al. 2017, 'Challenging the assumptions for thermal sensation scales', *Building Research & Information*, vol. 45, pp. 572–589. https://doi.org/10.1080/09613218.2016.1183185

Sebastian, A, Ghazani, SM & Marangoni, AG 2014, 'Quality and safety of frying oils used in restaurants', *Food Research International*, vol. 64, pp. 420–423. https://doi.org/10.1016/j.foodres.2014.07.033

Sebitosi, AB & Pillay, P 2007, 'New technologies for rural lighting in developing countries: White LEDs', *IEEE Transactions on Energy Conversion*, vol. 22, no. 3, pp. 674–679. https://doi.org/10.1109/TEC.2006.888024

Sekaran, U & Bougie, R 2016, *Research methods for business: A skill building approach*, John Wiley & Sons, West Sussex.

Seltenrich, N 2014, 'Take care in the kitchen: Avoiding cooking-related pollutants', *Environmental Health Perspectives*, vol. 122, no. 6, pp. 154–159. https://doi.org/10.1289/ehp.122-A154

Seow, A, Poh, W, Teh, M, Eng, P, Wang, Y, Tan, W, Mimi, CY & Lee, H 2000, 'Fumes from meat cooking and lung cancer risk in Chinese women', *Cancer Epidemiology and Prevention Biomarkers*, vol. 9, no. 11, pp. 1215–1221.

Serfozo, K 2018, 'In need of a tranquil kitchen', *FesMag*, viewed 14 April 2020, https://fesmag.com/features/foodservice-perspectives/15843-in-need-of-a-tranquil-kitchen.

Serghides, DK, Chatzinikola, C & Katafygiotou, M 2015, 'Comparative studies of the occupants' behaviour in a university building during winter and summer time', *International Journal of Sustainable Energy*, vol. 34, no. 8, pp. 528–551. https://doi.org/10.1080/14786451.2014.905578

Sethi, M & Malhan, S 2015, *Catering management-an integrated approach*, New Age International, New Delhi.

Shah, K 2013, 'Use of a high temperature tandoor oven for production of white wheat naan with enhanced nutrition, sensory traits and shelf life', MSc, South Dakota State University, Brookings.

Shah, S & Dufva, K 2017a, 'CFD modeling of airflow in a kitchen environment: Towards improving energy efficiency in buildings', BSc thesis, South-Eastern Finland University, Kouvola.

Shah, S & Dufva, K 2017b, 'Towards improving energy efficiency in buildings', in *CFD modeling of airflow in a kitchen environment: Towards improving energy efficiency in buildings*, South-Eastern Finland University of Applied Sciences, Grano Oy, viewed 28 April 2022, https://www.theseus.fi/bitstream/handle/10024/132489/URNISBN9789523440227.pdf?sequence=1

Sharma, D & Jain, S 2019, 'Impact of intervention of biomass cookstove technologies and kitchen characteristics on indoor air quality and human exposure in rural settings of India', *Environment International*, vol. 123, pp. 240–255. https://doi.org/10.1016/j.envint.2018.11.059

Sharma, S 2019, 'Descriptive statistics', PhD thesis, Horisons University, Paris.

Shen, H, Shen, G, Chen, Y, Russell, AG, Hu, Y, Duan, X et al. 2021, 'Increased air pollution exposure among the Chinese population during the national quarantine in 2020', *Nature Human Behaviour*, vol. 5, pp. 239–246. https://doi.org/10.1038/s41562-020-01018-z

Shin, S, Park, J & Lee, J 2015, 'Does the hair influence heat extraction from the head during head cooling under heat stress?', *Industrial Health*, vol. 53, pp. 533–541. https://doi.org/10.2486/indhealth.2015-0005

Shriram, S & Ramamurthy, K 2019, 'Assessment of CO_2-based demand controlled ventilation requirement for a flexible work environment with ductless split air conditioners', *Science and Technology for the Built Environment*, vol. 25, no. 7, pp. 805–818. https://doi.org/10.1080/23744731.2019.1569458

Siddiqui, AR, Gold, EB, Yang, X, Lee, K, Brown, KH & Bhutta, ZA 2008, 'Prenatal exposure to wood fuel smoke and low birth weight', *Environmental Health Perspectives*, vol. 116, no. 4, pp. 543–549. https://doi.org/10.1289/ehp.10782

Silvester, J & Konstantinou, E 2010, *Lighting, well-being and work performance: A review of the literature*, University of London Institutional Repository, London.

Simone, A, Olesen, BW, Stoops, JL & Watkins, AW 2013, 'Thermal comfort in commercial kitchens (RP-1469): Procedure and physical measurements (part 1)', *HVAC & R Research*, vol. 19, no. 8, pp. 1001–1015. https://doi.org/10.1080/10789669.2013.840494

Singer, B, Delp, W & Zhao, H 2021, *Effective kitchen ventilation for healthy zero net energy homes with natural gas*, California Energy Commission, Sacremento.

