# An evaluation of Sick Building Syndrome amongst administrative employees in an office environment in Durban, KwaZulu-Natal.

Submitted in fulfillment of the requirements for the Degree of Master of Health Sciences: Environmental Health Faculty of Health Sciences at the Durban University of Technology.

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## DECLARATION

I, Demi Moodley hereby declare the content of this research project is the author's own unaided original work, except where specific indication is given to the contrary (by reference). This work has not been previously submitted to the Durban University of Technology (DUT) or any other University.

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**ABSTRACT**

**Introduction**: Approximately 90% of the populace spends their time indoors. The building environment, in which an individual is ensconced, is directly related to the sustenance of the health of the human body as well as psychological well-being (Murniati 2020: 278). Sick Building Syndrome (SBS) has been a controversial topic over the years, as there are several definitions published in research. Nevertheless, common SBS symptoms and characteristics make it prevalent as a consequence of exposure to several possible indoor factors such as; low/ high temperature, inadequate ventilation, overcrowding, stress, poor building and ventilation maintenance, inadequate cleaning and pollutant accumulation.

**Methodology**: This study focuses on investigating the association between indoor carbon dioxide levels ($CO_2$), air flow rate, indoor temperature and the prevalence of SBS contributing to the health and wellbeing of employees in an administrative office building in Durban, KwaZulu-Natal. This was achieved with the use of two phases of investigation. A commonly used questionnaire on health, lifestyle and office conditions focused on their perceptions of the participants, regarding their environment. Thereafter, objective sampling of $CO_2$, indoor temperature and air flow rate was conducted and assessed. Both sampling methods were discussed and assessed simultaneously in relation to the Biopsychosocial Model as the objective sampling further validated the outcome from the questionnaire results.

**Results**: The results showed that there was a correlation between age ($p$-value < 0.01), female gender ($p$-value < 0.01; n= 135), psychological conditions and physical environmental quality (temperature, ventilation and $CO_2$; $p$-value < 0.01) with SBS. No correlation was identified between lifestyle conditions, smoking behavior, ergonomic factors, noise and illumination with the occurrence of Sick Building Syndrome ($p$-value > 0.05). It can be said that more than half of the participants were unhappy due to their working conditions. This did not meet the 80% occupant satisfactory requirement in the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standard 62.1. As a result of the below standard specifications and under maintained ventilation and air-conditioning system, an accumulation of $CO_2$ occurred towards the end of the day with an overall low temperature on the sampling days. The accumulation of $CO_2$ in the afternoon was a result of the extraction system which was not adequate to supply the level of overcrowding in the building. Furthermore, the negatively perceived environment added to the factors above resulting in the common SBS symptoms of watery eyes, dizziness, dry and burning eyes, fatigue/ tiredness, drowsiness/

lethargy, headaches, sinusitis, blocked /stuffy nose, runny nose, skin irritations, sore dry throat and influenza like symptoms being experienced amongst most participants. The most significant ($p$<0.001) symptoms experienced by participants were headaches and sinusitis. The defining factor which determined the prevalence of SBS was if the symptoms disappeared after a few hours of leaving the building and almost all ($p$-value <0.01; n=165) participants stated that this was true.

**Conclusion**: It can be concluded employees in the office of study definitely experienced SBS. Finally, recommendations were suggested in relation to the hierarchy of control as well as transitioning into 'green' buildings. This is the first study in South Africa to associate SBS in an office using a multidisciplinary method since 1993 in South Africa (Truter 1993:1).

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*Mathew 19:26 "With God everything is possible".*

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| BRI | Building Related Illness |
| SBS | Sick Building Syndrome |
| OHS | Occupational Health and Safety |
| SHE | Safety Health Environmental |
| WHO | World Health Organization |
| $CO_2$ | Carbon Dioxide |
| IAQ | Indoor Air Quality |
| VOC | Volatile organic compounds |
| HVAC | Heating Ventilation and Air-conditioning system |
| VDU's | Visual Display Units |
| µm | Micrometer |
| cfm | cubic feet per minute of air |
| RH | Relative Humidity |
| NIOSH | National Institute of Occupational Safety and Health |
| ACGIH | The American Conference of Governmental Industrial Hygienists |
| ASHRAE | The American Society of Heating, Refrigerating and Air-Conditioning Engineers |
| ANSI | American National Standards Institute |
| SANS | South African National Standards |
| BMI | Body Mass Index |
| HIV | Human Immunodeficiency virus |

| | |
|---|---|
| GP | General Practitioner |
| Ppm | Parts per million |
| Hr | Hour |
| L | Litre |
| Kg | Kilogram |
| % | Percentage |
| $l.s^{-1}$ | Litre per second |
| $m^3.s^{-1}$ | meter cubed per second |
| °C | Degree Celsius |
| $m.s^{-1}$ | meter per second |

## LIST OF DEFINITIONS

| | |
|---|---|
| Office | A room or part of a building in which people work, especially sitting at tables with computers and phones, as a part of an organization or as a part of a government department (MZ and Saliluddin 2019: 22). |
| Indoor environmental quality | Integrated psychological and physiological effects on occupants of indoor environmental quality, as well as air quality, lighting quality, thermal comfort, and noise. These factors not only affect the health and wellbeing of employees but also productivity and creativity (Samani, Rasid and Sofian 2015: 29). |
| Heath | state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (The World Health Organisation 2014:1) |
| Psychophysical stressors | can be defined as the relationship of human ability to sense the physical environment of external stimuli (such as temperature) and biological signals of the human body by what is perceived in the environment (feeling of coldness) which could affect or influence human health and comfort (Filingeri and Havenith 2015: 86). |
| Psychosocial stressors | Psychological stress includes factors that consist of physiological and social parameters which affect health and comfort. Factors such as stress levels, personality, behaviour, emotional capacity and perceived indoor environment (Lehman, David and Gruber 2017: 17). |

# CHAPTER 1

# INTRODUCTION

## 1.1. INTRODUCTION TO THE STUDY

The health and wellbeing of employees are vitally important aspects of people centric building design and are roots of productivity at the workplace (Ghaffarianhoseini *et al*.2018: 99, Hayleeyesus and Manaye 2014: S312). The majority of office employees spend between five to eight hours of their day, five days a week in an office environment (Hayleeyesus and Manaye 2014: S312). For this reason, much attention has been placed, over the years, on indoor physical environments and occupants' health, with recommendations to improve the work environment (Mohan 2012: 107, Bluyssen et al. 2016: 298). Due to the 1970s oil and energy crisis, energy- saving strategies consequentially led to airtight reduced rooms and to reduced ventilation rates, causing reduced air circulation. Moreover, materials and energy efficient standards have dramatically changed over the past decade. The utilisation of poorer building materials, poor ventilation rate and circulation has resulted in various pollutants and contaminants being harboured in buildings, consequently resulting in indoor health issues.

The context of the term Sick Building Syndrome (SBS) is said to be a controversial one. This is because there is no single agent or pollutant directly linked to the etiology of SBS (Cooley *et al.* 1998:579). It can be said that the presence of sickness in the workplace is an important public health issue, which impacts directly and/or indirectly on employees and employers. An Office Building Occupants Guide to Indoor Air Quality (IAQ) highlighted that factors which affect indoor employees' comfort and productivity level, is not only measured through pollutant, microbiological, chemical and other objective methods but also in the number of environmental and personal factors which can affect how people perceive air quality (Brits 2011: 35).

Given that we breathe about 12000 litres of air every day (Ram 2019: 1), buildings have the potential to either protect us from physical factors or contribute to negative well-being us in the work place (MacNaughton *et al*. 2017: 178); therefore, management plays a significant role in the prevalence of SBS as performance efficiency of indoor employees will be increased by 40% if management improved working conditions and provided supportive actions (Zamani-Badi *et al.* 2019: 423).

## 1.2. BACKGROUND

Older research on SBS originally began in office environments with or without open plan office spaces. Thereafter, more recent studies focused on medical facilities, schools and residential buildings (MZ and Saliluddin 2019: 22).

Sick Building Syndrome has become a global 20th century controversial issue at the workplace. According to the World Health Organisation (WHO) the prevalence of SBS is estimated to be up to 30% in new buildings (Keyvani *et al*. 2017:19). Due to the recent global energy crises, engineers have begun to develop buildings that are more energy efficient by 'tightening' up buildings to reduce heating and cooling costs. Building engineers have also cut off fresh air supply and made buildings more insulated. As a result, many buildings have resorted to Heating, Ventilating, and Air-conditioning systems (HVAC) or air conditioning systems which are associated with a host of other direct and indirect health effects (Truter 1993: 10). In light of the increase of sealed or 'airtight' high rise building structures being erected, more people are working indoors for longer periods of time in poorly ventilated and polluted unhealthy environments, therefore possibly causing an increase in SBS over the current years (Vafaeenasab *et al*. 2015: 247, Rostron 2008: 294).

In light of this, no recent research has been published in South Africa where many parameters were monitored using a multidisciplinary approach. There have been, however, South African studies solely focusing on a singular possible cause, such as ventilation systems or IAQ and the relation to SBS or other health effects (Helsop 2002: 432; Meintjes 2013: 3 and Barnes *et al*. 2009: 4). Moreover, there has been some South African research regarding occupants' health effects from factors related to residential buildings, but very few on administrative office settings (Aigbavboa and Dosumu 2017: 68). International cross-sectional studies have focused primarily on non-industrial settings, such as hospitals, offices and schools (Vafaeenasab *et al*. 2015: 247; Keyvani *et al*. 2017:19; Magnavita 2015: 185; Edvardsson *et al.* 2007: 805). Internationally, there has been a spike in research conducted between 1982 and 1994 (Finnegen, Pickering and Burge 1984: 1573; Skov *et al.* 1989: 286; Wargocki *et al*. 1999: 165; Truter 1993:1). Thereafter very few studies focused on SBS and office environments. Despite the numerous studies that had been published, no recent research evidenced a completely holistic approach to identifying the prevalence of SBS. This has been achieved by the use of a biopsychosocial model to encompass a method of triangulation (Magnavita 2015: 186). This study will use a multidisciplinary approach to add to current literature and possibly create increased awareness in office environments, specifically at the study site to be conducted. In addition to increased awareness, possible causes and new linkages or trends in the field of SBS may be established thereby creating new innovative ways to reduce the prevalence of SBS, which could possibly be valuable to policy makers. With the severe paucity of research on SBS in South Africa, this study will be beneficial to other researchers in the field.

The office building under study has had increased prevalence of verbal complaints regarding 'stuffy air', too low or too high indoor temperatures at different sections, and a severe lack of working space or overcrowding in some areas. It was noted, based on the National Building Regulations of ventilation systems, that the number of toilets initially installed, building space and air conditioners were originally designed to accommodate approximately 240 employees. The building currently holds approximately ± 410 employees at any given time. Furthermore, the employment rate at the office continues to increase. The perceived IAQ complaints at the office site selected have triggered a multidisciplinary study on SBS. Future studies should consider including all factors, using a multi-disciplinary approach as SBS can only be accurately diagnosed if all aspects and factors are considered (Gomzi *et al*. 2007: 147).

## 1.3. RESEARCH PROBLEM

Poor management, inefficient or inadequate ventilation and high $CO_2$ levels systems within a building, are among the factors that affect a physical office environment and which could potentially contribute to the prevalence of SBS. This could negatively impact both the health and well-being of employees, and consequently productivity. The paucity of research in the current context makes this study timely.

## 1.4. AIMS AND OBJECTIVES

Aim

To investigate the association between indoor carbon dioxide levels, air flow rate, indoor temperature and the prevalence of SBS contributing to the health and wellbeing of employees in an administrative office building in Durban, KwaZulu-Natal.

In order to achieve this aim, the following objectives will be pursued:

1. To determine perceived environmental, psychophysical and psychosocial stressors experienced amongst employees at an administrative office in Durban during 2019-2020.

2. To determine $CO_2$ level, air flow rate and indoor temperature affecting employees in accordance with the minimum requirements of the ASHRAE standards, to inform, using results from objectives 2 and 3, recommendations to improve the working environment.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1. INTRODUCTION

Approximately 1.6 million deaths occur annually due to indoor air quality related health problems and indoor pollution (Zainal *et al*. 2019: 127). Research has proved that people in high income countries spend between 80% and 90% of their time indoors (Wang 2019: D1 and Sun *et al.* 2019: 112), with office employees spending on average 8.5 hours indoors (Zainal *et al*. 2019: 126). As a result, considerable attention has been placed on indoor work environments and offices, as there has been an increase in health effects and diseases such as Sick Building Syndrome (SBS) and Building Related Illness (BRI) (Kim *et al.* 2019: 633; Kapalo *et al.* 2018: 61 and Guo *et al.* 2016: 1854). Urbanisation, coupled with the world's energy crises and the lack of land space has led to an increase in high-rise, airtight buildings with inadequate ventilation systems and over population (Zamani-Badi *et al.* 2019: 422; Vafaeenasab *et al*. 2015: 247 and Jafari *et al*. 2015: 55). Consequently, engineers and architects have revolutionised the design aspects of buildings over the years to accommodate the increased demand in healthy, cost effective and efficient environments. This was achieved by installing electronic equipment, and appropriate furniture, while work methods which have been considered to be low-emitting, 'green' and healthier for employees, have been integrated into the workplace (Wang 2019: ii). This is implemented in most cases where new buildings are currently being built. Existing buildings however, will not be designed to these standards and therefore may not contribute towards a healthy environment.

Sick Building Syndrome was first acknowledged as an IAQ issue in the 1960 when employees highlighted poor lighting, "bad" air and uncomfortable thermal conditions (Brauer and Mikkelsen 2010: 639). A more recent study argued that SBS is a result of poor building designs (Murniati 2020: 278). Fundamental building components such as inadequate lighting, uncomfortable temperatures, noise levels, poor ventilation and office layouts directly and indirectly affect the health and wellbeing of occupants (Forooraghi, Wallbaum, and Ryd 2019: 2; Jun, Hamzaha and Anuaa 2017: 7; Jafari *et al*. 2015: 55 and Sundin 2012: 1). These concerns have been reported to result in low productivity and efficiency which subsequently increased absenteeism and sick leave rates (Zamani-Badi *et al.* 2019: 423 and Brauer and Mikkelsen 2010: 639).

Sick Building Syndrome has raised much attention concerning the impacts of the poor building management on the health, comfort and well-being of office workers (Ghaffarianhoseini *et al*. 2018: 99). It can be acknowledged that building design and maintenance is a contributing factor in SBS. International government and society have recently taken an active stand on improving indoor environments and building structures through promoting healthier lifestyles, improving healthier indoor environments, encouraging productive work spaces, promoting greater equity and supporting more resilient places in the low-carbon future (Ghaffarianhoseini *et al*. 2018: 100). The WHO highlighted a significant statistic in reporting that 30% of occupants in all new buildings around the world may be subjected to poor indoor quality, consequently leading to symptoms of SBS which may possibly cause long term negative health effects (Zainal *et al*. 2019: 126 and Brits 2011: 21). Poor building management has proved to be an important medium in which pollutants create harmful conditions for human health (MacNaughton *et al*. 2017: 178). Buildings determine the exposure of outdoor air supply by either facilitating entry of outdoor pollutants or acting as a barrier through filtration. The type of building management and structural design could cause harm to human health or improve work morale, productivity, efficiency and employee wellbeing (MacNaughton *et al*. 2017: 178).

Recent studies throughout the world are currently focusing extensively on green designed buildings and the impact on the health of occupants within the building (Ghaffarianhoseini *et al.* 2018: 99; Tham, Wargocki and Tan 2015: 35 and Thatcher and Milner 2014: 38). Smart cities have revolutionised their technological, architectural, structural and responsive traits of buildings, making them a lot more sustainable and healthier (Ghaffarianhoseini *et al*. 2018: 99). A study by Zamani-Badi *et al.* (2019: 423) inferred that performance efficiency of indoor employees will be increased by 40% if management improved working conditions and provided supportive actions (Bluyssen *et al.* 2016: 299).

### 2.1.1. Defining Sick Building Syndrome

In 1982, the WHO discussed the impact of poor indoor air quality on human health. This topic was highlighted due to the prevalence of cases with non-specific symptoms that related to indoor environmental and occupational factors in office buildings in the United States of

America and Scandinavia (Brauer 2005: 8). Human health problems arising from building conditions were commonly ascribed to SBS or tight building syndrome, building related disease or building related symptoms (Joshi 2008: 61). Building related illnesses may affect individuals in their first encounter of an unhealthy or otherwise compromised environment. This may result in health effects continuing to affect an individual the day after exposure, which is contrary to SBS, where symptoms disappear after being removed from the exposure to the affected environment (Barbu, Niculescu and Moise 2018: 13; Chirico *et al.* 2017: 33; Lukcso, *et al.* 2016: 85 and Brits 2011:21). Several studies have attempted to define SBS (MZ and Saliluddin 2019: 22; Chirico *et al.* 2017: 33 and Gale *et al.* 2005: 8). Jansz (2011: 3) asserted that the common theme presented in these definitions seemed to be people developing ill health caused by exposure to a specific building environment (Jansz 2011: 3).

In 1983, the WHO defined SBS as a set of nonspecific symptoms which included: headaches, fatigue, irritation or dryness of the upper respiratory tract, nose, eyes, throat, hands and skin. A study by Zamani-Badi *et al.* (2019: 423) included details on symptoms of loss of concentration, memory disease, nausea, vomiting and loss of breath, including lethargy (Amouei *et al.* 2019: 2). Symptoms generally occur in low severity and in different combinations and concentrations (MZ and Saliluddin 2019: 22; Chirico *et al.* 2017: 33 and Gale *et al.* 2005: 8) and are more common amongst office workers (Murniati 2020: 278). Sick Building Syndrome was often overlooked and commonly misdiagnosed as the common cold or flu. This was due to the commonality and vagueness of the symptoms of SBS. Complaints may be localised in particular spaces or wide- spread throughout a building (Abu Eleinen, Elries and Elnahas 2018: 1). Vesitara and Surahman (2019: 2) determined that these symptoms and complaints may differ from person to person. People with existing respiratory diseases and asthma may display more severe SBS symptoms.