Singh, A, Kamal, R, Mudiam, MKR, Gupta, MK, Satyanarayana, GNV, Bihari, V et al. 2016, 'Heat and PAHs emissions in indoor kitchen air and its impact on kidney dysfunctions among kitchen workers in Lucknow, North India', *PLoS One*, vol. 11, no. 2, pp. 1–16. https://doi.org/10.1371/journal.pone.0148641

Singh, LP, Bhardwaj, A & Deepak, KK 2010, 'Occupational exposure in small and medium scale industry with specific reference to heat and noise', *Noise and Health*, vol. 12, p. 37. https://doi.org/10.4103/1463-1741.59998

Singh, P, Arora, R & Goyal, R 2020, 'Impact of lighting on performance of students in Delhi schools', in A Sharma, R Goyal & R Mittal (eds.), *Indoor environmental quality*, Springer, Singapore.

Sjaastad, AK 2010, 'Exposure to cooking fumes during the pan frying of beefsteak under domestic and occupational conditions', PhD thesis, Norwegian University of Science and Technology, Trondheim.

Sjaastad, AK & Svendsen, K 2010, 'Different types and settings of kitchen canopy hoods and particulate exposure conditions during pan-frying of beefsteak', *Indoor and Built Environment*, vol. 19, no. 2, pp. 267–274. https://doi.org/10.1177/1420326X09347426

Smit, M, Wilders, CJ & Strydom, GL 2011, 'Physical activity and physical fitness profiles of South African women', *African Journal for Physical Health Education, Recreation and Dance*, vol. 17, no. 3, pp. 450–461. https://doi.org/10.4314/ajpherd.v17i3.71331

Smith, DC 2018, 'Why space matters: Density', *Cushman and Wakefield*, viewed 12 November 2019, http://blog.cushwake.com/americas/why-space-matters-density.html

Smolders, KC & De Kort, YA 2017, 'Investigating daytime effects of correlated colour temperature on experiences, performance, and arousal', *Journal of Environmental Psychology*, vol. 50, pp. 80–93. https://doi.org/10.1016/j.jenvp.2017.02.001

Soebarto, V, Williamson, T, Bennetts, H, Martins, LA, Pisaniello, D, Hansen, A et al. 2020, 'Development of an integrated data acquisition system for thermal comfort studies of older people', *Conference: Eco house Initiative and Network for Comfort and Energy Use in Buildings*, Windsor, pp. 155–170.

Sonae Arauco 2020, 'Maximise natural light in your spaces', *Sonae Arauco*, blog post, viewed 10 July 2020, from https://sonaearauco.co.za/maximise-natural-light-in-your-spaces/

South African Bureau of Standards (SABS) 2008, *SANS 10103:2008 (Ed. 6.00)*, South African Bureau of Standards, Cape Town, viewed 06 November 2020, https://store.sabs.co.za/catalog/product/view/id/217983/s/sans-10103-2008-ed-6-00/

South African Bureau of Standards (SABS) 2019, *Metrology and calibration – Standards and publications*, South African Bureau of Standards, Cape Town, viewed 06 November 2020, https://www.sabs.co.za/Sectors-and-Services/Sectors/Metrology/metrology_sp.asp

South African Legal Information Institute 1993, *Occupational Health and Safety Act, 1993 [No. 85 of 1993] – G 14918*, South African Legal Information Institute, Cape Town, pp. 1–27.

South African Weather Services 2020, 'Educational questions-what is discomfort index?', South African Weather Services, viewed 18 October 2021, http://www.weathersa.co.za/home/educques

Spellman, FR 2006, *Industrial hygiene simplified: A guide to anticipation, recognition, evaluation, and control of workplace hazards*, The Scarecrow Press, Inc, Lanham.

Sperandei, S 2014, 'Understanding logistic regression analysis', *Biochemia Medica*, vol. 24, no. 1, pp. 12–18. https://doi.org/10.11613/BM.2014.003

Standards Council of Canada 2011, *Procedures for the measurement of occupational noise exposure*, Crown corporation, Ottawa.

Stanpro 2019, 'Restaurant lighting: A unique challenge', *Standard Productions Inc*, blog post, viewed 06 November 2021, https://www.standardpro.com/restaurant-lighting/

Starkey Hearing 2017, '18 Everyday sounds that can hurt your hearing', *Starkey*, blog post, viewed 26 January 2020, https://www.starkey.com/blog/2017/02/18-sounds-that-can-hurt-your-hearing

Statistics South Africa (StatsSA) 2017, 'Category archives: Tourism', Statistics South Africa, viewed 05 November 2020, http://www.statssa.gov.za/?cat=36

Stavridou, AD 2015, 'Breathing architecture: Conceptual architectural design based on the investigation into the natural ventilation of buildings', *Frontiers of Architectural Research*, vol. 4, no. 2, pp. 127–145. https://doi.org/10.1016/j.foar.2015.03.001

Steg, L & De Groot, JIM 2019, *Environmental psychology: An introduction*, John Wiley, San Francisco, viewed 29 April 2022, https://onlinelibrary.wiley.com/doi/book/10.1002/9781119241072

Stephen, P 2018, 'Keeping cool in your wig-pick your wig wisely to beat the heat', Verywell Health, viewed 05 November 2021, https://www.verywellhealth.com/keeping-cool-in-your-wig-430252

Stoakes, P, Passe, U & Battaglia, F 2011, 'Predicting natural ventilation flows in whole buildings. Part 2: The Esherick House', in *Building simulation*, Springer, Sydney, pp. 365–377.

Surmiak, AD 2018, 'Confidentiality in qualitative research involving vulnerable participants: Researchers' perspectives', *Forum: Qualitative Social Research*, viewed 12 November 2019, https://www.qualitative-research.net/index.php/fqs/article/view/3099

Swierczyna, R, Johnson, MF, Lafleur, J & Stein, J 2022, 'Evaluating residential kitchen IAQ and hood performance', *ASHRAE Transactions*, vol. 128, pp. 429–436.

Swisher, ME 2017, *Basics of sampling*, Unpublished work, pp. 1–12.

Tabachnick, BG, Fidell, LS & Ullman, JB 2007, *Using multivariate statistics*, Pearson, Boston.

Tanaka, M 2007, 'Heat stress standard for hot work environments in Japan', *Industrial Health*, vol. 45, no. 1, pp. 85–90. https://doi.org/10.2486/indhealth.45.85

Tang, N, Heath, C & Silverberg, NB 2015, 'Developmental biology of black skin, hair, and nails', in *Pediatric skin of color*, Springer, New York.

Tartarini, F, Cooper, P & Fleming, R 2018, 'Thermal perceptions, preferences and adaptive behaviours of occupants of nursing homes', *Building and Environment*, vol. 132, pp. 57–69. https://doi.org/10.1016/j.buildenv.2018.01.018

Tassou, SA, Ge, Y, Hadawey, A & Marriott, D 2011, 'Energy consumption and conservation in food retailing', *Applied Thermal Engineering*, vol 31, no. 2–3, pp. 147–156. https://doi.org/10.1016/j.applthermaleng.2010.08.023

Tawatsupa, B, Lim, L, Kjellstrom, T, Seubsman, S & Sleigh, A 2010, 'The association between overall health, psychological distress, and occupational heat stress among a large national cohort of 40,913 Thai workers', *Global Health Action*, vol. 3, pp. 1–11. https://doi.org/10.3402/gha.v3i0.5034

Taylor, DP 2022, 'Does Closing Doors Help Air-Conditioning?', *Angi*, blog post, viewed 01 August 2022, https://www.angi.com/articles/do-closed-doors-reduce-heating-cooling-costs.htm

Taylor, NA & Cotter, JD 2006, 'Heat adaptation: Guidelines for the optimisation of human performance', *International SportMed Journal*, vol. 7, no. 1, pp. 33–57. https://doi.org/10.1016/j.jtherbio.2005.11.007

Taylor, NAS 2006, 'Ethnic differences in thermoregulation: Genotypic versus phenotypic heat adaptation', *Journal of Thermal Biology*, vol. 31, no. 1–2, pp. 90–104.

Taylor, P & Lewontin, R 2017, 'The genotype/phenotype distinction', in N.E. Zalta (ed.), *Stanford encyclopedia of philosophy*, viewed n.d., https://plato.stanford.edu/entries/genotype-phenotype/

Teder, H 2019, 'Common transient sounds: The kitchen is a very noisy place', *Canadian Audiologist*, vol. 6, no. 4, pp. 10–11.

Tekce, I, Artan, D & Ergen, E 2021, 'An empirical study of visual comfort in office buildings', in *Sustainable design and manufacturing 2020*, Springer, Singapore, pp. 319–331.

Tetlow, K 2007, 'Task lighting solutions: Their economic and ergonomic benefits', *Educational Advertising Section,* Continuing Education Center, Cape Town, pp. 173–180.

Thomas, B 2014, 'HVAC UV lights for AC systems–do they work?', *House so Green*, blog post, viewed 17 January 2020, https://housesogreen.com/2014/07/hvac-uv-lights-for-ac-systems-do-they-work/

Thuillier, L 2017, 'What is visual comfort and how do you achieve it?' Saint-Gobain, viewed 29 April 2022, https://multicomfort.saint-gobain.co.uk/recommended-level-of-light-into-a-building

Thwaites, G 2017, 'What are the advantages of having curly hair?', *Quora*, viewed 05 May 2019, https://www.quora.com/What-are-the-advantages-of-having-curly-hair-What-is-the-evolutionary-drive-behind-it-if-there-is-any

Tian, Z, Zhu, N, Zheng, G & Wei, H 2011, 'Experimental study on physiological and psychological effects of heat acclimatization in extreme hot environments', *Building and Environment*, vol. 46, no. 10, pp. 2033–2041. https://doi.org/10.1016/j.buildenv.2011.04.027

Timerbaeva, E 2010, 'Ventilation systems for commercial kitchens', BSc thesis, Mikkeli University of Applied Sciences, Mikkeli.

Tong, Y, Zhang, R, Liu, Z & Tan, Z 2021, 'Effect of natural sounds masking on perception of noise in the kitchen environment', *International Conference on Applied Human Factors and Ergonomics*, Springer, New York, pp. 521–528.

Torresin, S, Pernigotto, G, Cappelletti, F & Gasparella, A 2018, 'Combined effects of environmental factors on human perception and objective performance: A review of experimental laboratory works', *Indoor Air*, vol. 28, no. 4, pp. 525–538. https://doi.org/10.1111/ina.12457

Totsky, L 2006, 'Workplace heat hazards', Samford University, Homewood, AL, viewed 13 November 2020, https://www.coursehero.com/file/39536905/wsh-heat-hazards-242049-7doc/

Trochim, WM, Donnelly, JP & Arora, K 2016, *Research methods: The essential knowledge base*, Cengage Learning, Boston.