These symptoms are said to be an attribution of the building environment around the individual, such as the lighting, personal factors, biological contamination, humidity, temperature, indoor ventilation or ventilation systems, ergonomic design of the work space, psychosocial work characteristics, personal factors and air quality contamination (Yildiz 2020: 210 and Keyvani *et al.* 2017: 19). Nopiyanti *et al.* (2019: 363) argued that SBS is mainly caused by poor building design, maintenance and operation. According to Lu *et al*. (2017: 2); Orosa and Oliveira (2011: 482); Edvardsson *et al*. (2007:805) and Truter (1993: 11) the prominent characteristic of SBS is exposure related - once people are removed from the affected environment, their symptoms disappear or improve and once they present themselves in the same space of that environment, their symptoms reappear. This characteristic had been presented in several studies and is part of the definition in the prevalence of SBS (Yildiz 2020: 210; Lu *et al*. 2017:2; Orosa and Oliveira 2011: 482; Edvardsson *et al*. 2007:805 and Truter 1993: 11). Nevertheless, the cause of SBS is still unknown (Murniati 2020: 278).

Similarly, SBS could be defined as “a condition that comprises otherwise healthy individuals experiencing symptoms of physical distress and uncomfortable environments in the workplace” (Redman *et al.* 2011: 14 and Joshi 2008: 61). A study by Magnavita (2015: 185) also highlighted that SBS may be characterised by neuropsychological, mucosal, and dermal symptoms closely related to the employee’s occupational environment. A study conducted at Iranian hospitals defined SBS as a disease associated with indoor air quality resulting in symptoms of headache, dizziness, nausea, coughing and sneezing, irritation of eyes, throat and nose, mucous membrane, skin itching and inflammation (Vafaeenasab *et al*. 2015: 247); however, Zamani-Badi *et al.* (2019: 427) however, argued that different studies with different indoor environments yielded different SBS symptoms. In a study by Ghaffarianhoseini *et al.* (2018: 102); Magnavita (2015: 186 and Cooley *et al.* (1998:579), it was emphasised that researchers have not found the aetiology of SBS and the condition may be due to the multidisciplinary nature with SBS having no single agent or pollutant directly linked to its cause and that there were several symptoms linked to it. Similarly, Carrer and Wolkoff (2018: 2) argued that the term SBS is misleading and therefore obsolete.

Although the WHO had defined SBS in the 1980s, the current term is defined differently in other studies (MZ and Saliluddin 2019: 32; Jun, Hamzah and Anua 2017: 8; Sulaiman *et al.* 2013: 318). A number of studies defined SBS by the density of employee comfort complaints (Jun, Hamzah and Anua 2017: 8; Sulaiman *et al.* 2013: 318 and Jansz 2011: 3). Conversely, Brauer (2005: 9) argued that there is no agreement about how often the occupants in a building have to experience these temporary symptoms, for the building to be considered as “sick”. The Environmental Protection Agency stated that occupant complaints may come from an entire building, one department or one section of the entire building. The WHO, however, defined SBS as an occurrence when an average of 25% or more of employees complain of symptoms of SBS (Murniati 2020: 279, Gladyszewska-Fiedoruk 2019: 1; Thach *et al.* 2019: 2; Jun, Hamzah and Anua 2017: 8; Jafari *et al*. 2015: 55 and Jansz 2011: 3). Some authors have also suggested that SBS may be present in an environment if an average of more than two symptoms appears a specific number of times in a week or month;

albeit, this approach is only briefly addressed in literature (Nopiyanti *et al.* 2019: 363; Zamani-Badi *et al.* 2019: 423; Azuma *et al.* 2017: 4 and Gale *et al.* 2005: 8). A study reported that the duration of time spent in a building significantly influences the occurrence of SBS. The study found that the administration office employees who spent their day performing sedentary work suffered with SBS symptoms more frequently than employees who were intermittently in and out of the office (Jansz 2011: 33). A definition synthesized from the literature could therefore be considered as a temporal mental and physical unpleasant mood or illness where 25% of indoor occupants suffer with at least two SBS symptoms with no particular cause due to the time spent in a building with no particular cause. Once employees remove themselves from the building, their SBS symptoms are relieved (Zamani-Badi *et al.* 2019: 423 and Thach *et al.* 2019: 2).

### 2.1.2. Global significance of Sick Building Syndrome

Over the past fifteen years, extensive international research had been conducted on SBS, more specifically in Asia, United States and Europe, and focusing on investigating the prevalence and aetiology of SBS. This research also expanded on the existing literature on SBS (Azuma *et al.* 2017: 3; Rendon, Gracia and Vital 2017: 178; Alsmo and Alsmo 2014: 1022 and Bluyssen *et al.* 2003: 209). Internationally, a spike in research was noted between 1982 and 1994 when the theory of SBS began within occupational and residential settings (Wargocki *et al.* 1999: 165; Skov *et al*. 1989: 286; Finnegen, Pickering and Burge 1984: 1573).

Various studies have shown the association of SBS to ventilation flow rates, where the impact of poor ventilation on human health in an office setting is evidenced, depicting the detailed methodology used to measure ventilation rates compared to now dated standards (Sierpinska 2019: 50; Zainal *et al.* 2019: 127; Keyvani *et al*. 2017:19; Vafaeenasab *et al*. 2015: 247 and Redman *et al.* 2011: 15). Nevertheless, over the current years there has been a paucity of national and international studies looking at such association (Jaakkola, Tuomaala and Seppänen 1994: 422; Norbäck, Torgen and Edling 1990: 733; Menzies *et al.*1993: 821 and Wargocki *et al.* 1999: 165). Research on IAQ in the South African office settings has been practically non-existent over the years, although a few studies have been conducted on IAQ in dwellings and homes (Aigbavboa and Dosumu 2017: 68). The ASHRAE responded by developing the ASHRAE 62.1 standard - Ventilation for Acceptable Indoor Air Quality.

The ASHRAE committee further highlighted that this standard has greatly assisted building designers and builders to ensure best practice and to educate them (Turpin 2014: 17). The ASHRAE standard points to the context of SBS by ensuring acceptable IAQ by implementing requirements for air-cleaning designs and maintenance of ventilation systems. The standard pertains to old and new buildings based on the physical, chemical and biological contaminants that affect air quality (ASHRAE Standing Standard Project Committee 2016: 3).

Many studies have relied on the cross-sectional design study to interpret the investigations of SBS (Keyvani *et al*. 2017:19; Vafaeenasab *et al*. 2015: 247; Magnavita 2015: 185 and Edvardsson *et al*. 2007: 805); however, nationally and internationally, only minimum research has been conducted on the longitudinal study design (MZ and Saliluddin 2019: 32). Researchers Caruana *et al*. (2015: E537) and Carrer and Wolkoff (2018: 8) highlighted the importance of longitudinal studies in the sector of human health. One of the fundamentals of SBS is the symptom effect and therefore cross sectional studies may only dissect what the current state of the environment or symptom may be for a point in time; whereas, longitudinal studies have the ability to relate symptoms and possible causes or events of SBS to particular exposures, with reference to presence, timing and chronicity (Caruana *et al*. 2015: E537).

Although research on SBS has broadend internationally, there has been a paucity of building related health studies and SBS in South Africa and in developing countries (Afacan and Demirkan 2016: 229). To date, no recent research has been published in South Africa consisting of a spectrum of parameters being investigated; instead, studies have almost exclusively focused on one or two factors, such as ventilation, psychosocial or IAQ factors and the relation to SBS was noted (Aigbavboa and Dosumu 2017; Oodith 2012: 532; Jafta *et al.* 2012: 1110: 68 and Helsop 2002: 432). Longitudinal studies which have employed a method of Biopsychosocial triangulation have not been methodically dealt with in past literature. The lack of research within South Africa affects their ability to set standards, building specifications and guidelines to control the indoor environment. The lack of research in South Africa may stem from inadequate resources of equipment, researchers being unfamiliar with SBS and the general lack of legal standards and guidelines for SBS.

A more systematic and theoretical analysis is required in research on the long term consequences of SBS, and behavioural parameters related to SBS, economic consequences and remedial costs due to SBS have not yet been intensely researched in developed and underdeveloped countries. Zainal *et al*. (2019: 126) argued that the lack of scientific studies related to IAQ and health in developing countries over developed countries.

Taking into account that SBS was investigated by several studies, this study has explored literature in a similar fashion. The relationship of IAQ such as airflow rate, carbon dioxide levels and indoor temperatures, including the psychological influences and health effects of these parameters were explored in relation to SBS. This study may beneficially differ in a multifactorial manner via the utilisation of the Biopsychosocial Model.

## 2.2. BUILDING COMFORT FACTORS

As defined above, SBS is a condition that comprises otherwise healthy individuals experiencing symptoms of physical distress and uncomfortable environments in the workplace (Redman *et al.* 2011: 14 and Joshi 2008: 61); therefore, it can be said that SBS includes both indoor environmental factors such as IAQ and a lack of comfort or psychological wellness (Fard *et al*. 2018: 332). Furthermore, Tarantini, Pernigotto, and Gasparella (2017: 1) highlighted the importance IAQ has on occupants, not only on the health, wellbeing and comfort of occupants but also has an impact on productivity and satisfaction. Good building conditions and sufficient ventilation creates a comfortable and healthy environment. The target of building maintenance managers is to satisfy the human comfort requirements, thermal comfort, good office ergonomics, adequate outdoor fresh air and the absence of poor odour was considered (Fahad Alomirah and Moda 2020: 2 and Hedge 1996: 69). This can be measured through occupant’s perceptions and discomfort of indoor air quality, including their assessment of thermal comfort, odors, office designs and psychological stress in the building environment (Murniati 2020: 279 and Hedge 1996: 69). Furthermore, Murniati (2020: 279) associated psychological factors with SBS symptoms.

### 2.2.1. Psychological stress

Psychological stress include factors that consist of physiological and social parameters which affect the human health. These factors include: stress levels, personality, behavior, emotional capacity and perceived indoor environment (Lehman, David and Gruber 2017: 17). Perceived IAQ was mentioned to be equally important as objective monitoring of IAQ. These personal factors or psychological work characteristic include: odours, temperature, air flow and air freshness, glare from ceiling lights or monitor screens, furniture, overcrowding, stress in the workplace or home, work environment satisfaction, work space ergonomics and inadequate cleaning practices (Brits 2011: 35). The perception of the indoor environment heavily relies on personal characteristics of occupants, such as: allergic diseases, smoking, anxiety, depression, gender, rumors amongst occupants about the work environment, as well as a general tendency to complain. These factors have a major impact on the way occupants perceive the environment and in turn influence the prevalence of SBS (Kim *et al.* 2019: 632 and Brauer and Mikkelsen 2010: 640).

Personal factors such as stress or management control over their work environment have an influence on the participants' perception of the indoor environment. It has been reported that with an increase in the reported level of stress and psychosocial factors, there is an increase in the prevalence of reported symptoms of SBS, environmental complaints and increased chances of developing cardiovascular diseases (Carrer and Wolkoff 2018: 6; Bluyssen *et al.* 2016: 299 and Runeson *et al.* 2006: 446). There had been no recent study reiterating the same concept; concomitantly, a much older study clearly highlighted the relationship that work stress and personal factors have on an individual (Crawford and Bolas 1996: 244). Fahad Alomirah and Moda (2020: 2) suggested that personal stress and the type of job may increase sensitivity to indoor environmental factors such as indoor pollutants, discomfort and other adverse sources (Crawford and Bolas 1996: 244). In consideration of SBS, occupational health has divided into two processes: the first related to the physical surrounds and the second to psychological variables; therefore, it can be suggested that SBS cannot be thoroughly investigated by one process exclusively (Fahad Alomirah and Moda 2020: 2 and Crawford and Bolas 1996: 245).

Skyberg *et al*. (2003: 251) highlight that different types of factors are good indicators for reported symptoms of SBS, such as allergies, passive smoking, visual display units (VDU) work, psychological load, and reporting on cleanliness within the office also had an impact on reported SBS symptoms. It was noted that when cleaning was done in offices once a week, there was an increased prevalence of reported SBS symptoms, whereas, when cleaning was done three to four times a week, minimal complaints were reported. Bluyssen *et al*. (2016: 315) reported that cleaning processes undertaken in the evening rather than in the morning, before employees arrive at work have increased the prevalence of SBS and overall discomfort and office satisfaction in the workplace. Bluyssen *et al.* (2016: 315) argued that this occurrence was due to the cleaning activities completed before the ventilation was switched and on before employees began their work.

Responses yielded from occupants provide the researcher with an idea of the building conditions. Occupants may respond by describing the environment as being too cold, too hot or too noisy, leading to a comfortable or uncomfortable, satisfied or dissatisfied occupant. Dissatisfaction with the indoor environment may cause demoralized or ill occupants and; furthermore, might possibly increase sick leave and decrease productivity (Brauer and Mikkelsen 2010: 639 and Shadwell 1995: 1).

### 2.2.2. Indoor odour

Perceptions of IAQ include sensory irritations. The perception of IAQ complaints have been used as an indicator of poor IAQ (Hedge 1996: 70). Sources of indoor odour are usually contributed by: human bodily odours, cosmetic products such as perfumes, air fresheners, building materials and bio-odourants from mold, animal derived materials and fungal growth (Kim *et al.* 2019: 633 and Wang *et al.* 2013: 2). Odour irritation is said to stimulate "mucosal tissue, chemically stimulated skin sensations or the trigeminal nerve endings" (Wang *et al.* 2013: 1). Every individual perceives odour differently; some may perceive a certain smell as pleasant and others unpleasant (Wang *et al.* 2013: 1). Kim *et al.* (2019: 634) critiqued that it was common for odour and humidity perceptions to be used as qualitative indicators of IAQ. Recent scientific research in the office environment strongly correlated individuals who smoke with increased skin sensitivity. This was because smokers are exposed to environmental tobacco smoke, which contains 'more than 1000 chemical substances with more than 20 toxic chemicals and carcinogens' (Zainal *et al.* 2019: 131).

Few studies, in recent times have investigated the association of SBS and odours within a building (Wang *et al.* 2013: 1); nonetheless, the ASHRAE group investigated an incident whereby employees of a large building had complained of intermittent odour issues at their offices. At that stage, the incident was never declared to be an SBS issue: however, over the past two years the odour had become more persistent with more frequent complaints of the foul odour. Consequently, this led to the incident being categorised as a SBS case. The building had an indoor environmental issue that was impacting on the quality of the work and wellbeing of people using the building (Turpin 2014: 18). The building was deemed 'sick' on the basis of occupant complaints and the individual's sensory irritation. Contrary to this concept, Rostron (2008: 293) argued that sensoric irritations, such as taste and smell of odours were not considered symptoms of SBS but rather environmental perceptions unique to specific individuals. Evidently, relevant literature is contradictory, as some literature considers perceived individual odour as a SBS case and others do not. (Rostron 2008: 293 and Turpin 2014: 18).

### 2.2.3. Building design and comfort

The comfort of an office space often denoted the ability of the environment to create a healthy, pleasant, stimulating physical environment in order for occupants to be productive, efficient and comfortable (Rasheed, Khoshbakht and Baird 2019: 2). Literature on indoor design focused intensively on features that employ positive stimulation and human health in the work place (Lee and Brand 2005: 323; Rasheed, Khoshbakht and Baird 2019: 2 and Forooraghi, Wallbaum, and Ryd 2019: 2). The space in which occupants work in has a direct and personal effect on their health and wellbeing. Therefore open plan office spaces have previously been supported in a positive light; alternatively, some studies refute the concept (Rasheed, Khoshbakht and Baird 2019: 2 and Forooraghi, Wallbaum, and Ryd 2019: 2). As a result of revolutionising the workplace, building designs emphasised access to facilities and services such as green spaces, height adjustable desks, bicycle parking and gyms (Forooraghi, Wallbaum, and Ryd 2019: 2 and Dadvand *et al.* 2016).

According to Dahlan (2015: 116), reports of the influences on indoor environment have been identified through occupants' perceptions of the environment. Shadwell (1995: 1) highlighted that poor IAQ causes occupants to feel tense and anxious when they cannot control their environment, such as indoor temperature, ventilation and space. This may impact humans psychologically and therefore negatively change their perceptions of the environment. Providing individual control and thermal comfort when there is four full height walls with a closed door for each office person; creates indoor environments specifically adapted to each person (Oodith 2012: 532 and Wyon and Wargocki 2006: 181-182). Undoubtedly, providing each employee with a singular office would prove to be a costly method. Consequently, open planned offices are more feasible for companies as it accommodates more employees on the same floor space at a lower cost (Oodith 2012: 532 and Wyon and Wargocki 2006: 181-182).

Designers of intelligent buildings have made efforts to ensure flexibility, reduced space and maintenance costs rendering open planned offices more desirable than singular enclosed offices. Furthermore, open plan offices increase communications, teamwork and creativity between employees (Rasheed, Khoshbakht and Baird 2019: 2; Samani, Rasid and Sofian 2015: 28-29 and Hwang and Kim 2013: 139).