Truity 2017, 'Chef or head cook', *Truity*, blog post, viewed 12 November 2019, https://www.truity.com/career-profile/chef-or-head-cook

Tuomaala, P, Holopainen, R, Piira, K & Airaksinen, M 2013, 'Impact of individual characteristics such as age, gender, BMI and fitness on human thermal sensation', *Proceedings of the Thirteen Internatinal Building Performance Simulation Association Conference*, Chambéry, France, pp. 2305–2311.

Twin City Fan 2020, 'Centrifugal fans- installation, operation & maintenance manual', Twin City Fan, viewed 15 November 2020, https://www.tcf.com/wp-content/uploads/2018/06/Centrifugal-Fans-IM-995.pdf

UK Homes and Communities Agency 2015, *Employment density guide*, 3rd edn, GVA Grimley Ltd, London, pp. 1–40.

University of California, Los Angeles (UCLA): Statistical Consulting Group 2016, *Introduction to SAS*, University of California, Los Angeles, viewed 18 November 2019, https://stats.idre.ucla.edu/other/mult-pkg/faq/general/faq-how-do-i-cite-web-pages-and-programs-from-the-ucla-statistical-consulting-group/

Unison 2014, 'Temperature at work', in Unison (ed.), *Health and safety information sheet*, Unison, London.

USC Libraries 2019, 'Organizing your social sciences research paper: 6 the methodology', University of Southern California, viewed 12 November 2019, https://libguides.usc.edu/writingguide/methodology

Van Bommel, W 2012, *Light, health and alertness*, Health & Safety International, Weymouth.

Van Bommel, WJ 2006, 'Non-visual biological effect of lighting and the practical meaning for lighting for work', *Applied Ergonomics*, vol. 37, no. 4, pp. 461–466. https://doi.org/10.1016/j.apergo.2006.04.009

Van Creveld, K & Mansfield, K 2020, 'Lit environments that promote health and well-being', *Building Services Engineering Research and Technology*, vol. 41, no. 2, pp. 193–209. https://doi.org/10.1177/0143624419896250

Van Den, WK & Inanici, M 2014, 'A critical investigation of common lighting design metrics for predicting human visual comfort in offices with daylight', *Leukos*, vol. 10, no. 3, pp. 145–164. https://doi.org/10.1080/15502724.2014.881720

Van Deusen, P 2018, 'Color temperature explained', *Diedrik Builders*, blog post, viewed 12 November 2019, https://web.archive.org/web/20190527004150/http://www.diedrikbuilders.com/Color-Temperature-Explained.html

Van Duijnhoven, J, Aarts, MPJ, Aries, MBC, Böhmer, MN & Rosemann, ALP 2019, 'Recommendations for measuring non-image-forming effects of light: A practical method to apply on cognitive impaired and unaffected participants', *Indoor and Built Environment*, vol. 28, pp. 171–186. https://doi.org/10.3233/THC-161258

Van Hoof, J 2008, 'Forty years of Fanger's model of thermal comfort: Comfort for all?', *Indoor Air*, vol. 18, no. 3, pp. 182–201. https://doi.org/10.1111/j.1600-0668.2007.00516.x

Van Hoof, J, Schellen, L, Soebarto, V, Wong, J & Kazak, J 2017, 'Ten questions concerning thermal comfort and ageing', *Building and Environment*, vol. 120, pp. 123–133. https://doi.org/10.1016/j.buildenv.2017.05.008

Vardaxis, N, Bard, D & Persson Waye, K 2018, 'Review of acoustic comfort evaluation in dwellings-part I: Associations of acoustic field data to subjective responses from building surveys', *Building Acoustics*, vol. 25, no. 4, pp. 151–170. https://doi.org/10.1177/1351010X18762687

Veal, AJ 2011, *Research methods for leisure and tourism: A practical guide*, Pearson, London.

Venter, M 2015, 'The day I "discovered" my South African culture', *SA People*, blog post, viewed 31 October 2019, https://www.sapeople.com/2015/02/11/the-day-i-discovered-my-south-african-culture/

Venugopal, V, Latha, P & Shanmugam, R 2021a, 'Occupational heat exposures and renal health implications - a cross-sectional study among commercial kitchen workers in South India', *Occupational and Environmental Medicine*, vol. 78, a22. http://dx.doi.org/10.1136/OEM-2021-EPI.57

Venugopal, V, Shanmugam, R & Kamalakkannan, LP 2021b, 'Heat-health vulnerabilities in the climate change context – comparing risk profiles between indoor and outdoor workers in developing country settings', *Environmental Research Letters*, vol. 16, no. 8, a085008.

Villines, Z 2018, 'What can cause flushed skin?', *Medical News Today*, viewed 31 October 2019, https://www.medicalnewstoday.com/articles/323219.php

Viola, AU, James, LM, Schlangen, LJ & Dijk, D 2008, 'Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality', *Scandinavian Journal of Work, Environment and Health*, vol. 34, no. 2, pp. 297–306. https://doi.org/10.5271/sjweh.1268

Walker, A 2016, 'Natural ventilation', *Whole building design guide*, viewed 12 November 2019, https://www.wbdg.org/resources/natural-ventilation

Walker, E 2011, *Intermediate statistics*, s.n., South Orange.