Differing from the advantages of open plan office, Wang (2019: D6) postulated that personalised ventilation over general ventilation may decrease SBS, improve perceived IAQ and thermal comfort as well as work productivity. Open plan designed offices may create negative effects on employees' comfort and satisfaction due to a lack of personal space, heightened environmental noise and essentially a lack of control over physical environmental factors, such as temperature and airflow. Consequently, a lack of privacy and physical control is said to decrease concentration, and performance efficiency and increase stress levels, which may introduce a host of additional health effects (Forooraghi, Wallbaum, and Ryd 2019: 2; Samani, Rasid and Sofian 2015: 28-29 and Lee and Brand 2005: 324). Conclusively, it can be deduced that from an employer's point of view financially, open planned office spaces were advantageous. In contradiction, employees may find this uncomfortable and are also susceptible to other airborne viruses, especially if overcrowding was observed.

### 2.2.4. Overcrowded office spaces

While there is much research pertaining to prison overcrowding within South Africa, what constitutes office overcrowding has not been defined. Similarly, international studies have not define overcrowding clearly. One study used school classrooms as an example to define overcrowding when the number of occupants in the building is more than the number of occupants the building was designed to accommodate (Ready, lee and Welner 2004: 1993).

Carrer and Wolkoff (2018: 4) highlighted that the type of environment, for example, overcrowded offices plays a major role in reported incidents of illness and absenteeism. Occupants report more cases of discomfort compared to those in less crowed areas. Factors such as noise, distance from windows and availability of privacy also play a role in reporting cases of discomfort and increased symptoms of IAQ. Overcrowding is known to be directly and indirectly is linked to more sickness related complaints; albeit, very few studies have incorporated office space and the number of occupants into their questionnaires administered to employees. The most prevalent complaint among occupants in open plan offices was noise annoyance from people talking, laughing and ringing phones (Pierrette *et al*. 2015: 5 and Pejtersen *et al.* 2011: 377-380). Furthermore, these occupants perceived that they have less privacy to conduct personal calls and less job satisfaction (Pejtersen *et al.* 2011: 377-380). Nevertheless, Marmot *et al.* (2006: 283) and Pierrette *et al*. (2015: 5) demonstrated that people whom were able to adjust their physical environment (lighting, noise and temperature) suffered with less SBS than those who were unable to influence their environment.

Mechanically ventilated systems were designed to supply occupants within the building with a percentage of fresh air to dilute the amount of indoor pollutants in an aid to elevate employee dissatisfaction and simultaneously maintain building costs (Wang 2019: ii). Overcrowding within the office space has been proved to directly increase the amount of $CO_2$ and bacteria; thus, leading to a decrease in the amount of adequate fresh air per person, consequently causing a decrease in work performance and wellbeing (Maddalena 2015: 361). In addition, indoor overcrowding facilitates provided easy transmission of bacteria and even some viruses, such as the influenza virus through close transmission of particle droplets from sneezing and coughing (Peci *et al.* 2019: 2). Occupants in open plan offices are more prone to contracting the common cold and flu over occupants located in cellular offices. Pejtersen *et al.* (2011: 377-380) strongly suggested that these complaints are generally higher in mechanically ventilated areas. Although the researcher has not explained this phenomenon, it may be suggested this was due to air and the viruses being circulated mechanically around the room.

The current Covid-19 pandemic created a global public health concern. Covid-19, due to SARS-CoV-2 is transmitted through person-to-person contact and droplets spread through coughing or sneezing, similar to that of the common flu (Rothan and Byrareddy 2020: 1). Standard global controls have been implemented to curve the exponential infection rate. Social distancing has been the key element in reducing the transmission of the virus (Fauci, Lane and Redfield 2020: 1269). Overcrowded office spaces or open planned settings do not accommodate for social distancing and this presents a greater risk to employees in office buildings.

The severity with which physical environmental factors affected and created adverse health effects or strain on an individual highly depended on their ability to cope with these stressors. Indoor environmental complaints often arise from the physical environment which affected the body. The personal strain experienced from the environment is said to alter a person's sensitivity to environmental irritants and possibly affect their health and possibly causing SBS symptoms (Hedge 1996: 73). Yildiz (2020: 210) highlighted that psychological parameters are important and a significant element in SBS symptoms; nonetheless, methods to evaluate psychological parameters are very limited.

## 2.3. ENVIRONMENTAL PARAMETERS OF SICK BUILDING SYNDROME

In current times, most working people spend approximately 90% of their time indoors (Sun *et al.* 2019: 112). In most cases the pollutant load is 100 times higher indoors than it is outdoors because of human bioeffluents, furniture and material off gassing, such as formaldehyde (Brown 2019: 2 and Pitarma, Marques and Ferreira 2017: 1). Ram (2019: 231) highlighted that poor indoor air quality is the second highest killer in the world, with cancer being the first. This was primarily due to poor outdoor air quality which directly had an impact on IAQ. Increasing ventilation rate alone will not improve IAQ but gas and particulate filtration is required. Human beings consume 12000 L of air a day. It should be imperative that a healthy IAQ is maintained. Several studies have investigated the environmental parameters around SBS and its related human health effects and psychological stress (Keyvani *et al.* 2017:19; Vafaeenasab *et al*. 2015: 247; Gomzi *et al*. 2007:147 and Spurgeon 2002: 601). This component of the study includes physical environmental parameters of quantitation, which is primarily used in the field of environmental and occupational health to determine the cause of illness. (Spurgeon 2002: 602).

### 2.3.1. Indoor Air Quality: Building ventilation

IAQ consists of many factors, namely; temperature control, relative humidity (RH), odours, air movement, ventilation, and volatile organic compounds (VOC) and biological contamination (Lu *et al.* 2018:1-2; Mohan 2012:107 and Rios *et al*. 2005: 3727). The source of indoor air pollutions differs with exposure and effect. An exposure may be classified by the way it is produced, by the type of group it is (example, VOC's, gas, dust or fibers), the location, rate and pattern of the emission or pollutant in the air (Rios *et al*. 2005: 3728). Over the years, research on the impact of exposures to indoor pollutants has diminished, whilst research on the impact of outdoor pollutants on health effects has significantly increased. This did not benefit indoor environments as the number of exposure to contaminates indoors is 100 times more than outdoors and the concentration of contaminants indoors is usually 2/4 times more than outdoors (Vesitara and Surahman 2019: 2; Jafari 2015: 56 and Ahmadi, Golbabaei and Behzadi 2014: 211).

A recent study highlighted that an estimation of 30-40% of the world's energy contributed to the operation and construction of commercial buildings, more especially ventilation systems (Gladyszewska-Fiedoruk 2019: 1). Due to the recent global energy crises, urbanisation and limited land space engineers and architects have begun to develop high rise buildings that are more energy efficient by 'tightening' up buildings to reduce heating and cooling costs. Effective and efficient ventilation is vital for the dilution of pollutants within the building (Burge 2004: 187). As a result, many buildings have installed HVAC or central air conditioning systems which were associated with a host of other direct and indirect health effects through the generation of pollutants within the building ventilation system and ducting (Ahmadi, Golbabaei and Behzadi 2014: 21; Burge 2004: 187 and Truter 1993: 10). In light of the increase in sealed or 'airtight' high rise building structures being erected and a high occupancy of people spending 80-90 % of their time indoors; healthy environments are pertinent in ensuring occupant health and wellbeing (Lu *et al*. 2018:1). Over time these structural changes to a building have influenced building conditions with inadequate ventilation therefore possibly creating an environment for SBS to develop (Vafaeenasab *et al*. 2015: 247 and Rostron 2008: 294).

Persily and Gorfain (2004: 1) stated that building ventilations was the primary determinate of IAQ, as it directly affected human health and comfort levels; therefore, many studies have investigated the linkage between indoor ventilation and the proportion of the occupants reporting SBS symptoms (Sierpinska 2019: 51; Zainal *et al*. 2019: 126 and Al Horr *et al.* 2016: 376). The fundamental aim of ventilation is to exchange indoor air with outdoor fresh air for the purpose of reducing indoor contaminants (Meintjes 2013: 5). Indoor ventilation has a major influence on indoor pollutants and consequently on human health (Sun *et al.* 2019: 116). Therefore, Murniati (2020: 278) recommended that increasing the flow of indoor air may reduce the risk of SBS.

SBS incidents have been known to originate from poor design, irregular maintenance and repair or insufficient cleaning processes, inadequate air supply per person and overcrowded working offices (Turpin 2014: 19; Oodith 2012: 532 and Bonette *et al.* 2010: 473). In some cases, employees had access to diffusers from the ventilation system whereby physical alterations are made to satisfy the individual temperature control, resulting in irregular distribution of air (Turpin 2014: 19 and Bonette *et al.* 2010: 473. Compromising indoor ventilation rates have demonstrated negatively on productivity and increased the symptoms of SBS (Zainal *et al*. 2019: 126 and Al Horr *et al.* 2016: 376). These problems have resulted in IAQ problems which in turn had contributed to the advent of sustainably or ‘green’ designed buildings (Al Horr *et al*. 2016: 369).

Air-tight energy efficient buildings are commonly referred to as intelligent buildings which are controlled by mechanically ventilated systems. These building systems consume large amounts of energy to ensure that the indoor environment is stabilised in terms of comfort, ventilation and efficiency (Hwang and Kim 2013: 139). The increase in modern technologies has placed an increased dependency on mechanical systems in the built environments which had over time, become a norm, specifically in developed countries. Air-conditioning systems have become a standard requirement in most parts of the world, especially in environments with tropical climates of warm weathers (Andamon, Williamson and Soebarto 2006: 1). Brown (2019: 2) and Mohan (2012: 108) claimed that acceptable IAQ is classified by the absence of known contaminations at harmful concentrations and when 80% of the occupants consider environment to be satisfactory.

A growing body of research demonstrated a link between mechanical ventilation with poor maintenance and IAQ problems; consequently leading to inadequate ventilation and accumulation of $CO_2$ and other contaminants (Zainal *et al*. 2019: 127). According to the ASHRAE committee (Cited in Turpin 2014: 18) and Gladyszewska-Fiedoruk (2019: 1) a large number of SBS cases, regarding poor IAQ is said to originate from mechanical ventilation systems. There may be several reasons for poor IAQ through ventilation systems within a building facility, such as; inadequate outdoor air supplied indoors, the ventilation system may start too late in the morning and shut down too late in the afternoon, as well as poor air distribution throughout different sections. The maintenance of the ventilation system may not be adequate. This may lead to the accumulation of dirt in air intakes, filters and ducting (Brown 2019: 2).

According to comparison study conducted by Gomzi *et al*. (2007: 153) and Orosa and Oliveira (2011: 482), symptoms of SBS were clearly intensified in air-conditioned rooms in comparison to naturally ventilated rooms. Naturally ventilated buildings allowed for more fresh air into the building and therefore a greater dilution factor of contaminations.

Gladyszewska-Fiedoruk (2019: 1) suggested that the lack of flowing fresh air was the reason for SBS to appear. Moreover, with natural ventilation occupants have a choice to open and close windows or doors therefore regulating individual temperature and ventilation according to their discretion. Conversely, mechanical systems are subject to design faults, poor installation and component failures resulting in devastating effect on the systems performance (Rostron 2008: 294).

#### 2.3.1.1. Human health and building ventilation

Mechanical ventilations, such as a HVAC systems or air-conditioning systems would naturally stimulate the nervous system, skin, and respiratory system, and may cause symptoms of SBS including headaches, dizziness, nausea, coughing, sneezing, irritated mucous membrane (Keyvani *et al*. 2017:19 and Vafaeenasab *et al*. 2015: 247). Sierpinska (2019: 50) synthesized similar symptoms of dry mucosal membranes and eyes. Furthermore, Zainal *et al.* (2019: 127) and Redman *et al.* (2011: 15) argued that air-conditioning systems have generated the most common problem causing symptoms of SBS. Consequently, it may be expected that with an increase in ventilation there would be an increase in perceived IQA, comfort and performance (Sierpinska 2019: 50). Conversely, some literature was less consistent as results highlighted higher ventilation reported inconveniences such as dry or stuffy air, eyes irritation or headaches (Sierpinska 2019: 51). A more recent and extensive study highlighted that findings in an offices with no regular inspection and maintenance plan on the HVAC systems was strongly correlated to health effects, specifically eye irritation, cough and upper respiratory symptoms. When the drip tray pans and cooling coils of the HVAC system were cleaned less frequently, occupants complained of frequent headaches (Zainal *et al.* 2019: 131). Conclusively, only a handful of studies have demonstrated the possible health effects related to ventilation and more uncommonly, with ventilation rates; however, many studies have suggested overall symptoms of SBS as stated in the definitions (Sun *et al*. 2019: 112).

Strong irritants in the air during the summer months, rather than other months, are known to cause severe skin and upper respiratory irritation (Azuma *et al.* 2017: 2). These health effects were from short term cross-sectional studies. The lack of longitudinal studies within the office environment could have been because of the complexity and required resources for clinical testing (Carrer and Wolkoff 2018: 8); Concomitantly, long term effects of continuous exposure to indoor pollution due to inadequate ventilation over a long period of time has not been researched enough. Nevertheless, Carrer and Wolkoff (2018: 7-8) argued that long term effects may be attributed to "asthma exacerbation, allergic response, oxidative stress and inflammation, chronic obstructive and pulmonary disease, lung cancer and cardiovascular disease".

In addition, it was observed in a large cross-sectional study amongst thirteen different office buildings, that older employees report more frequently with more types of symptoms than younger employees (Skyberg *et al*. 2003: 250). Again, the phenomenon for this is still unexplained. Van Marken Lichtenbelt *et al.* (2017: 823) assumed that elderly people were at risk for other or enhanced ailments and conditions which could skew the data. Bentayeb *et al*. (2015: 1229) further agreed that ageing has led to the deterioration of the immune system and lung function, placing the elderly in the predisposition for respiratory infections. Comorbidity plays a role as a contributing factor to the signs and symptoms of SBS. Individuals who had more than one health issue may have an intensified impact of SBS symptoms and health related quality of life (Valderas *et al*. 2009:357). For these reasons a better understanding of indoor environments and health effects are needed to ensure a healthy living.

#### 2.3.1.2. The impact of IAQ on cognitive function

Controlling indoor contaminants at the source was a fundamental aspect in maintaining good indoor air quality as, Ram (2019: 231), recognized the negative impact indoor pollutants had on human health and occupant wellbeing. It was suggested that better indoor air quality promoted work efficiency, enhanced learning results, created a sense of wellbeing and increased productivity. Researchers have argued the lack in severity of SBS symptoms stemming from the temporal nature of the condition; however, SBS is said to have broader implications. Reduced productivity was one of the significant implications, aside from a host of temporal symptoms (Rostron 2008: 293). Comfort levels and rate of productivity rely heavily on the individuals control over the physical environment, such as personal working space and temperature control. The ability to change the physical environment to suit the individual's needs was important (Samani, Rasid and Sofian 2015: 28).

A recent body of literature demonstrated, through an experimental study, that when an old carpet was present in an office, 70% of the occupants were dissatisfied with the IAQ. This was concluded through the use of different cognitive and typing tests. Moreover, 25% of the occupants were dissatisfied when the carpet was removed. The presence of the used carpet caused occupants to type 6.5% slower with 18% more typing errors. These occupants also suffered with more headaches. This experimental study was performed on a different group of occupants and the results were synonymous with the first study (Wargocki and Wyon 2017: 364). Furthermore, a study conducted by Rashid and Zimring (2008: 12) and Wargocki (1999: 176) indicated that when there was poor ventilation, employees exerted less work effort and typed 6,5 % fewer words with more errors on the computer. It was difficult to measure productivity but several studies have proved that an increase in ventilation up to 30 liters/sec/person produced a direct increase in thinking, typing faster and increased work performance, including an increase in perceived IAQ and a decrease in sick leave amongst employees (Maula 2017: 1141; Bennett 2012: 309; Seppänen and Fisk 2006: 4-5; Burge 2004:188 and Heerwagen 2000:8). These studies importantly highlighted the impact that indoor environments and air quality have on cognitive function, comfort and consequently productivity and efficiency.

Poor ventilation proved to have affected health and comfort, consequently productivity and directly increased short-term sick leave due to airborne contracted infections (Seppänen and Fisk 2006: 6). Seppänen and Fisk (2006: 5) argued how sick leave, absenteeism and illness was directly linked to ventilation rate per person in an office building; nevertheless, the susceptibility to contracting an infection from the air will vary with the age, health status and immunity of the occupant. Intervention studies have exhibited an assumed relation between SBS symptoms and decreased ventilation. It us also worth noting that ventilation rate does not affect performance directly but indirectly through an accumulation of indoor air pollution and in turn may be responsible for a reduction in work performance (Seppänen and Fisk 2006: 15).

### 2.3.2. Carbon dioxide

In an effort to assist in the reduction of building energy consumption costs, indoor ventilation systems have been compromised, thus leading to inadequate indoor ventilation and high indoor $CO_2$ concentrations (Satish *et al.* 2012: 1671). Carbon dioxide is a colorless, odourless gas that is produced by metabolic processes and emitted through human exhalation from the lungs (Meintjies 2013: 25). Since humans produce $CO_2$ through metabolic processes, $CO_2$ levels will always be higher indoors compared to outdoor environments (Amouei *et al.* 2019: 2 and Satish *et al.* 2012: 1671). As the rate of indoor ventilation per person decreases, the concentration of $CO_2$ increases (Satish *et al.* 2012: 1671). Indoor $CO_2$ concentrations have historically known to be benign; in contrast, demonstrations over recent studies have differed from this statement (Mooney 2015: 2). Ram (2019: 231) argued that $CO_2$ is neither a direct nor indirect health hazard in normal concentrations of 500-1200 ppm; whereas, another study suggested that human bioeffluents were the contributing factor to poor IAQ and high $CO_2$ concentrations (Persily and de Jonge 2017: 868).

Overcrowding within the office space will directly increase the amount of $CO_2$ produced by the human respiratory system (Norbäck and Nordström 2008: 29). Carbon dioxide was therefore used as an indicator of inadequate ventilation, poor odour control and overcrowding indoors (Ram 2019: 231; Jafari *et al.* 2018: 83; Gall *et al*. 2016: 59; Szczurek *et al.* 2015: 2193; Meintjies 2013: 25 and Brits 2011: 39). Notwithstanding, it is evident that high $CO_2$ levels are not a good indicator of adequate ventilation if measurements are conducted whilst the area is not occupied to its usual capacity (Brits 2011: 46). Synonymously, Meintjies (2013: 25) agrees that $CO_2$ was a good indicator of human and appliance pollution but $CO_2$ is a bad indictor of perceived IQA. Orosa and Oliveira (2011: 483) argued that while $CO_2$ levels may be within the ASHRAE standard limits, occupants may still report SBS symptoms. To date, no other study to date, has demonstrated similar results.

Gall *et al*. (2016: 59) critiqued that elevated levels of $CO_2$ was not a cause for direct concern, but rather an indication of insufficient dilution of indoor pollutants with outdoor air. $CO_2$ levels were closely related to "ventilation intake rate, ventilation isolation reliability, leak tightness of the building, duration of the $CO_2$ releases, protective equipment, and clean purge air supplies, as applicable" (Kapalo *et al.* 2018: 62). Tsai, Lin and Chan (2012: 345) argued that $CO_2$ may act as an indicator of poor indoor ventilation and occupant generated pollution levels; however, accurate associations between $CO_2$ and SBS are not reliable if possible confounding factors are present that are not always controlled or considered. The researchers therefore suggested inconstant associations between indoor $CO_2$ levels and SBS.

There has been a significant paucity of research within the South African context on $CO_2$ and its relationship to SBS. South African studies investigated $CO_2$ levels in conjunction with other parameters such as temperature and SBS (Meintjes 2013: 3; Brits 2011: 79 and Shadwell 1995: 1). Alternatively, international researchers have executed various studies on $CO_2$ and its relationship to SBS or health effects and wellbeing in indoor office environments, as well as schools or universities (Jafari *et al*. 2018: 85; Lu *et al*. 2015: 3834 and Gall *et al*. 2016: 59; Gall and Nazaroff 2015: 6). More recent studies have provided evidence indicating that elevated $CO_2$ levels are consistent with higher rates of absenteeism and sick leave. These results, however, are largely attributed to inadequate ventilation rates elevating contaminants in the work place (Persily and de Jonge 2017: 868;  Zhang *et al.* 2017: 51 and  Gall *et al*. 2016: 59).

**2.3.2.1. Health effects of carbon dioxide**

Previous studies have not recognised $CO_2$ as a causative or hazardous agent (Mooney 2015: 2). Gall *et al*. (2016: 59) suggested that in many studies, at high concentrations, $CO_2$ has been reported to adversely affect human health, human cognition and decision-making performance. Exceeding levels of $CO_2$ are a type of indoor air pollution that has been related to respiratory problems, reduced comfort and even death (Amouei *et al.* 2019: 2). While the specific role of $CO_2$ as an indoor pollutant contributing to SBS needs further investigation, several studies have demonstrated the clear correlation between increased $CO_2$ levels with an increase in symptoms of SBS, as a result of poor ventilation systems or over population in an office environment (Sierpinska 2019: 46; Jafari *et al*. 2018: 85; Lu *et al*. 2015: 3834 and Gall and Nazaroff 2015: 6). Lu *et al.* (2015: 3842) highlighted the significant association of human health and increased $CO_2$ through biological mechanisms where increased levels of $CO_2$ in the blood may increase with high $CO_2$ in the air. As a consequence, a decrease in oxygen saturation of the haemoglobin results in oxygen deprivation causing the body to feel tired and dizzy. This explains the phenomenon demonstrated in a study where increased $CO_2$ made occupants put more effort into breathing, their heart rates increased and the level of cells oxygenation was reduced, consequently leading to poor concentration and fatigue in the workplace (Kapalo *et al*. 2018: 62).

A study was conducted in three office rooms with a group of approximately 20 men and women. The main aim of this study was to determine the relationship between men and women of different ages and mass (kg). Human pulse rate and blood pressure was monitored and questionnaires were administered to all participants. Carbon dioxide, air temperature and humidity levels were also monitored. The results were significant as it demonstrated how an increase of $CO_2$ in the air (poor air quality) reported lower pulse rate for people of a heavier weight. As a result, the people who weighed less were more biologically responsive to higher $CO_2$ levels than those who weighed more (Kapalo *et al*. 2018: 62). Furthermore, it was observed that the people in rooms that received a constant steam of limited fresh air experienced an increased heart beat by approximately 20% in comparison with those in a room with constant outdoor fresh air. Consequently, individuals in an unventilated room had to exert more effort into performing their work tasks leaving them feeling more fatigued (Kapalo *et al*. 2018: 62-65). With this being said, the reliability of the study would be questionable as the study population was only of 20 people and in one building site.

Previously, the gas $CO_2$ in the air had not been considered to cause serious health effects, although at certain levels of $CO_2$ indoors often lead to fatigue, lack of fresh air, headaches, tiredness, tired or dry eyes, upper respiratory irritation and lethargy, discomfort and dissatisfaction, often as a result of poor ventilation systems (Azuma *et al.* 2018: 52; Zhang *et al.* 2017: 47; Szczurek *et al*. 2015: 2193 and Tsai, Lin and Chan 2012: 350). Automated ventilation systems often use $CO_2$ levels as a measuring tool to regulate the fresh air intake into buildings (Jafari *et al.* 2018: 83). Excess $CO_2$ from the air can result in occupants becoming sick, having headaches, increased sweating and respiratory issues. A high $CO_2$ level has been known to increase the prevalence of SBS, impaired work performance and poorer perceived air quality (Jafari *et al.* 2018: 83 and Satish *et al.* 2012: 1671).

A similar study conducted in households for $CO_2$ levels revealed alarming results where high numbers of children and infants were being admitted into the hospital for severe lower respiratory infection problems. After much investigation, it was highlighted that the homes of the patients were poorly ventilated and extremely over crowded thus aiding the easy transmission of airborne infections and reducing oxygen per person. Furthermore, the detection of indoor airborne Rhinovirus was associated with reduced ventilation (Kovesi *et al.* 2007: 158).

As humans we produce and exhale large amounts of $CO_2$, making indoor concentrations higher than outdoors (Sierpinska 2019: 46). A study conducted by Seppänen, Fisk and Mendell (1999: 226) which included approximately 30 000 participants in nearly 400 office buildings highlighted significant association: when the $CO_2$ concentration decreased below 800 ppm, there was a direct decrease in symptoms of SBS. Synonymously, some studies argued that an increase above 800 ppm increased complaints of eye irritation and respiratory problems (Lu *et al*. 2015: 3834 and Tsai, Lin and Chan 2012: 345). Conversely, a study by Lu *et al.* (2015: 3841) in eight high rise office buildings demonstrated symptoms of tiredness and dizziness with high $CO_2$ levels and no significant relationship between eye irritation and respiratory issues.

Table 1: The carbon dioxide levels and potential health problems:

| **Concentration (ppm)** | **Potential health problems** |
|---|---|
| 250-350 ppm | Background (normal) outdoor air (Bonino 2016: 46-48) |
| 800 ppm | Eye irritation or upper respiratory symptoms (Tsai, Lin and Chan 2012: 345). |
| 350-1 000 ppm | Typical level found in occupied spaces with good air exchange (Bonino 2016: 46-48). |
| 1 000- 2 000 ppm | Level associated with complaints of drowsiness, respiratory symptoms and poor air (Bonino 2016: 46-48 and Azuma *et al*. 2018: 51) |
| 2 000- 5 000 ppm | Level associated with headaches, sleepiness, and stagnant, stale, stuffy air; poor concentration, loss of attention, increased heart rate and slight nausea may also be present (Bonino 2016: 46-48). |
| >5 000 ppm | This indicates unusual air conditions where high levels of other gasses also could be present. Toxicity or oxygen deprivation could occur. This is the permissible exposure limit for daily workplace exposure (Bonino 2016: 46-48). |
| >10 000 ppm for >30 min | Respiratory acidosis, headache, confusion, anxiety, drowsiness and stupor (Sierpinska 2019: 47). |
| >20 000 ppm | Deepened breathing (Satish *et al.* 2012: 1671). |
| >30 000 ppm | Headaches, dizziness, nausea (Meintjies 2013: 26) |
| >40 000 ppm | This level is immediately harmful due to oxygen deprivation (Bonino 2016: 46-48). |
| 60 000 - 80 000 ppm | Possible death (Meintjies 2013: 26) |

| | |
|---|---|
| 100 000 ppm | Visual disturbances, tremors and loss of consciousness (Satish *et al.* 2012: 1671). |
| 250 000 ppm | Which is a 25% concentration of $CO_2$ can cause death (Satish *et al.* 2012: 1671). |

#### 2.3.2.2. Effect of carbon dioxide on cognitive function

A number of authors have recognised elevated levels of $CO_2$ intake and its linkage to reduced cognitive function, thinking and performance having a detrimental effect on productivity (Snow *et al.* 2019: 243; Kapalo *et al.* 2018: 62; Gall and Nazaroff 2015: 2 and Maddalena *et al*. 2015: 361). In a longitudinal experimental study, Azuma *et al*. (2018: 51) and Allen *et al*. (2016: 810-811) demonstrated that when there was an increase in $CO_2$ levels of approximately normal indoor space concentrations of 1000 ppm there was a significant decline in cognitive function scores; however, the 950 ppm level satisfies the limits stated in the ASHRAE ventilation rate guidance for acceptable indoor air quality. Furthermore, Azuma (*et al.* 2018: 51) argued that 700 ppm was known to initiate the beginning of symptoms of SBS. Interestingly, Gall and Nazaroff (2015: 2) critique that on average, with an increase of $CO_2$ level of 400 ppm there would possibly be a 21% decline in cognitive function. It should then be noted that different studies have demonstrated elevated $CO_2$ levels at different concentrations with a negative effect on cognitive function and performance.

In a Washington report, an environmental health practitioner, together with other scientists conducted a study in two offices; a 'green' office and a conventional building. The researchers manipulated the environmental indoor conditions of $CO_2$ levels. Over six days, the $CO_2$ level were either increased or decreased between 550 ppm, 945 ppm and 1400 ppm. A 1.5 hour cognitive function test called the Strategic Management Simulation test was performed every day at 15h00. Results revealed that cognitive function was significantly lower by 50% on the day $CO_2$ levels were 1400 ppm, and 15% lower on days $CO_2$ levels were approximately 950 ppm. Furthermore, cognitive function was significantly higher in greener buildings than the conventional building (Mooney 2015: 1-4). This was synonymous with another study, that conducted the same technique on participants at concentrations of 600 ppm, 1000 ppm and 2500 ppm revealed a significant reduction in decision making and performance at higher levels of $CO_2$ (Satish *et al.* 2012: 1677).

Removing high metabolic $CO_2$ from the indoor environment could be done by implementing various engineering controls or improving the system design. Removing $CO_2$ from the air has been proven to be more cost effective in comparison to the cost spent on loss of productivity due poor air quality of high $CO_2$ levels (Gall and Nazaroff 2015: 6). It could be agreed that indoor concentrations of $CO_2$ are highly influenced by outdoor air concentrations of $CO_2$ and consequently affect cognitive function. Outdoor air of $CO_2$ generally at 350 ppm was the baseline for indoor $CO_2$ levels; however outdoor levels in urban areas have been known to be above 500 ppm. Due to global warming, outdoor $CO_2$ levels have increased dramatically; this in turn has increased $CO_2$ levels indoors making it harder to ensure indoor levels are within guidelines and other regulations stipulated by public health research. The outdoor atmospheric $CO_2$ levels urgently need to be suppressed (Azuma *et al*. 2018: 52 and Mooney 2015:3).

### 2.3.3. Indoor temperature

Thermal conditions constantly change according to outdoor and indoor temperatures. Mavrogianni *et al.* (2013: 360,361) recognised that over recent decades, since 1960's, there had been a significant increase in thermal comfort expectations and an increase in the use of air-conditioning systems. This may be due to a shift in cultural norms, climate change towards thermal comfort and high fuel costs (Redman *et al.* 2011: 14). High fuel costs had forced industries to cut costs on air-conditioning and heating systems which in turn have forced occupants to adapt to warmer indoor climates over time (Mavrogianni *et al.* 2013: 366).

Thermal comfort or thermal environmental quality is the second most important factors to influence indoor environmental quality, with IAQ being the first (Huizenga *et al.* 2006: 393). Thermal environmental quality has a significant effect on the overall human satisfaction and comfort of the environment; nevertheless, it has been argued that thermal conditions in commercial buildings nationally and internationally have not been adequately managed and controlled (Mora and Bean 2018: 40). Mora and Bean (2018: 40) further highlighted that building operators and facility managers are often unaware of the unsatisfactory thermal conditions. Post-occupancy evaluations are still uncommon and therefore often no feedback is giving to building designers to improve their designs to ensure that thermal comfort is maintained. As a consequence, this may indirectly lead to occupant satisfactory, well-being and work performance being compromised (Mora and Bean 2018: 40). Comparatively, while Maula *et al.* (2016: 286) demonstrated through an experimental office study that warmer temperatures affected concentration abilities but had no effect on human health, a more recent study provided evidence of participants blood pressure being affected more with indoor temperatures as compared to outdoor temperatures (Wang *et al.* 2017: 284).

Higher income people are spending more time indoors due to the continuous economic development and lifestyle improvements; which places an additional strain on the demand for comfortable indoor environments (Guo *et al*. 2016: 1854). A report from the ASHRAE journal defined thermal comfort as the "condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation" (Mora and Bean 2018: 41 and Maula *et al.* 2016: 286). The assessment of thermal comfort includes three fundamental factors; physical, physiological and psychological; which were determined through questionnaires administered to occupants, objective measurements and empirically derived thermal comfort models (Mora and Bean 2018: 41). This definition is closely tied to the definition of SBS stated above.

Mavrogianni *et al.* (2013: 361) critiqued that many studies have quantified the relationship between temperature and thermal comfort over a shortterm period; however, this was problematic as it generalized the theme of thermal comfort expectations, as every person perceives thermal comfort differently. A more systematic and theoretical analysis may be required to conceive a representative relationship and possible illnesses of thermal conditions over a longer period of time.

Thermal comfort is influenced by factors such as RH, air temperature and air velocity although there are other unquantifiable factors that influence thermal temperature such as thermal comfort feelings such as acclimatisation ability, habits and behaviours (Yamtraipat, Khedari and Hirunlabh 2005: 512). Synonymously, Meintjies (2013: 16-17) describes thermal comfort as an emotional and or physical state that makes an individual feel comfortable. According to the ASHRAE Handbook - Fundamentals (2017 cited in Mora and Bean 2018: 41), "the conscious mind appears to reach conclusions about thermal comfort and discomfort from direct temperature and moisture sensation from the skin, deep body temperatures, and the efforts necessary to regulate body temperatures. In general, comfort occurs when body temperatures are held within narrow ranges, skin moisture is low, and the physiological effort of thermoregulation is minimized". It was noted, by members of the ASHRAE committee that occupants only complained when the thermal environment became intolerable; mostly since occupants relied on portable heaters or extra clothing when it was colder or open windows and make use of portable fans when it was warmer (2017 cited in Mora and Bean 2018: 41).

Personal control over the physical environment, specifically thermal comfort was important for efficient productivity, comfort and employee wellness. Personal control over the environment refers to the ability of employees to adjust and acclimatize to the working environment therefore; making it personalised to suit their individual needs (Wargocki and Wyon 2017: 360; Samani, Rasid and Sofian 2015: 29; Wyon and Wargocki 2006: 181 and Lee and Brand 2005: 324). Boerstra *et al.* (2015: 315) and Lee and Brand (2005: 324) argued that personal control over thermal comfort regulates the relationship between the environmental conditions and employee perceptions and reactions to the environment. Therefore, the more control the occupant has over their environment, such as temperature control, the better they perceived the environment to be. The degree of change in thermal comfort for personal need was previously associated with employee satisfaction (Lee and Brand 2005: 324). Furthermore, Boerstra *et al.* (2015: 316) illuminated that it was not just temperature in its self that had impacted occupants' comfort and satisfaction, but also the ability to have control over adjustable thermostats and other controls, such as openable windows. A lack of provision in controls has resulted in dissatisfied, uncomfortable occupants, reduced productivity and increased sick leave days. Notwithstanding, a lack of control over indoor temperatures have proved to increase symptoms of SBS (Boerstra *et al.* 2015: 315-316).

Indoor temperature is one of the most important indicators of poor IAQ, as it plays a significant role in building occupants' perception of ambient temperature and comfort. Thermal discomfort can distract employees from their work, exacerbate building-related symptoms and cause more building complaints (Wargocki and Wyon 2017: 361; Wyon and Wargocki 2006: 181-182). Thermal comfort is dependent in different humans. Apart from a healthy lifestyle, it was highlighted that thermal environments have a significant impact on human health, more especially on metabolic rate (van Marken Lichtenbelt *et al*. 2017: 823). Individuals have different metabolic rates where some individuals are overweight and some underweight. Some individuals may be active at work while some perform sedentary work, but everyone may be subjected to one air-conditioning/ HVAC system at one specific temperature (Jansz 2011: 48). Therefore, it can be said that the perception an individual may have is highly dependent on their individual characteristics, such as health and age; however, human acclimatization to thermal temperatures will result in increased comfort ratings (van Marken Lichtenbelt *et al*. 2017: 819 and Mavrogianni *et al.* 2013: 370).