Wang, B, Klemeš, JJ, Malášek, J, Hemzal, M, Liang, Y & Zeng, M 2021a, 'A novel turbine ventilator with a damper regulator to adjust exhausted air for energy-saving in buildings', *Journal of Building Engineering*, vol. 38, a102141. https://doi.org/10.1016/j.jobe.2020.102141

Walker, I 2022, IEA Annex 86 Formaldehyde and Cooking Contaminants, Berkeley Lab, Berkeley.

Wang, L, Zhang, L, Ristovski, Z, Zheng, X, Wang, H, Li, L et al. 2020, 'Assessing the effect of reactive oxygen species and volatile organic compound profiles coming from certain types of Chinese cooking on the toxicity of human bronchial epithelial cells', *Environmental Science & Technology*, vol. 54, no. 14, pp. 8868–8877. https://doi.org/10.1021/acs.est.9b07553

Wang, N & Boubekri, M 2009, 'Behavioral responses to daylit space: A pilot study', *Journal of the Human-Environment System*, vol. 12, no. 1, pp. 15–25. https://doi.org/10.1618/jhes.12.15

Wang, Q, Qian, M, Yang, L, Shi, J, Hong, Y, Han, K et al. 2021b, 'Audiometric phenotypes of noise-induced hearing loss by data-driven cluster analysis and their relevant characteristics', *Frontiers in Medicine*, vol. 8, a662045. https://doi.org/10.3389/fmed.2021.662045

Wang, Z & Hong, T 2020, 'Learning occupants' indoor comfort temperature through a Bayesian inference approach for office buildings in United States', *Renewable and Sustainable Energy Reviews*, vol. 119, pp. 1–11. https://doi.org/10.1016/j.rser.2019.109593

Warehouse Lighting 2020, 'Commercial kitchen lighting', *Warehouse Lighting*, blog post, viewed 05 October 2020, https://www.warehouse-lighting.com/blogs/lighting-application-suggestions/commercial-kitchen-lighting

Webber, R, Franz, R, Marx, W & Schutte, P 2003, 'A review of local and international heat stress indices, standards and limits with reference to ultra-deep mining', *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 103, pp. 313–323.

Webstaurant Store 2018, 'OSHA regulations for restaurants', Webstaurant Store, web article, viewed 12 November 2019, https://www.webstaurantstore.com/article/255/osha-regulations-for-restaurants.html

Webstaurant Store 2019, 'Installation and maintenance', Webstaurant Store, web article, viewed 12 November 2019, https://www.webstaurantstore.com/food-service-resources/installation-maintenance/

Welch, A 2017, 'Analyzing indoor and outdoor heat index measurements in kitchens', MSc thesis, University of South Florida, Tampa.

Welch, D, Shepherd, D, Dirks, KN, Mcbride, D & Marsh, S 2013, 'Road traffic noise and health-related quality of life: A cross-sectional study', *Noise and Health*, vol. 15, no. 65, p. 224. https://doi.org/10.4103/1463-1741.113513

Welman, C, Kruger, S & Mitchell, B 2005, *Research methodology*, 3rd edn., Oxford University Press, Cape Town.

Widaman, KF 2012, 'Exploratory factor analysis and confirmatory factor analysis', in HM Cooper & PM Camic (eds.), *APA handbook of research methods in psychology*, vol. 3, American Psychological Association, Ipswich, MA, pp. 361–389.

Williams, G & Short, AE 2022, 'Effects of noise on anxiety related to the experience of dining in restaurants', *Music and Medicine*, vol. 14, no. 1, a806. https://doi.org/10.47513/mmd.v14i1.806

Winter, DJCF, Dodou, D & Wieringa, PA 2009, 'Exploratory factor analysis with small sample sizes', *Multivariate Behavioral Research*, vol. 44, no. 2, pp. 147–181. https://doi.org/10.1080/00273170902794206

Wong, NH, Tan, E & Adelia, AS 2020, 'Utilization of natural ventilation for hot and humid Singapore', in N Enteria, H Awbi & M Santamouris (eds.), *Building in hot and humid regions*, Springer, Singapore.

Wong, TW, Wong, AH, Lee, FS & Qiu, H 2011, 'Respiratory health and lung function in Chinese restaurant kitchen workers', *Occupational and Environmental Medicine*, vol. 68, no. 10, pp. 746–752. https://doi.org/10.1136/oem.2010.059378

Woo, M, Macnaughton, P, Lee, J, Tinianov, B, Satish, U & Boubekri, M 2021, 'Access to daylight and views improves physical and emotional wellbeing of office workers: A crossover study', *Frontiers in Sustainable Cities*, vol. 2021, pp. 92–102. https://doi.org/10.3389/frsc.2021.690055

Woofter, J 2020, 'A light on illumination for buildings', *Strategic sustainability consultant*, viewed 28 January 2020, from http://www.sustainabilityconsulting.com/blog/2014/4/29/ssc-president-jennifer-woofter-shines-a-light-on-illumination-for-buildings

World Health Organization (WHO) 2015, *Hearing loss due to recreational exposure to loud sounds: A review*, World Health Organization, Geneva.