#### 2.3.3.1. Thermal discomfort and health effects

It is fundamentally important for humans to work efficiently in environments which they consider comfortable. All buildings are designed to consider this factor (Ahmadi, Golbabaei and Behzadi 2014: 210). Different environments have different indoor temperatures. Wyon and Wargocki (2006: 181) and Wargocki and Wyon (2017: 362) argue that warmer temperatures exacerbate SBS symptoms but lowers arousal to thermal discomfort; whereas, high temperatures cause vasoconstriction which increases $CO_2$ in the blood gas level; consequently, causing headaches and difficulty thinking. Low thermal conditions may lower finger temperature which reduces finger and hand movement (Wargocki and Wyon 2017: 362) this may negatively impact occupants who conduct sedentary work, consequently leading to low productivity and efficiency.

The human body regulates its own temperature around 37 °C through homeostasis, as we are homeotherms. The normal body temperature varies daily only around 1 °C. Against this background, a range of thermal conditions from the environment is required to ensure thermal comfort and maintain normal bodily temperature without exerting the body beyond the normal metabolic rate and needing more energy. Without those environmental conditions, the human body triggers a psychological response which directly offsets the thermal balance in the body (Mora and Bean 2018: 41). Furthermore, recent research demonstrated that colder indoor environments directly affect the sensory nerves of the mucous membrane and skin, resulting in a negative response to neurosensory functions and therefore leading to a change in blood circulation (Murniati 2020: 279).

Thermal discomfort is said to have a knock-on effect. Thermal discomfort increases the occupant's comfort and health complaints which generate unplanned maintenance costs and changes. Moreover, to overcome the increment in energy costs, simultaneously with the increase in temperature through global warming, commercial buildings have become increasingly energy efficient by reducing building system costs. Mavrogianni *et al.* (2013: 369) argued that once people are accustomed to high thermal temperatures, it becomes difficult to compromise thermal comfort. As a result, the human body acclimatizes to high temperatures, usually as a result of global increase in temperatures; with that being said, the human adaptability to thermal temperatures was bound to become less flexible over the future. One study, conducted in an office demonstrated that if office employees kept the indoor temperatures between 21-24 °C, there would be a reduction in complaints and maintenance costs by 20%. These reductions include an increase in productivity and increase thermal comfort. Employees mentioned, in the survey, that when they felt thermally uncomfortable, they were demotivated to work and took more breaks during working hours. Furthermore, it was mentioned that when employees do not feel well, they do not work very well (Wyon and Wargocki 2006: 181). Conversely to this study, Stoecklein and Phipps (2007: 3) argue a different view that overall, SBS symptoms increased between temperatures of 21-24 °C. Conclusively, it can be said that temperature range and its relation to health effects are inconclusive.

In environments with a hot summer, the air-conditioning is usually maintained at 25°C to ensure the human body maintains a neutral bodily temperature and therefore not cause any pathological harm. In addition, the use of air-conditioning systems often leads to a significant difference between indoor and outdoor temperatures. The indoors to outdoor movement of change in temperature triggered a sudden intense thermal stimulation in people (Cao *et al*. 2013: 491). Thermal adaptation is a psychological adaptation method naturally developed in our body since birth. Psychologically, the metabolism is at optimal stable rate when the temperature is between 20-30 °C. Anything over 30 °C will increase the metabolic rate by increasing the respiration, perspiration and circulation. This heat stress will more easily put additional strain on bodily organs and increase psychological burden, thereby causing a sense of discomfort. Once the human body is exposed to heated environments the body naturally adjusts maintaining a cool body temperature by lowering metabolic rate and increasing the perspiration rate. This natural adjustment enhances the body’s endurance to high temperatures or even low temperatures (Cao *et al*. 2013: 491).

Many people spend large amounts of their time indoors, mostly in air-conditioned environments over a long period of time, often resulting in a weakened response to acclimatising and a weaker ability to endure hotter environments. Consequently, this increases the risk of heat stress and affects their physiological regulation system therefore causing thermal discomfort (Cao *et al.* 2013: 490-491). It has been noted that a variation in indoor thermal temperature would be more beneficial than a stable thermal environment of normal air temperature, air humidity and supplied air velocity because occupants may better acclimatise to a variation of environmental temperatures (Cao *et al*. 2013: 491). Conversely, one study in Thailand demonstrated the significance of maintaining the highest average temperature acceptable, because it could be used as a set standard for upper temperature limits in open plan office buildings. Additionally, this would reduce building energy costs from air-conditioners. If a building maintained temperatures lower than the lowest acceptable average temperature will use more electricity would be used and energy costs would increase. It was therefore suggested that single comfort temperature values should be used, in line with the standards. Furthermore, this simplifies the implementation of the systems (Yamtraipat *et al.* 2005: 511).

In recent years, the development of automated computer simulated air-conditioning systems has risen. These systems are favoured in current times as they predict the need for outdoor air supply and automatically regulate indoor temperature by the automatic opening of windows or ventilation outlets (Guo *et al.* 2016: 1854). Before advancement in indoor thermal controls are done, more research is needed to verify the existing research and demonstrated relationships between temperature and health in differently populations, different temperature intensities, over longer periods and the study of additional health parameters need to be considered. It has been highlighted that elderly people are more vulnerable to temperature changes, where reduced temperatures may result in a higher blood pressure results compared to younger individuals (van Marken Lichtenbelt *et al*. 2017: 823); however, insufficient literature has explored this phenomenon.

Nevertheless, the health field is rapidly progressing, and recent studies have highlighted additional human health factors as a result of temperature extremities, which future studies have the opportunity to study in depth, such as “energy expenditure, skeletal muscle metabolism, insulin sensitivity, blood pressure, cardiac output and the immune system” (van Marken Lichtenbelt *et al*. 2017: 824).

#### 2.3.3.2. Thermal discomfort and cognitive functioning

Air temperatures could indirectly affect productivity through effects of SBS symptoms (Seppänen and Fisk 2006: 10). These studies provide strong and quantitative evidence for the association between thermal comfort and productivity (Wargocki and Wyon 2017: 361; Rostron 2008: 294; Wyon and Wargocki 2006: 182-186 and Seppänen and Fisk 2006:14). The relationship between thermal conditions and comfort has been broadly researched, whereas work performance and wellbeing of thermal conditions have received much less attention (Seppänen and Fisk 2006: 10). Wargocki and Wyon (2017: 360) determined that when office occupants had most control over their thermal conditions, productivity and mental tasks were improved by 2.7%. Alternately, when individual thermal control was temporarily disabled there was a 2.8% decrease in productivity.

Two surveys conducted in the United Kingdom conclusively revealed that SBS symptoms increased with a temperature from a minimum of 20-22 °C. Significantly, those computer users who had individual control over the temperature levels revealed a 30% reduction in sick leave and significant reduction in environmental complains. Insufficient thermal comfort conditions can reduce human efficiency, such as reading, logical thinking and bodily movement from 5 to 15% (Wyon 1996: 5); nevertheless, no new study has confirmed this. Contrary to these temperatures, Rostron (2008: 294) argued that strong evidence has been published to establish the correlation between SBS and temperatures above 23 °C and less than 22 °C in winter seasons. Synonymously, another study developed by Seppänen and Fisk (2006: 10) highlighted the relationship between performance and temperature: where there was an increment in temperature range of 25-32 °C, there was a decrease of 2% in office work performance. Furthermore, there was no effect on performance when the temperature range was 21 °C – 25 °C. A more recent study highlighted that an optimal working temperature indoors would be between 20 °C – 26 °C. Inconclusively, several studies have illustrated ranges of indoor temperatures that showed differences in work performances (Wargocki and Wyon 2017: 361; Wyon 1996: 5; Rostron 2008: 294; Seppänen and Fisk 2006: 10 and Wyon and Wargocki 2006: 181).

## 2.4. CONCLUSION

Employees spend between five and eight hours of their day, five days a week, breathing 14 $m^3$ of air every 24 hours in the workplace environment (Hayleeyesus and Manaye 2014:

S312). For this reason, over the years much attention has been focused on indoor physical environments, IAQ and occupant's health with some recommendations to improve the work environment (MZ and Saliluddin 2019: 22; Bluyssen *et al.* 2016: 298 and Mohan 2012: 107). The term SBS is said to be controversial: despite this, several studies have attempted to define and investigate the prevalence of SBS in an office or similar environment (Yildiz 2020: 210; Kongcharoen, Onmek and Karrila 2019: 93; Lu *et al*. 2017:2; Edvardsson *et al*. 2007:805 and Truter 1993: 11).

Sick Building Syndrome has received much attention globally, both on public and research platforms. Ghaffarianhoseini *et al.* (2018: 100) argued that the reasons for this highlighted topic include: "overheating, inadequate ventilation, poor IAQ and growing global awareness of the role of the built environment on human health". Furthermore, the indoor contamination of microbial, chemical and physical was widely known to be a serious health problem in the workplace (Jafakesh *et al.* 2019: 146). There are many factors that may be contributing to a workplace environment, causing employees to suffer with symptoms of SBS; the etiology of SBS however, is still unknown (Murniati 2020: 278). A common theme of possible causes contributing to the prevalence of SBS was identified. These themes include: poor indoor ventilation systems, temperature and humidity extremes, and poor sanitation and hygiene practices (Brits 2011: 42).

The common theme represented amongst many studies was the nonspecific relationship of SBS symptoms. This highlights the significant variability in the signs of SBS which has affected the human body with various health effects making it difficult to correlate health effects with SBS (Ghaffarianhoseini *et al.* 2018: 102). Nevertheless, several studies have associated SBS with health effects such as dry eyes, respiratory and mucous system issues, flu like symptoms, fatigue, dermal irritation and difficulty concentrating (Ghaffarianhoseini *et al.* 2018: 102; Azuma *et al*. 2018: 51; Bonino 2016: 46-48; Cao *et al.* 2013: 492 and Jansz 2011: 49). Bernstein *et al.* (2008: 590) argued that whether or not people believe in SBS, it was the responsibility of practitioners such as allergist or clinical immunologist to investigate and approach SBS with adequate knowledge of the history of exposure in the outpatient setting. Furthermore, symptoms collected directly from occupants are known to be questionable and therefore an objective approach was required. Objective monitoring such as IAQ surveys or medical "tests such as allergy skin testing, pulmonary function testing, methacholine provocation, and appropriate blood work should be performed to exclude more prevalent and diagnostically accurate conditions such as chronic allergic or non-allergic rhinitis and/or asthma”.

There are current gaps in research that should be considered, such as studies on the four seasonal variations of spring, summer, autumn and winter as differing temperatures, RH and dry or wet periods and the impact on SBS. In addition to this, research in large cohort studies on the nature of SBS was minimal and therefore short, medium and long term consequences of SBS would be beneficial. Furthermore, studies have neglected to apply the Biopsychosocial model in their research methodology to incorporate all elements and parameters of SBS. This may possibly fall under the surveillance of the occupational health and safety unit (MZ and Saliluddin 2019: 38).

Many years of research highlighted the significance of improving indoor environmental factors and the association it has with improved human health (MacNaughton *et al*. 2017: 178). Education and communication are imperative factors in ensuring that remedial and preventative measures are taken to prevent poor IAQ (Brits 2011: 42). When building occupants, management and maintenance teams are aware of the causes and consequences of poor indoor air problems, they can work collectively to ensure healthy working environments (Brits 2011: 42). To date, limited South African legal resources are available to ensure that the buildings and IAQ are maintained at a standard that will not negatively impact an employee’s health, wellbeing and quality of life. The next chapter will explore current legislation and standards that relate to SBS and IAQ.

# CHAPTER THREE

# REVIEWING OF LEGISLATIVE GUIDELINES AND LEGAL CONSEQUESNCES

## 3.1. INTRODUCTION

It is important to consider and implement acts, regulation, legislation, bylaws and standards to ensure that the basic minimum requirements are met to safe guard employees and employer's health and wellbeing. Currently there is no specific legislation which may enhance indoor air quality in South African office buildings.

According to the South African constitution, Section 24, 27 and 28 addressed the basic human rights. Section 24 specifically stated 'everyone has the right to an environment that is not harmful to their health or well-being' (South Africa. Constitution of the Republic of South Africa 1996: 1251, 1252). This is the highest law for all people to adhere to. As a result, employers have the duty to ensure a healthy and safe working environment. This study relates to an office environment with employees conducting sedentary work, which consists of a number of factors contributing to the possible SBS cases. Through relevant environmental investigations, possible factors contributing to SBS are identified. This will ensure that relevant mitigating measures are implemented thereafter, which will be driven by various regulations and standards, with the constitution being the highest law as mentioned above.

The Constitution extends into the National Health Act by providing preventative health measures on a local, provincial and national basis. Chapter 3 specifically states that measures should be implemented to ensure adherence to environmental conditions that constitute a health hazard to facilitate the provision of indoor and outdoor environmental pollution control services (South Africa. Department of Health 2004: 15). Furthermore, Chapter 10 of the National Health Act provides enforcements of environmental health investigations into violations pertaining to the National Health Act (South Africa. Department of Health 2004:42). This is initiated by Environmental Health Practitioners whose scope of practice includes indoor pollution control and health surveillance on each premise. Conducting health surveillances of a premise comprises of IQA monitoring, assessment of indoor ventilation, thermal quality, and structural safety, floor space such as overcrowding and unsatisfactory conditions (South Africa. Department of Health 2008: 17, 19).

### 3.1.1. Occupational Health and Safety (OHS) Act No.85 Of 1993

The Long title of the Act includes the provisions "To provide for the health and safety of persons at work and for the health and safety of persons in connection with the use of plant and machinery; the protection of persons other than persons at work against hazards to health and safety arising out of or in connection with the activities of persons at work; to establish an advisory council for occupational health and safety; and to provide for matters connected therewith" (South Africa 1993: 10-11). The OHS Act ensures the safety of any persons at work regardless of the severity of the hazard and aims to remove or mitigate the hazard or risk as reasonably practicable.

According to OHS Act No.85 of 1993, section 8 outlines the duties of employers to their employee's. It is important for employees and management of office buildings to ensure that "every employer shall provide and maintain, as far as reasonably practicable, a working environment that is safe and without risk to the health of the employee's". In the context of section 8 as above, the employer must make provisions and be responsible for maintenance of work systems such as ventilation systems, ensure that temperature and humidity are of legal standards, as well as implement the cleaning of buildings and its mechanical systems (South Africa 1993: 10-11). Management must make arrangements for securing, as far as is reasonably practicable, the safety and absence of risks to health in connection with the production of substances, such as fungal, mold and bacterial growth from inadequate cleaning and dampness. All employers have the right to be made aware of the possible causes of SBS and control measures to be implemented. Employers are obligated to "provide such information, instructions and training as may be necessary to ensure, as far as reasonably practicable, the health and safety at work of his employees" (South Africa 1993: 10-11). The Act, section 8 was explicit in ensuring the health and safety of employees at work, regardless of the type of environment.

The OHS Act No.85 of 1993, section 8 ensures that employers create a healthy and conducive working environment for employees. The Environmental Regulations for workplaces in the Act, section 6 of housekeeping stated that 2.25m² per person was the minimum requirement to establish that the workspace is of effective open floor area (South Africa 1993: 168). This is important in the event of overcrowded office spaces. The minimum work space per person allows for optimum comfort. To date there has been no South African literature exploring the minimum requirements of working spaces and related comfort factors to SBS.

Office ergonomics is an important factor in ensuring a healthy, comfortable environment for employees. The OHS Act No.85 of 1993 had recently implemented in December of 2019 the Ergonomics Regulations which clearly indicated to employers the measures and systems needed to ensure that workplace comfort and health is maintained (South Africa. Department of labour 2019: 18). Office comfort and satisfaction is a factor contributing to SBS as detailed in Chapter 2. This study did not fully investigated the ergonomics aspect; however, office ergonomics related to comfort should later be included.

## 3.2. INDOOR AIR QUALITY GUIDELINES

Licina, Bhangar and Pyke (2019: 75) postulated that despite the progress in building design ventilation and indoor air quality standards; occupant satisfactory surveys indicated that occupant satisfaction was lower than the 80% goal as per the ASHRAE standards. Although there is no specific Act, standard or stringent policy governing IAQ, there are certain acts which safe guard the health of employees. These acts which safe guard the health of employees do not feature IAQ as a prominent topic. The right to breathe healthy indoor air is a fundamental right according to the WHO (WHO 2010: xv). This ruling was passed by the WHO as the quality of air directly affects the quality of life, health and wellbeing of people (Gansan, Gqaleni and Ehiri 2002: 655).

The minimum outdoor air flow rate supply via the ventilation system is required per person in a space. This is to ensure that good air quality is supplied for occupants' good health and productivity. The ASHRAE standard 62.1 (ASHRAE Standing Standard Project Committee 2016: 3) stated that an environment will be deemed satisfactory when 80% of the occupants express satisfaction. Kosonen *et al.* (2011: 76) argued that the minimum range commonly used nationally and internationally in commercial office buildings is 7–10 L/sec per person. The most commonly used standard for flow rate per person is the ASHRAE Standard, of 10L/ per person (Abu Eleinen, Elries and Elnahas 2018: 7; 2017 cited in Mora and Bean 2018: 41

and Turpin 2014: 17). While recent studies have suggested, through testing, that a 20-30 L/sec per person will significantly enhance perceived IAQ (Kosonen *et al.* 2011: 84). The South African National Standards (SANS) 10400 code requirements state that the building should allow for 7.5 L/s outdoor/per person in office areas (South African National Standards 2011: 19).

### 3.2.1. SANS Code 10400

The code set out provisions to satisfy technical aspects of the National Building Regulations and was approved by Council of the South African Bureau of Standards (South African National Standards 2011: 2). The SANS 10400 code Part O of Lighting and Ventilation specifically highlighted that all artificially ventilation is required to, as far as is reasonably possible, ensure that the air coming through the inlet is free from local contamination (South African National Standards 2011: 14).

The code prescribes requirements for artificial ventilation design, maintenance and testing of the air-conditioning system. The design and installation of the system shall be carried out by a competent person certified as per regulation A19. Before installation of the air-conditioning system for the purpose of thermal comfort, the local authority is required to grant permissions and provide written approval. The maintenance and testing forms an imperative part of ensuring compliance with the code. Records and logs should be kept of all maintenance, repairs and monitoring should be documented. The testing reports should be submitted to the local authority in a regular basis (South African National Standards 2011: 22). The internals of submission are not stated in the code. It is noteworthy that the owner of the building under study currently does not submit these documents to the local authority.

### 3.2.2. Carbon dioxide guidelines

National and international bodies have attempted to set legal limits, for example, guidelines have been set by ASHRAE, The National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) where exposure limits are set at 1000 ppm to ensure the health of individuals (Azuma *et al.* 2018: 51; Tsai, Lin and Chan 2012: 350 and National Institute for Occupational Safety and Health 2011: 1). Conversely, the ANSI/ASHRAE standard for ventilation guidelines in 2013 suggested a limit of 700 ppm (Gall and Nazaroff 2015: 2), whereas the National Swedish Board of Occupational Safety and Health of the ventilation standard recommends a limit of 1000 ppm and that outdoor air supply into the building should be at least 7L/s per person and additionally 0.35 l/s and $m^2$ floor surface (Norbäck and Nordström 2008: 22). Conclusively several national and international standards have been set to ensure good IAQ.

#### 3.2.2.1. Occupational Health and Safety Act No.85 of 1993: Environmental Regulations

According to the Occupational Health and Safety Act of Environmental regulations for workplaces, section 5 of Ventilation the employer has to ensure that the workplace is ventilated either through natural ventilation or mechanical means in such a way that:
"a) the air breathed by employees does not endanger their safety;
b) The time-weighted average concentration of carbon dioxide therein, taken over an eight-hour period, does not exceed one half percent by volume of air;
c) the carbon dioxide content thereof does not at any time exceed 3% by volume of air".
(South Africa 1993: 168)

### 3.2.3. Indoor temperature guidelines

Thermal comfort standards are used by building designers to ensure that indoor climate conditions are thermally comfortable. This is not only important for the success of the building but also to ensure occupancy comfort (Nicol and Humphreys 2002: 563). While humans can endure a wide range of temperatures, the range for comfort is narrow. Every individual has their own thermal comfort range but standards have been set to ensure that the building is controlled to accommodate the thermal comfort of the larger population (Meintjies 2013: 17).

South African National Standard for energy efficiency in buildings was specific in its requirements for thermal comfort. The standard recommends indoor temperatures between 20°C and 24°C, with set points be 20°C in winter and 24°C in summer (South African National Standard 2011: 27); However, the ANSI/ASHRAE Standard 55-2013, Thermal Environmental Conditions for Human Occupancy U.S. Department of Health & Human Services 2015:1) recommends temperatures for indoor office buildings of 20.2°C to 23.8°C in winter and 23.8°C to 26.9°C in summer. A more updated version (2017) of the ANSI/ASHRAE standard was mentioned in a study by Jasman, Nasaruddin and Tee (2019:3) presented the figures of 20°C to 25.5°C. The standard also presents guidelines that are intended to achieve thermal conditions that at least 80% of the occupants would find acceptable or comfortable (Nathanson 1995: 22).

Furthermore, this standard provides a systematic approach in assisting architects and engineers to analyze building designs; thereby ensuring optimal thermal comfort by designing alternative systems that integrate suitable conditions for enclosures. The Standard 55-2017 provides scientific methods to support the evaluation process of an existing building by using surveys, objective environmental measurements and the building automation systems in conjunction with the other two methods (Mora and Bean 2018: 41). Nevertheless, it was highlighted that the ASHRAE Standard 55 did not accommodate and apply in practice thermal comfort for all people working indoors, as climatic variations ranged widely in different countries. Furthermore, the standard does not make accommodation for individual's habits that's influence perceived thermal comfort (Yamtraipat, Khedari and Hirunlabh 2005: 505).

Conversely to the required comfort temperatures stated in the standard ANSI/ASHRAE Standard 55-1992, Thermal Environmental Conditions for Human Occupancy, a study conducted in office environments in the Philippines demonstrated a contradictory response from employees regarding the recommended temperatures in currently accepted thermal comfort standards. The responses depicted a comfort range of 23 °C – 29 °C, which is over the recommended standard, on the cooler side during summer. This phenomenon could not be explained as Philippines is a tropical hot, humid environment and employees would have acclimatised to this; contradictorily, employees preferred much cooler indoor environment. It was suggested that psychosocial parameters influenced the need for lower temperatures (Andamon, Williamson and Soebarto 2006: 4-6). It has always been assumed that people living in warmer countries will require higher/ warmer indoor temperatures to maintain thermal comfort (Yamtraipat, Khedari and Hirunlabh 2005: 505).

### 3.3. LEGAL CONSEQUENCES

In light of implementing the relevant legal standards and regulations, there have been cases where employers and management have neglected their lawful duties to employees and as a consequence, have undergone legal prosecution or suffered heavy financial implications such as, severe penalties. Kongcharoen, Onmek and Karrila (2019: 94) argued that the possible economic impact of SBS is ill health, reduced work productivity and efficiency. The ultimate objective is to ensure that employees have a healthy working environment where they are comfortable and fully productive (Wijerathne, Karunasena and Mallawaarachchi 2012: 396). This may be to the detriment or benefit of a business, as the researcher highlighted how businesses have undergone financial strain as a result of their working environment (Jansz 2011: 48 and Brauer 2005: 9). Research focusing on the economic consequences of SBS and the preventative and intervention costs of SBS would be highly beneficial to the research pool, as well as to management (MZ and Saliluddin 2019: 38 and Seppänen and Fisk 2006: 12).

Economic consequences of SBS stems right back to the symptoms of SBS having a 'knock-on" effect moving forward. Symptoms of SBS often lead to occupants feeling dissatisfied with their working environment thus lowering the employee morale. Moreover, SBS symptoms often lead to employees feeling sick, thus leading to a higher rate of absenteeism and more people taking sick leave. As more employees waste time complaining, feeling uncomfortable, absent or on sick leave, there will undoubtedly be a reduction in productivity and efficiency in the workplace (Barbu, Niculescu and Moise 2018: 16 and Rostron 2008: 293). Productivity is said to reduce by an average of 20% once occupants suffer with SBS. Furthermore, with a reduction in productivity and dissatisfied employees comes with possible high staff turnover. The other economic consequence of SBS recently highlighted was that office staff regularly change jobs rather than dedicate their career to one company. This could be due to the recent volatility of the working population. It is likely that environmental conditions in the workplace are influencing employees in their decision to continue working in a specific company (Rostron 2008: 293).

Mohan (2012: 112) argued that policymakers and company management have neglected health of employees by not acting on IAQ complaints. Building owners lack the incentive to improve building designs to make it greener or even healthier or more comfortable for occupants. Businesses have suffered legal implications as a result of neglecting their working environment (Barbu, Niculescu and Moise 2018: 16 and Brauer 2005: 9). In Denmark several buildings had be evacuated and torn down due to mould and fungal growth. This cost companies millions of dollars in the United States. Law suits prevailed in several countries, more frequently in the United States due to chronic illness from mould in the workplace. Insurance companies paid millions of dollars in claims to cover these workplace buildings

(Brauer 2005: 9). Another study depicted the severity and consequence of neglecting a building, which resulted in a private litigation against management by employees who had become ill as a result of a foul odour inside the building; consequently, the business suffered substantial financial settlements (Jansz 2011: 48).

Some affected buildings may require substantial financial resources and extensive remedial work such as replacing a mechanical ventilation system or installing windows throughout a building. Corrective action could further result in demolition of the building as this may prove to be the most economical solution. It had been noted in several studies that more fresh air and high capacity air-conditioning or HVAC systems are too costly to operate; yet one study proved that employee salary, staff turnover and recruitment costs were significantly higher than a building to operate adequate ventilation. Calculations demonstrated that employees' costs were nearly 100 times more than the total building energy costs. A 1% increase in productivity would result in a 50% savings in building energy costs (Jansz 2011: 48). Wargcki and Wyon (2017: 359) agreed that as a result of poor indoor environmental conditions such as thermal and IAQ parameters, labour costs in buildings exceed energy costs by double the amount. Furthermore, reduced performance by 5-10% was demonstrated.

Several studies have highlighted events in history where legal action was taken and the Litigants (Employees/occupants) emerged victorious. Alternatively, there have been incidents where cases were unsuccessful (Jansz 2011: 3 and Brauer 2005: 9). This was mainly because there is no definite cause of SBS and therefore it was difficult to prove that employee's ill health was caused by SBS (Jansz 2011: 3). MZ and Saliluddin (2019: 32) argued the importance of education and awareness amongst employers, employees and medical practitioners on the nature and illness of SBS. It is clear that the cost of remedial measures in accordance with the hierarchy of controls, cost of high staff turnover and reduced productivity make prevention methods undoubtedly more desirable over the cure (Rostron 2008: 293 and Seppänen and Fisk 2006: 1).

### 3.4. CONCLUSION

Bernstein *et al.* (2008: 590) criticises the lack of legal grounding for indoor office environments. Indoor environments lack standards for biological, chemical and physical exposures, and ventilation and IAQ have not been routinely monitored. It can be said that the legislation pertaining to SBS is currently not being implemented adequately. Nonetheless, some governmental entities have established guidelines and standards, with including limits of exposure; however, South Africa is not setting guidelines which match that of international standards and limits.

# CHAPTER FOUR

# METHODOLOGY

## 4.1. INTRODUCTION

This chapter details the methodology to the entire research study. The study design, rationale behind the sampling tools used, research tools, sampling strategies, data collection procedures, data analysis and ethical considerations are included. The first phase of the study highlights the research methods used during the self-administered questionnaire. This method is used to further validate the findings from the second phase. The second phase includes the research methods used to conduct objective surveys, namely; indoor temperature, $CO_2$ and air flow rate, in relation to the Biopsychosocial Model. Implementation of this method may contribute to the study validity and reliability via the use and application of different methods and approaches (Farmer *et al.* 2006: 377).

Sedgwick (2014: 1,2) highlighted that cross-sectional studies are the best tools in aiding the estimation of prevalence of a behaviour and disease or health effect in the most efficient and time-saving way. This tool makes it advantageous in the aim to investigate the association between indoor environmental factors and the prevalence of SBS contributing to the health and wellbeing of employees in an administrative office building in Durban, Kwa-Zulu Natal.

## 4.2. RATIONALE FOR THE MTHOD USED

### 4.2.1. Biopsychosocial Model

The original linear model used to depict health status was the "cause-effect" model (Surgeon 2002:602); on the other hand, Bluyssen *et al.* (2016: 299) argued that the traditional model did not suffice as other factors need to be considered to evaluate employees' health, comfort and productivity in relation to SBS. Demonstrations of scientific literature have treated and investigated the parameters of SBS independently and not always holistically (Chirico *et al*. 2017: 33; Amin, Akasah and Razzaly 2015: 19; Mohan 2012: 108; Cooley *et al*. 1998: 579; and Shadwell 1995: 30).

Sick Building Syndrome is diverse and may be triggered by various occupational, environmental and psychosocial parameters, where one or many factors may occur simultaneously. This multifactorial health problem can be described by the use of a Biopsychosocial Model provided in Figure 1, which was adapted from a previous study which explored psychological, somatic, and environmental determinants of SBS (Gomzi *et al*. 2007: 147), and covers the elements concerning SBS. Over the years, detailed literature concerning the possible etiology of SBS has come to light.

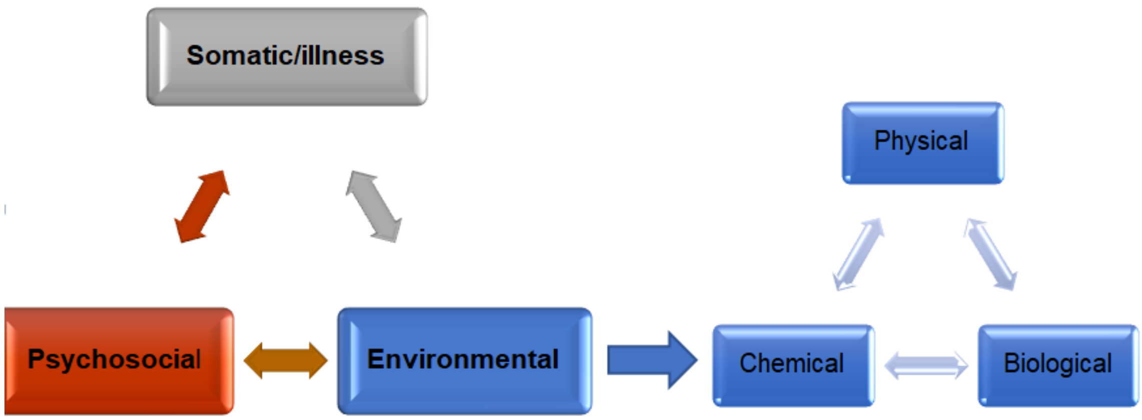



Figure 1: Biopsychosocial Model (Wade and Halligan 2017: 995, Gomzi *et al.* 2007:150-154 and Spurgeon 2002: 601-602).

Few studies have demonstrated the use on the Biopsychosocial Model related to SBS (Wade and Halligan 2017: 995; Bluyssen *et al.* 2016: 299 and Gomzi *et al.* 2007:150-154). This may suggest a severe lack of scientific research related to SBS on a holistic basis. Therefore, this study may contribute greatly towards research as no recent study within South Africa has covered SBS with reference to the Biopsychosocial Model. This may fill a gap regarding SBS in the South African context with the possibility of adding to international literature with reference to the etiology or published trends.

### 4.3. STUDY SITE

The study site was located at an administrative office within Durban, on the east coast of the KwaZulu-Natal (KZN) province, in an office park with several other office buildings in the surrounding area. The city of Durban is based in the EThekwini Municipality of South

Africa. The municipality covers an area of 2297 km² and is home to some 3,5 million people, with a possible increase in 2019/2020 (Statistics South Africa 2011: 1).

The study was conducted in a two-story office building consisting of the ground floor and level 1. Both floors consisted of office work spaces and two staff kitchens with lavatories on each floor. The age of the building ranged between fifteen and sixteen years old and held the capacity of 410 employees in the May 2019. The total size of the building was 4403,56 m², where the 1st and 2nd floor were 1860 m² each. A water-cooled air-conditioning plant with cooling towers on the roof had been installed when the building was originally erected in the early 2000s. The air-conditioning system feeds directly through the ducts and into each office and open plan office space via outlet vents. The building layout had a few singular enclosed offices scattered throughout the building with majority of open plan offices surrounding it. The concrete building, which was entirely carpeted, encompasses that of typical office furniture, comprising of photocopying and printing machines, filing cabinets, book shelves, desks with computer as well as individual partitioning with blinds over the windows. Each desk usually contained large amounts of paper content and a computer desktop user or laptop. The openable windows which were seldom opened unless it was a hot or humid day, were located sporadically around the building. Cleaning of the carpeted floor was conducted once or twice a month, depending on each section of the office as some were cleaned more often than others. Cleaning of desk surfaces and work stations were completed at the discretion of the office employees. Designated smoking areas were located outside of the building in a single quart-yard.

## 4.4. STUDY DESIGN

A cross sectional descriptive study was conducted in an office building yielding quantitative results to illustrate the environmental conditions at "one point in time". The study also employed a method of multi- disciplinary triangulation whereby a Biopsychosocial Model was used, as per the Figure 1. This model depicted the multidisciplinary relationship between different SBS factors that were investigated. The psychosocial factor was monitored through the use of a validated self-administered questionnaire which was adapted from a previous South African study on SBS. The questionnaire was designed to reflect the occupant's health and wellbeing status at that current time (Truter 1993:142). Thereafter, environmental factors of objective surveys were conducted, namely; indoor air flow velocity, indoor temperature and chemical monitoring of $CO_2$ levels. Biological sampling of indoor bacteria and fungi was originally part of this study to fulfill the 3rd parameter under the environmental elements of the Biopsychosocial Model. This was later removed due to the 2020 COVID-19 pandemic during March/April 2020. Consequently, the local laboratories were filled with COVID-19 research samples and public testing; therefore, no local laboratory was able to assist in culturing and analysing the biological samples for this study.

#### 4.4.1. Questionnaire design

This study made use of a South African questionnaire previously designed in 1993. The questionnaire's aim was to ensure that a "broadly based approach was utilised as far as is possible to consider all the various factors which have been shown to play a role in the Sick Building Syndrome" (Truter 1993: 14). Additionally, Truter's (1993: 39) questionnaire had been developed by a certified senior epidemiologist from the occupational health department together with a biostatistician. Truter's questionnaire composed of 44 questions, which were separated into five sections, namely; personal and demographic data, residential status, health status, job and office environment and lastly medical history. The results of the pilot study yielded no significant changes to the questionnaires (Truter 1993:42).

Due to the questionnaire being designed in 1993, the researcher made attempts to modify the questionnaire to best suit the environment and time of the current study. This study questionnaire contained 55 questions which included additional ten questions related to current times and which covered all objectives of this study. The questionnaire included several questions about a participant's lifestyle and home conditions. This was included to highlight confounding factors, thereby yielding more accurate results and conclusions. The questionnaires were compiled and administrated in English as it is the primary written language in the study office. Every questionnaire was numbered to correspond with each of the thirteen sections to ensure that equal amounts of questionnaires were distributed to each section and were accounted for.

#### 4.4.2. Objective survey design

Following the questionnaire, a series of chemical and physical surveys were carried out over 8 days as per the Figure 2. Eight days of sampling for each parameter was adequate to yield representative results. The occupational surveys were an objective view to investigate SBS; whereas, the questionnaires pertain to the employee health, illnesses, personal experiences and perspective of the employees. This was important to verify the validity of the questionnaires.