World Health Organization (WHO), 2018, *Information and public health advice: Heat and health*, World Health Organization, Geneva.

Wu, MT, Lin, PC, Pan, CH & Peng, CY 2019, 'Risk assessment of personal exposure to polycyclic aromatic hydrocarbons and aldehydes in three commercial cooking workplaces', *Scientific Reports* vol. 9, p. 1661. https://doi.org/10.1038/s41598-018-38082-5

Xiang, J, Bi, P, Pisaniello, D & Hansen, A 2014, 'The impact of heatwaves on workers' health and safety in Adelaide, South Australia', *Environmental Research*, vol. 133, pp. 90–95. https://doi.org/10.1016/j.envres.2014.04.042

Xiang, J, Hao, J, Austin, E, Shirai, J & Seto, E 2021, 'Residential cooking-related $PM_{2.5}$: Spatial-temporal variations under various intervention scenarios', *Building and Environment*, vol. 201, a108002. https://doi.org/10.1016/j.buildenv.2021.108002

Xie, W, Gao, J, Lv, L, Hou, Y, Cao, C, Zeng, L & Xia, Y 2021, 'Parametrized design for the integration of range hood and air cleaner in the kitchen'. *Journal of Building Engineering*, vol. 43, a102878. https://doi.org/10.1016/j.jobe.2021.102878

Xu, H, Hu, X, Guan, H & He, G 2017, 'Development of a fine-scale discomfort index map and its application in measuring living environments using remotely-sensed thermal infrared imagery', *Energy and Buildings*, vol. 150, pp. 598–607. https://doi.org/10.1016/j.enbuild.2017.06.003

Yamaguchi, K & Ihara, T 2020, 'Counter measures to urban heat island considering urban energy usage', in N Enteria, H Awbi & M Santamouris (eds.), *Building in hot and humid regions*, Springer, Singapore, pp. 15–57.

Yamaguchi, Y, Kim, B, Kitamura, T, Akizawa, K, Chen, H & Shimoda, Y 2022, 'Building stock energy modeling considering building system composition and long-term change for climate change mitigation of commercial building stocks', *Applied Energy*, vol. 306, pp. 1–19. https://doi.org/10.1016/j.apenergy.2021.117907

Yamasoba, T, Lin, FR, Someya, S, Kashio, A, Sakamoto, T & Kondo, K 2013, 'Current concepts in age-related hearing loss: Epidemiology and mechanistic pathways', *Hearing Research*, vol. 303, pp. 30–38. https://doi.org/10.1016/j.heares.2013.01.021

Yan, H, Liu, Q, Zhao, W, Pang, C, Dong, M, Zhang, H et al. 2020, 'The coupled effect of temperature, humidity, and air movement on human thermal response in hot–humid and hot–arid climates in summer in China', *Building and Environment*, vol. 177, a106898. https://doi.org/10.1016/j.buildenv.2020.106898

Yang, C, Zhong, T, Li, J, You, S, Yang, S, Zhang, H et al. 2022, 'Extended tube acoustic metamaterial: Its modeling and application to a kitchen hood', *Applied Acoustics*, vol. 185, a108398. https://doi.org/10.1016/j.apacoust.2021.108398

Yang, W & Jeon, JY 2020, 'Effects of correlated colour temperature of LED light on visual sensation, perception, and cognitive performance in a classroom lighting environment', *Sustainability*, vol. 12, no. 10, a4051. https://doi.org/10.3390/su12104051

Yang, W & Moon, HJ 2019, 'Combined effects of acoustic, thermal, and illumination conditions on the comfort of discrete senses and overall indoor environment', *Building and Environment*, vol. 148, pp. 623–633. https://doi.org/10.1016/j.buildenv.2018.11.040

Yang, Y, Li, B, Liu, H, Tan, M & Yao, R 2015, 'A study of adaptive thermal comfort in a well-controlled climate chamber', *Applied Thermal Engineering*, vol. 76, pp. 283–291. https://doi.org/10.1016/j.applthermaleng.2014.11.004

Yao, J 2014, 'An investigation into the impact of movable solar shades on energy, indoor thermal and visual comfort improvements', *Building and Environment*, vol. 71, pp. 24–32. https://doi.org/10.1016/j.buildenv.2013.09.011

Yazicioğlu, DA & Kanoğlu, A 2016, 'Determining effects of kitchen design rules on kitchen functionality in a comparative way', *Academic Research International*, vol. 3, no. 7, pp. 25–44.

Yeasmin, S & Rahman, KF 2012, 'Triangulation research method as the tool of social science research', *BUP Journal*, vol. 1, no. 1, pp. 154–163.

Yi, KW, Kim, YI & Bae, G 2016, 'Effect of air flow rates on concurrent supply and exhaust kitchen ventilation system', *Indoor and Built Environment*, vol. 25, no. 1, pp. 180–190. https://doi.org/10.1177/1420326X14541558

Yin, RK 2003, *Case study research: Design and methods*, Sage Publications, London.

Yin, RK 2013, *Case study research: Design and methods*, Sage, Thousand Oaks.