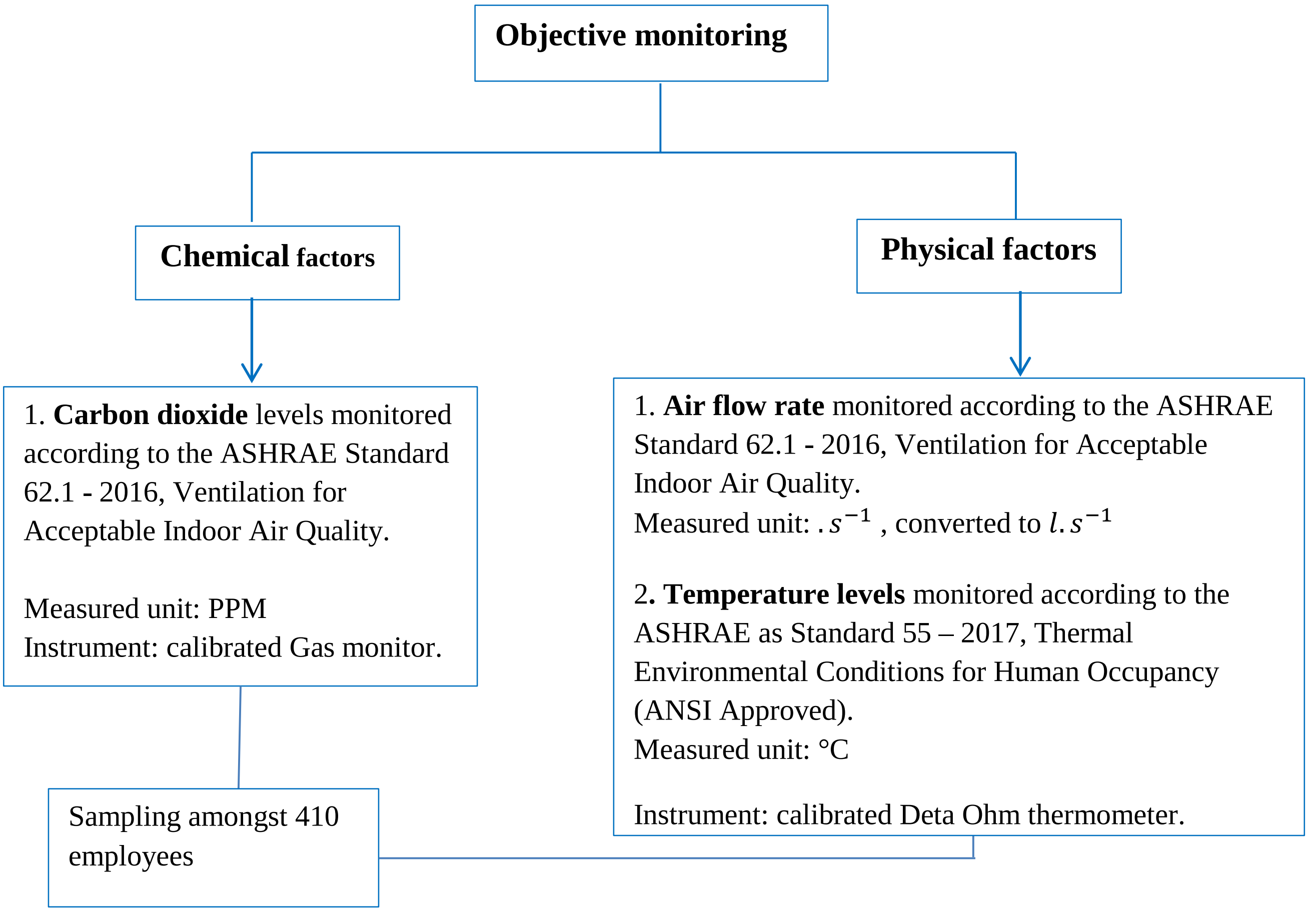



Figure 2. Occupational objective survey design

### 4.5. DATA COLLECTION INSTRUMENT AND PROCEDURE

The pilot study included ten participants. All study participants were provided with an information letter and an informed consent form in English (Appendix B). On completion of Appendix B, the participants completed the self-administered questionnaire. Thereafter, objective surveys of air flow rates, temperature and $CO_2$ sampling were conducted using hand held instruments over eight consecutive days and the ninth day, control samples were conducted according to the ASHRAE standards. The duration of eight days was selected to allow each sampling method was selected to obtain an adequate reliable representation of the sampling results and the environmental conditions, as one day of sampling would have not been adequately reliable.

### 4.5.1. Phase 1: Self-administered questionnaires

The questionnaire employed (Appendix A) was adapted from a previous South African study conducted by Truter in 1993 in his Appendix 2, which was designed and prepared for the purpose of ascertaining the prevalence of symptoms relevant to SBS in an office environment (Truter 1993:142).

Stratified systematic sampling was used to produce 250 self-administered questionnaires (Singh 2019: 1). Thirteen sections of the open plan offices were selected to participate in the study. Every alternate employee at their desk received an information and consent form (Appendix B) followed by the self-administered questionnaire handed from the researcher to the selected participant at their work station. For the purpose of confidentiality, all self-administered questionnaires remained anonymous. The questionnaire was given to the participants at the beginning of the day and was returned to the researcher, in closed ballot boxes, at the end of the day.

#### 4.5.1.1. Pilot study

Truter's questionnaire was piloted among 60 employees out of a sample population of 400 in two office buildings, which was more than the common number of piloted subjects. This further validated the use of Truter's questionnaire as an assessment tool (Truter 1993: 40). As the questionnaire had been already reviewed and drawn up by professionals, the researcher did not find it applicable to pilot more than ten employees.

This questionnaire was piloted among ten employees on a Wednesday at the office site to test the understanding and reliability of the questionnaires. Participation in the pilot study was voluntary and every employee was made to read, understand and sign the information and consent forms (Appendix B). The sample pilot groups, located in the same office, were randomly selected on the basis of availability at that point in time of day. They were made to fill the questionnaire out within one working day. Thereafter, they were given an evaluation form (Appendix C) to provide information on the understanding, quality and clarity of the questions in the questionnaire (Levy 2016: 27). Relevant minor grammar and wording changes were made to the questionnaire prior to the main research data collection. The pilot study results and participants were not used in the final data analysis and sample size.

#### 4.5.1.2. Study population

Total population at the office: Approximately 410 staff. The company employed people at four levels of work:

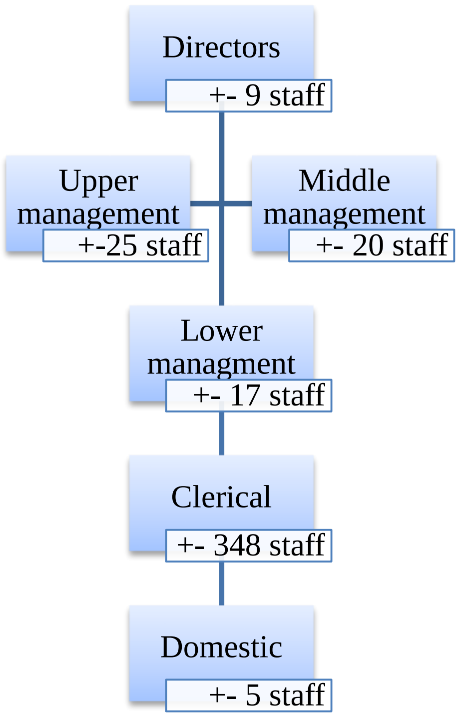



Figure 3: Population structure

The questionnaire was administered to the selected male and female participants in the open plan office spaces by the researcher. The open plan office spaces were occupied by employees of different job strata, including Head of Departments, a few managers, supervisors, team leaders and clerical employees. These employees ranged in age from 18 years to approximately 65 years. Employees located in the open plan office spaces were selected to participate in the study as they were in direct contact with environmental stressors, as well as being the majority of the population at the office; whereas singular offices were sporadically situated around the building.

The primary work function was desk-based, consisting of office work; filing, data capturing, typing on the computer, paperwork and attending meetings. Each open plan space work ranges from 1 $m^2$ to 2.25 $m^2$ per person with 2.25 $m^2$ being the minimum requirement according to the Occupational Health and Safety Act No. 85 of 1993, Environmental regulations for workplaces (Republic of South Africa 1993: 165). The employees spend between five to eight hours a day, five days a week at their desk or in the office environment. The office working hours were from Monday to Friday. The working hours were between 7h30 or 8h00 to 16h00 or 16h30; however, a few employees who arrived earlier and left later than the normal working hours.

#### 4.5.1.2.1. Inclusion criteria

- Permanent employees 18 years and older were selected to participate in the questionnaire. The company employment criterion is a minimum of a matric pass which most often is at the age of 18 years.
- Employees seated in open plan office spaces and which included upper, middle, lower and clerical staff.
- Office employees who read and agreed to participate in the study and signed the information and consent letter

#### 4.5.1.2.2. Exclusion criteria

- Visitors, casual workers, cleaning service staff and temporary staff working at the office.
- Employees older than 60 years were excluded as it is the age of retirement and most often on month to month contract-based employment. Elderly employees were also said to be at risk for other or enhanced ailments and conditions which could skew the data (van Marken Lichtenbelt *et al.* 2017: 823).
- Employees located in singular enclosed offices.
- Pregnant women were excluded due to their present discomfort and heightened senses, which could have resulted in yielding inaccurate representative data.
- Participants under the age of 18 years

- Employees who have participated in the pilot study.

#### 4.5.1.3. Questionnaire sampling strategy

The self-administered questionnaire was provided to 250 office employees using the stratified systematic sampling technique (Singh 2019: 1). Stratified systematic sampling technique was used for its easy and simple nature. Participants were stratified by first including the open plan offices from both floors of the office and by thirteen sections of the open plan spaces. The selection of the sample population started randomly in each of the 13 sections and proceeded to where every second employee systematically received a questionnaire. This ensured a proportional representation of the sample population. The information and consent letter was filled in by the selected participants, before they filled in the questionnaire.

#### 4.5.1.4. Sampling size

The minimum sampling size was 199 in which the margin of error was set at 5%; however, a total of 250 employees were systematically selected from a total population size of 410 to ensure accurate representative results from the majority of the population (Singh 2019: 1). A larger sample population than the minimum sampling size was chosen to ensure a higher accuracy representation.

Table 2: Break down of sample population

| | Total number | Sample selected | Actual response |
|---|---|---|---|
| 13 sections of open plan offices | 410 | 250 | 213 |

### 4.5.2. Phase 2: Objective survey

#### 4.5.2.1: Objective sampling strategy

All occupational objective surveys were conducted in the same month over eight days. The cross-sectional study entailed eight days of sampling and the ninth day as a control sample for an adequate representative sample of the indoor environmental conditions at the office of study. All physical monitoring was conducted in open plan office locations around the office space. A control sample was taken in the same manner, conditions and times as the sampling above. This was done on a Saturday; therefore no employees were at the office. The control samples were collected to ensure reliability of the results.

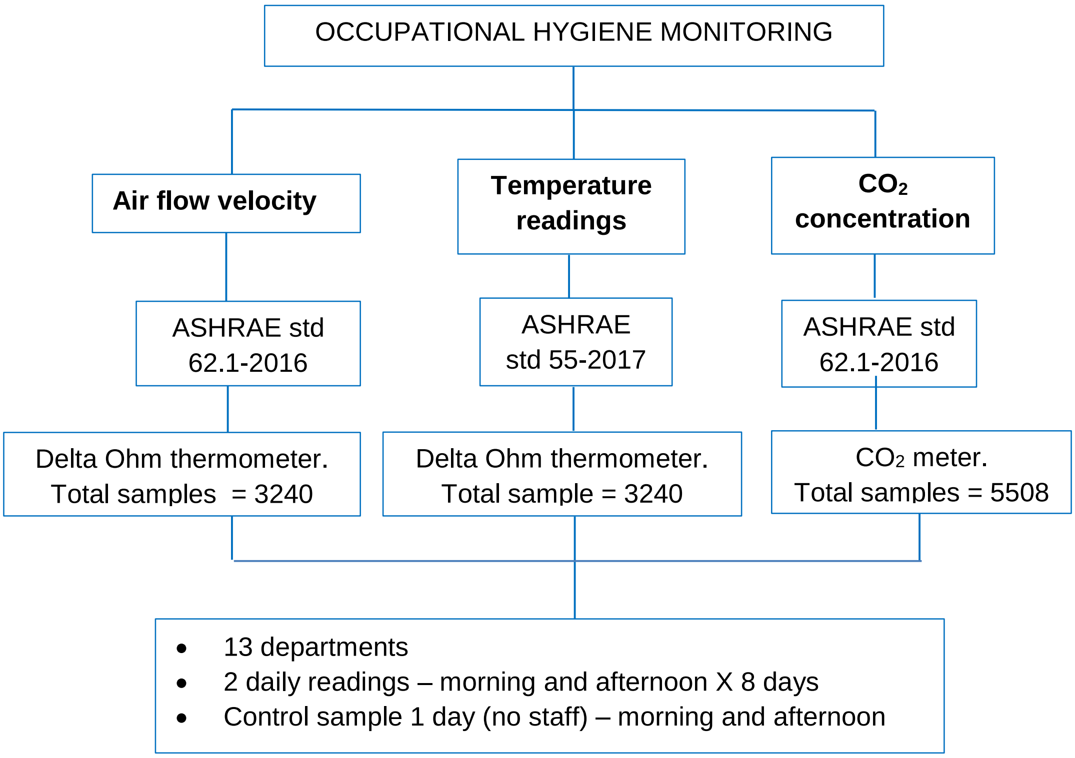



Figure 4: Sampling strategy.

**4.5.2.1.1. Air flow rates and temperature sampling**

The rate of indoor air flow and temperature was measured using a calibrated Delta Ohm Thermometer, serial number 12028190 (calibration certificates attached as Appendix H) (which provided a direct readout of indoor temperature (°C) and airflow velocity ($m.s^{-1}$). A calibrated Delta Ohm Thermometer was used to measure indoor temperature and air flow speed. Readings were taken throughout the office space on all two floors of the building perpendicular to the ventilation outlet vents. The sampling points were mapped out on the floor plan (Appendix E).

There were no documented limitations to using the Delta Ohm Thermometer; however, the Mine Ventilation and Refrigeration Specialist from whom the instrument had been procured, suggested that the readings taken were typically on the higher range due to the highly sensitive sensors. This may be used as an advantage, as lower readings may suggest much lower real readings.

Figure 5: Delta Ohm thermometer with the hot wire probe attached.

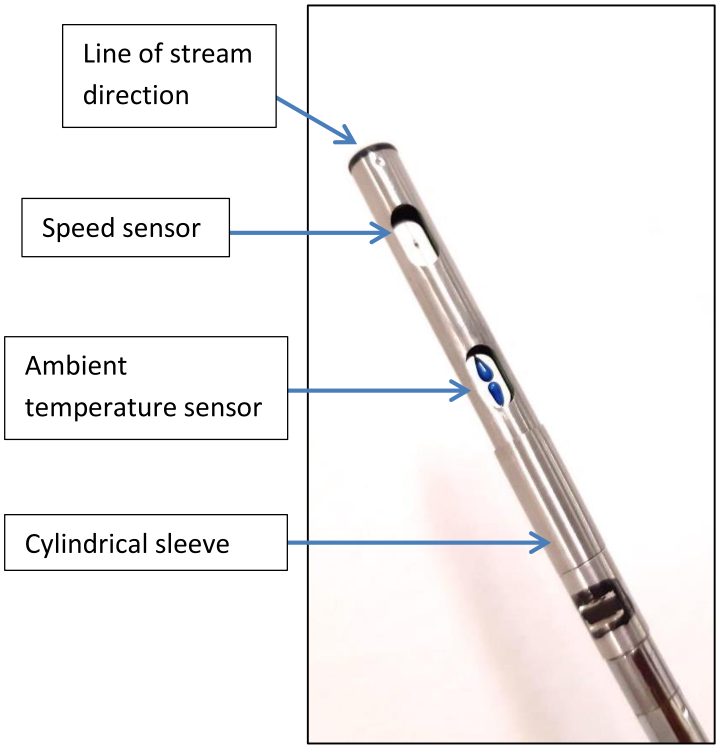



Figure 6: AP471S1 hot wire probe.

The date, time and location of each sample was recorded and mapped out onto a floor plan (Appendix E). Sixty locations were sampled to cover the entire building, consisting of the ground level and first floor. The air-conditioning technician was not informed of this survey to ensure that the system performed as usual. According to the air-conditioning maintenance personnel who services the system bi-monthly, no ventilation rate tests or microbiological sampling were ever conducted but rather general cleaning of the equipment and filters is done, electrical and refrigeration tests are conducted, and data is obtained. Measured air flow rates were compared to minimum ventilation requirements described by ASHRAE Standard 62.1 - 2016, Ventilation for Acceptable Indoor Air Quality (ASHRAE) and the South African Building regulations, SANS 10400 code part O of lighting and ventilation. Temperature readings were compared to minimum requirements published by ASHRAE as Standard 55 – 2017, Thermal Environmental Conditions for Human Occupancy (ANSI Approved).

It was important to ensure that the airflow rate was calculated in $l.s^{-1}$ to compare it to the SANS 10400 and ASHRAE standard. To determine the airflow rate in $l.s^{-1}$ the measurement of the air velocity from each diffuser was taken. The below Continuity Equation calculation was used to determine the l/s per person (Meyer 1995: 102-103):

**4.5.2.1.1.1. Calculation of airflow rate at each diffuser:**

$Q: Airflow\ rate\ diffuser\ (m^3.s^{-1})$

$A: Cross\ sectional\ area\ of\ circular\ diffuser\ (m^2): \ A = \pi r^2$

$V: air\ velocity\ (m.s^{-1})$

$$Q = A.V$$

Convert airflow rate $(m^3.s^{-1})$ to $(l.s^{-1})$

$$1\ m^3 = 1000\ l$$

Therefore: $Flow\ rate\ (l.s^{-1}) = \mathrm{Q}\ (m^3.s^{-1}) \times 1000$

(Meyer 1995: 102-103).