Yin, RK 2014, *Case study research: Design and methods*, Sage publications, Thousand Oaks.

Yokley, TR 2009, 'Ecogeographic variation in human nasal passages', *American Journal of Physical Anthropology*, vol. 138, no. 1, pp. 11–22. https://doi.org/10.1002/ajpa.20893

Yong, AG & Pearce, S 2013, 'A beginner's guide to factor analysis: Focusing on exploratory factor analysis', *Tutorials in Quantitative Methods For Psychology*, vol. 9, no. 2, pp. 79–94. https://doi.org/10.20982/tqmp.09.2.p079

Yousefi, M, Shemshadi, G, Khorshidian, N, Ghasemzadeh-Mohammadi, V, Fakhri, Y, Hosseini, H et al. 2018, 'Polycyclic aromatic hydrocarbons (PAHs) content of edible vegetable oils in Iran: A risk assessment study', *Food and Chemical Toxicology*, vol. 118, pp. 480–489. https://doi.org/10.1016/j.fct.2018.05.063

Yu, RM, Wang, M, Du, Z & Hu, P 2010, 'Investigation on the microclimate and air hygiene in PLA kitchen and mess hall', *Journal of Preventive Medicine of Chinese People's Liberation Army*, vol. 6, pp. 1–6.

Yu, X 2009, 'Sensory study in restaurant interior design', MSc thesis, Iowa State University, Ames.

Yuan, J, Wang, L & Liu, X 2013, 'The research of performance comparison of displacement and mixing ventilation system in catering kitchen', *Open Journal of Fluid Dynamics*, vol. 3, no. 2A, pp. 61–68. https://doi.org/10.4236/ojfd.2013.32A010

Yun, GY, Kong, HJ, Kim, H & Kim, JT 2012, 'A field survey of visual comfort and lighting energy consumption in open plan offices', *Energy and Buildings*, vol. 46, pp. 146–151. https://doi.org/10.1016/j.enbuild.2011.10.035

Zaidi, AA, Mattern, BC, Claes, P, Mcevoy, B, Hughes, C & Shriver, MD 2018, 'Correction: Investigating the case of human nose shape and climate adaptation', *PLoS Genetics*, vol. 14, no. 1, a1007207. https://doi.org/10.1371/journal.pgen.1007207

Zander, KK, Botzen, WJ, Oppermann, E, Kjellstrom, T & Garnett, ST 2015, 'Heat stress causes substantial labour productivity loss in Australia', *Nature Climate Change*, vol. 5, no. 7, pp. 647–651. https://doi.org/10.1038/nclimate2623

Zare, S, Baneshi, MR, Hemmatjo, R, Ahmadi, S, Omidvar, M & Dehaghi, BF 2019, 'The effect of occupational noise exposure on serum cortisol concentration of night-shift industrial workers: A field study', *Safety and Health at Work*, vol. 10, no. 1, pp. 109–113. https://doi.org/10.1016/j.shaw.2018.07.002

Zetterberg, M 2016, 'Age-related eye disease and gender', *Maturitas*, vol. 83, pp. 19–26. https://doi.org/10.1016/j.maturitas.2015.10.005

Zhai, SR & Albritton, D 2020, 'Airborne particles from cooking oils: Emission test and analysis on chemical and health implications', *Sustainable Cities and Society*, vol. 52, a101845. https://doi.org/10.1016/j.scs.2019.101845

Zhai, Y, Zhang, Y, Zhang, H, Pasut, W, Arens, E & Meng, Q 2015, 'Human comfort and perceived air quality in warm and humid environments with ceiling fans', *Building and Environment*, vol. 90, pp. 178–185. https://doi.org/10.1016/j.buildenv.2015.04.003

Zhang, A, Deng, N, Long, Z, Hao, R, Shen, C & Cao, G 2020a, 'Simulation study of the capture and purification performance of exhaust fume systems in Chinese commercial kitchens - case study in Tianjin', *Applied Sciences*, vol. 12, no. 17, a8896. https://doi.org/10.3390/app12178896

Zhang, A, Deng, N, Shen, C, Hao, R, Liu, J, Wang, Y et al. 2020b, 'Survey study on Chinese commercial kitchen exhaust fume systems in Tianjin', *Building and Environment*, vol. 171, a106629. https://doi.org/10.1016/j.buildenv.2019.106629

Zhang, F & De Dear, R 2019, 'Impacts of demographic, contextual and interaction effects on thermal sensation – Evidence from a global database', *Building and Environment*, vol. 162, a106286. https://doi.org/10.1016/j.buildenv.2019.106286

Zhang, Q, Gangupomu, RH, Ramirez, D & Zhu, Y 2010, 'Measurement of ultrafine particles and other air pollutants emitted by cooking activities', *International Journal of Environmental Research and Public Health*, vol. 7, no. 4, pp. 1744–1759. https://doi.org/10.3390/ijerph7041744

Zhao, D & You, X 2021, 'Cooking grease particles purification review and technology combination strategy evaluation for commercial kitchens', in *Building simulation*, pp. 1–21, Springer, New York.

Zhao, Y, Li, A, Tao, P & Gao, R 2013, 'The impact of various hood shapes, and side panel and exhaust duct arrangements, on the performance of typical Chinese style cooking hoods', *Building Simulation*, vol. 6, pp. 139–149. https://doi.org/10.1007/s12273-012-0096-1

Zhao, Y, Tao, P, Zhang, B & Huan, C 2020, 'Contribution of Chinese hot pot and barbecue restaurants on indoor environmental parameters', *Aerosol and Air Quality Research*, vol. 20, pp. 2925–2940. https://doi.org/10.4209/aaqr.2020.04.0141

Zhao, Y & Zhao, B 2018, 'Emissions of air pollutants from Chinese cooking: A literature review', *Building Simulation*, vol. 11, pp. 977–995. https://doi.org/10.1007/s12273-018-0456-6

Zhao, Y, Li, A, Gao, R, Tao, P & Shen, J 2014, 'Measurement of temperature, relative humidity and concentrations of CO, CO_2 and TVOC during cooking typical Chinese dishes', *Energy and Buildings*, vol. 69, pp. 544–561. https://doi.org/10.1016/j.enbuild.2013.11.037

Zhou, B, Wei, P, Tan, M, Xu, Y, Ding, L, Mao, X et al. 2019, 'Capture efficiency and thermal comfort in Chinese residential kitchen with push-pull ventilation system in winter-a field study', *Building and Environment*, vol. 149, pp. 182–195. https://doi.org/10.1016/j.buildenv.2018.12.017

Zlatar, T, Sa-Ngiamsak, T & Macêdo, G 2022, 'Variables influencing heat stress response in humans: A review on physical, clothing, acclimation and health factors', *Occupational and Environmental Safety and Health*, vol. 3, pp. 281–291. https://doi.org/10.1007/978-3-030-89617-1_26

Zolotareva, E 2011, 'Mechanical supply and exhaust ventilation in high rise residential buildings in Russia', BSc thesis, Mikkeli University, Mikkeli.

Zou, Y & Li, Y 2020, 'Indoor heat stress index based on the predicted heat strain model and its application', *ASHRAE Transactions*, vol. 126, no. 1, pp. 82–90, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.

Zuhaib, S, Manton, R, Griffin, C, Hajdukiewicz, M, Keane, MM & Goggins, J 2018, 'An indoor environmental quality (IEQ) assessment of a partially-retrofitted university building', *Building and Environment*, vol. 139, pp. 69–85. https://doi.org/10.1016/j.buildenv.2018.05.001

Zumtobel 2018, *The lighting handbook*, Zumtobel Lighting Gmbh, Dornbirn.

Index

Environmental ergonomics: Commercial kitchens in a semi-tropical city focuses on the environmental ergonomics of restaurant kitchens and the challenges related hereto in a semitropical city, Durban from a chef's perspective. It establishes the urgent need for commercial kitchens to be conducive to the well-being of kitchen workers, as heat illness is unreported in this industry. This research is relevant from an occupational health and safety point of view. It evaluates the indoor environmental quality (IEQ) parameters such as heat, ventilation and humidity, noise and lighting in kitchens, cognisant that with different cuisines, the kitchen loads are different. *Environmental ergonomics: Commercial kitchens in a semi-tropical city* generates new knowledge regarding the factors affecting the body mass index of kitchen workers, prediction of heat and humidity near cooking stoves, discomfort near ovens, lighting in preparation areas and factors affecting reaction to stove noise. The book implements an exploratory design with multiple case studies and is structured into broad chapters on heat, ventilation and humidity, noise, and lighting. The data analysis is essentially an important component of new knowledge, and the detailed description will promote certain research concepts among scholars to acquire research skills. This book scrutinises theory in respect of relationships between individual differences and contextual components, factoring these into controlled heat in work environment as well as other IEQ parameters. It advances existing physical conditions as well as physiological and psychological influences of these parameters in commercial kitchens on worker relief-seeking behaviour adaptations.

The core idea and concern of this book is to promote the health, safety and comfort of commercial kitchen workers and to increase the productivity, efficiency and quality of work for food industry business. This book produces awareness through interdisciplinary scientific study and analysis on IEQ parameters such as temperature, heat, humidity, lighting, ventilation, noise, and carbon dioxide (CO_2) and carbon monoxide (CO) levels and the influence of these on the comfort of work and well-being of workers. The food service workers' age, gender, ethnicity, physiology and psychology are also considered with respect to IEQ parameters. The study on 'environmental ergonomics of commercial kitchens' is restricted to Durban, a semi-tropical city. The methodology, general importance, outcomes and recommendations also assist the food production sector and are applicable to similar working environments and remain relevant to improving work performance. This book investigates the collected data with multiple case studies to explore differences within and between cases. The statistical data analysis and detailed description provide the reader with natural and social scientific research concepts and skill to understand the information both qualitatively and quantitatively. As in any organization, worker satisfaction is a basic element for better-quality survival, performance, and production. *Environmental ergonomics: Commercial kitchens in a semi-tropical city* offers insightful environmental contributions to improving commercial kitchen design and awareness among scholars and peers for developing an environmental quality policy and standard operating procedures.

Dr Tharmaraj Jesan, Environmental Survey Laboratory, Kalpakkam, India

AOSIS
aosis.co.za

Open access at https://doi.org/10.4102/aosis.2022.BK346

9 781779 952035

ISBN: 978-1-77995-203-5