**4.5.2.1.1.2. Calculation of required airflow rate per person:**

$Total\ flow\ rate : Sum\ of\ total\ flow\ rate\ from\ each\ diffuser\ in\ the\ building.$

$Fresh\ air\ total\ flow\ rate: Total\ flow\ rate\ (l.s^{-1}) \times 30\%$

*30% supplied by the HVAC designer.*

*ASHRAE Standard* = $10\ l.s^{-1}$

$$Number\ of\ people \times ASHRAE\ Standard\ (l.s^{-1}) = Fresh\ air\ total\ flow\ rate (l.s^{-1})$$

$$Number\ of\ people = \frac{Fresh\ air\ total\ flow\ rate}{ASHRAE\ Standard\ (10\ l.s^{-1})}$$

(Kosonen *et al.* 2011: 76; Abu Eleinen, Elries and Elnahas 2018: 7; 2017 cited in Mora and Bean 2018: 41 and Turpin 2014: 17).

The number of people calculated was the theoretical number of people that should be in the building with adequate fresh airflow rate per person. This theoretical number of people was subtracted from the actual number of people in the building to prove adequate or inadequate fresh airflow rate per person.

#### 4.5.2.1.2. Carbon dioxide

A calibrated (see calibration certificates attached as Appendix I) Draeger X-am 5600 gas monitor (Serial number ARMF-0014) was used to measure $CO_2$ levels at preselected areas of the offices. The monitor produced direct read outs in Parts Per Million (PPM).

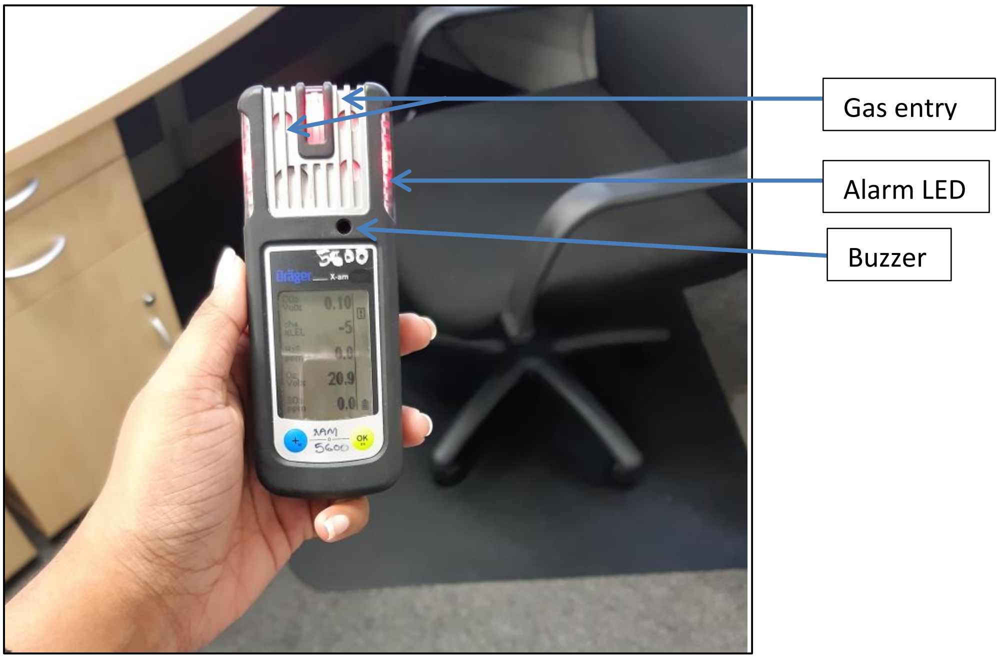



Figure 7: Draeger X-am 5600 gas monitor used in the office building.

Measurement readings were taken in the central location of the rooms and not directly in the breathing zone of employees to avoid incorrect representative readings. Measurements were done over eight days, twice daily; in the morning at 8h00 and afternoon at 15h00 and. The date, time and location was recorded and mapped out onto a floor plan (Appendix E). Sixty sample locations were sampled to cover the entire building, consisting of the ground level and first floor. At each sample location three readings were taken to ensure an accurate average result. Control samples were taken in the same manner, conditions and times as the sampling above. However, this was done on a Saturday as no employees were at the office. The control samples were done to ensure reliability of the results. Carbon dioxide readings were compared to minimum requirements published in ASHRAE Standard 62.1 - 2016, Ventilation for Acceptable Indoor Air Quality.

There was no evident limitation to using the Draeger gas monitor, as it is a commonly used instrument in the field of indoor air quality and occupational hygiene.

## 4.6. DATA ANALYSIS

### 4.6.1. Questionnaire data analysis

Once the questionnaires were filled by the selected employees, the researcher captured all data onto an excel sheet for the data analyst to analyse and interpret. The excel data collected was analysed with IBM® SPSS® Statistics version 26.0. Significant correlations between variables were presented. Inferential techniques include the use of correlations and chi square test values, which are interpreted using the p-values where statistical significance was expected at a $p<0.05$ level. Frequency tables were used to illustrate significant correlations with graphs and charts.

### 4.6.2. Objective sampling data analysis

All data was captured straight onto excel, each tab included $CO_2$, airflow speed and temperature. Three readings per sample location was captured for a total of nine days. This data was then analysed with the IBM® SPSS® Statistics version 26.0. As with the questionnaire data, similar tests and correlations were made; however, the mean from the three sample readings was processed and paired sample statistics between the nine days was done. Bar graphs illustrated trends between the readings of $CO_2$, airflow speed and temperature for each day.
Both data from the questionnaire and objective sampling was analysed together to identify significant correlations or trends.

## 4.7. VALIDITY AND RELIABILITY

The repeatability in sampling of air flow, indoor temperature and $CO_2$ levels over eight days, twice times a day and in the same positions, with three readings each ensured reliability of the study. All sampling processes and instructions were consistent throughout the eight days. The ninth day of sampling was used as a control sample for an adequate representative sample of the indoor environmental conditions at the office of study. The control samples were collected to ensure reliability of the results. Furthermore, the air-conditioning technicians, cleaning services and the maintenance department were not notified about the sampling process and types of sampling to ensure that all environmental conditions remained the same for an accurate representation of results.

Both the pilot study and the actual study were conducted under the same environmental conditions, during the same time period, within the same month of the actual study. This was done to ensure that reliability of the results was maintained. The questionnaire (Appendix A) used had been previously piloted on 60 South African individuals in an indoor settings (Truter 1993: 40). Moreover, the questionnaire was adapted to ensure that it incorporated data and questions relating to current times. This validated the use of the study, making it reliable. The questionnaire used was aimed to ensure that a "broadly based approach was utilised as far as is possible to consider all the various factors which have been shown to play a role in the SBS" (Truter 1993: 14). Therefore, the questionnaire tool used measured what was intended to be measured.

## 4.8. DUT ETHICS APPROVAL TO CONDUCT THE STUDY

Approval to register and conduct the study was obtained from the Faculty Research Committee (FRC) and the Institutional Research Ethics Committee (IREC) of the Durban University of Technology (DUT) (IREC Reference Number: 125/19) (Appendix F). A meeting was then set and all office staff was informed of the proposed study via an email sent by management. Verbal permission was granted, followed by a written confidentiality agreement contract, which was drawn up between the company and the researcher. A letter of permission was requested from the Managing Director of the company in order to conduct the study at the company (Appendix D). The company of study, who was very accommodating in providing all the necessary information required by the researcher, remained anonymous so as to guard propriety data. The following measures were used to ensure that the research process was conducted in an ethically sound manner;

### 4.8.1. Ethical process

The research proposal was submitted to the Faulty Research Committee thereafter submitted to the Durban University of Technology's Institutional Research Ethics Committee, where it was reviewed, approved and issued with an ethics clearance number (Appendix F). Thereafter, gatekeeper permission was sought from the Human Resource director of the office site chosen (Appendix D). A confidentiality agreement was drawn up between the researcher and the company, to maintain the image of the company and not disclose employee names and identifications. Once relevant permissions had been granted, the study commenced with the questionnaire and data collection processes.

### 4.8.2. Ethical principles

The study was carried out with anonymity and fairness throughout the study. All the questions in the questionnaires were designed in a manner that was not intrusive or offensive to participants. Beneficence and non-maleficence are the maximizing of benefits and minimizing of harm to the participants (Levy 2016: 28). Participants were not harmed in any way. All staff working at the company may not experience direct benefit of the study but they may benefit indirectly in the future. This is in keeping with the principle of beneficence with regards to research.

All physical and chemical monitoring did not cause any harm or interfere with employees in any way. All employees were asked to work and continue with work activities as usual.

### 4.8.3. Letter of information and consent

A letter of information and consent was provided to all participants, administrated with a hand delivered self-administered questionnaire (Appendix B). This highlighted to participants the nature of study, the processes involved, the voluntary nature of participation, and assurance of privacy and confidentiality (Uwimpuhwe 2012: 45-46). Furthermore, the information and consent letter described that the participant may participate out of their own free will and that they may leave the study at any time without any consequences. Participants were assured that all information and data collected in the study remained strictly confidential under all circumstances. The participant's privacy and the emotional well-being were protected at all times during the course of the study.

The completed questionnaires and information and consent forms were returned to the researcher in ballot boxes to ensure confidentiality and anonymity. All data will be kept under lock and key for five years at the researcher's office in a cupboard accessible only to the researcher and supervisor. Thereafter it will be disposed of by means of shredding. All electronic copies will be deleted.

#### 4.8.4. Anonymity and confidentiality

Anonymity and confidentiality was achieved by not asking for participants to provide, on the questionnaires, their names, addresses or where they currently work. All completed questionnaires were collected separately from the signed the consent forms, in sealed ballot boxes. The study site name and address remained confidential throughout the study as per the confidentiality agreement between the company and the researcher.

## 4.9. CONCLUSION

The cross sectional research study was conducted in a two story office site on the coast of Durban, KwaZulu-Natal. The study used a multidisciplinary approach to fully investigate the prevalence of SBS amongst office staff in the open plan office spaces. The study involved a two phased procedure whereby participants completed a self-administered questionnaire, followed by physical and chemical sampling over eight days to ensure that a holistic approach had been implemented. Research data was collected in accordance with the ASHRAE standard and compared to relevant recommended limits of exposure. All ethical procedures were followed and maintained throughout the study. Following the methodology behind this study, the results gave great insight as to what was yielded. From these results, appropriate controls may be implemented in the future to ensure a healthy building is maintained.

# CHAPTER 5

# RESULTS

## 5.1. INTRODUCTION

The ASHRAE standard 62.1 (ASHRAE Standing Standard Project Committee 2016: 3) highlighted that an environment will be deemed satisfactory when 80% of the occupants express satisfaction. In order to fulfill the objectives of this study, the questionnaire survey and objective sampling played an important role in determining overall occupant satisfaction.

This chapter of the study was broken into two phases; phase 1 reported on Objective 1 of the perceived environmental stresses reported in the questionnaires. Phase 2 discussed Objective 2, which highlighted the results of the objective sampling surveys, namely; $CO_2$, air flow rate and indoor temperature. The data collected from the responses was entered into Excel, and analysed with IBM® SPSS® Statistics version 26.0. The results in this chapter were presented in the form of cross tabulations, tables, figures, calculations and narratives for the quantitative data that was collected. Significant correlations between variables were also discussed. Inferential techniques include the use of correlations and chi square test values, which are interpreted using the *p*-values where statistical significance was expected at a $p<0.05$ level. A significant value (*p*-value) of less than 0.05 indicated significance and implied that the distributions were not similar (Levy 2016: 30).

## 5.2. PHASE 1: QUESTIONNAIRE ANALYSIS

### 5.2.1. STUDY POPULATION

The participation rate of employees over the thirteen sections of the ground and first floor was 213 of a total of 250 employees selected (N=213) as represented in Table 3. All participants who met the inclusion criteria for the study were approached and an 85% return rate was achieved.

Table 3: Sample size selected.

| | Total number | Minimum sample size (margin of error at 5%) | Sample selected | Actual response |
|---|---|---|---|---|
| 13 sections of open plan offices | 410 | 199 | 250 | 213 |

### 5.2.2. THE RESEARCH INSTRUMENT

The research instrument consisted of 104 items, with a level of measurement at a nominal or an ordinal level. The questionnaire was divided into five sections which measured various themes as illustrated below:

A Biographical data

B Residential Status

C Health Status

D Job and office environment

E Medical history

#### 5.2.2.1. Reliability statistics

The two most important aspects of precision are reliability and validity. Reliability is computed by taking several measurements on the same subjects. A reliability coefficient of 0.60 or higher is considered as "acceptable" for a newly developed construct.

Table 4: Cronbach's alpha score for all the items that constituted the questionnaire.

| Section | Number of Items | Cronbach's Alpha |
|---|---|---|
| Conditions that describe current working area | 14 | 0.884 |
| Level of control over factors in the office | 6 | 0.782 |

The reliability scores for all sections exceed the recommended Cronbach's alpha value. This indicates a degree of acceptable, consistent scoring for these sections of the research.

#### 5.2.2.2. Factor analysis

Factor analysis is a statistical technique, the main goal of which is data reduction. A typical use of factor analysis is in survey research, where a researcher wishes to represent a number of questions with a small number of hypothetical factors. Factor analysis can be used to establish whether the three measures do, in fact, measure the same thing. If so, they can then be combined to create a new variable, a factor score variable that contains a score for each respondent on the factor. Factor techniques are applicable to a variety of situations.

The matrix table 5 is preceded by a summarised table that reflects the results of KMO and Bartlett's Test. The requirement is that Kaiser-Meyer-Olkin Measure of Sampling Adequacy should be greater than 0.50 and Bartlett's Test of Sphericity less than 0.05. In all instances, the conditions are satisfied which allows for the factor analysis procedure.

Factor analysis was done only for the Likert scale items. Certain components divided into finer components. This is explained in the Table 5 below in the rotated component matrix.

Table 5: KMO and Bartlett

| | Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | Bartlett's Test of Sphericity | | |
|---|---|---|---|---|
| **Section** | | Approx. Chi-Square | df | Sig. |
| Conditions that describe current working area | 0.839 | 1431.294 | 91 | 0.000 |
| Level of control over factors in the office | 0.683 | 683.813 | 15 | 0.000 |

All of the conditions are satisfied for factor analysis. That is, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy value should be greater than 0.500 and the Bartlett's Test of Sphericity sig. value should be less than 0.05.

#### 5.2.2.2.1. Rotated component matrix

Factor analysis is a statistical technique the main goal of which is data reduction. A typical use of factor analysis is in survey research, where a researcher wishes to represent a number of questions with a small number of hypothetical factors. With reference to the Table 6 below:

The principle component analysis was used as the extraction method, and the rotation method was Varimax with Kaiser Normalization. This is an orthogonal rotation method that minimizes the number of variables that have high loadings on each factor. It simplifies the interpretation of the factors.

Items of questions that loaded similarly imply measurement along a similar factor. An examination of the content of items loading at or above 0.5 (and using the higher or highest loading in instances where items cross-loaded at greater than this value) effectively measured along the various components. It is noted that the variables that constituted Section D5 loaded along three components (sub-themes) and Section D17 loaded along two components (table 6). This means that respondents identified different trends within the section. Within the section, the splits are colour coded; and deduced from the Kaiser Normalization and Varimax test, it proved the validity of the test results. The colour code 'blue' represented in component three reflected the factors which required a least intense test to prove the validity of factors associated to SBS; similarly, the 'green' required a more intense test to prove the validity of these factors associated to SBS. Finally, the 'yellow' coded factors required the most intense test; therefore, making it the more significant than darkness/dim and brightness factors. Synonymously, the second section of table D17 highlighted that mechanical ventilation, natural ventilation, room temperature and humidity levels were intensely related to SBS. Contrastingly, workload and stress levels were least related to SBS.

Table 6: Rotated component matrix

| D5 | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Temperature | 0.828 | 0.055 | 0.046 |
| Air circulation/air flow | 0.886 | 0.161 | -0.044 |
| Air freshness | 0.836 | 0.165 | -0.049 |
| Cleanliness | 0.393 | 0.624 | -0.116 |
| Dusty air | 0.081 | 0.820 | 0.003 |
| Humidity | 0.281 | 0.591 | 0.145 |
| Noise level | 0.398 | 0.471 | 0.213 |
| Dirty | 0.034 | 0.836 | 0.154 |
| Darkness / dim | -0.022 | 0.183 | 0.861 |
| Brightness | 0.115 | 0.019 | 0.844 |
| Stuffiness | 0.493 | 0.438 | 0.230 |
| Odour | 0.438 | 0.484 | 0.316 |
| Comfort | 0.595 | 0.399 | 0.246 |
| Building maintenance | 0.618 | 0.388 | 0.219 |
| Extraction Method: Principal Component Analysis.<br>-Rotation Method: Varimax with Kaiser Normalization.<br>a. Rotation converged in 5 iterations. | | | |

| Rotated Component Matrix[a] | | |
|---|---|---|
| D17 | Component | |
| | 1 | 2 |
| Mechanical ventilation | 0.810 | 0.094 |
| Natural ventilation | 0.769 | 0.098 |
| Room temperature | 0.879 | 0.143 |
| Humidity levels | 0.836 | 0.171 |
| Work load | 0.203 | 0.925 |
| Levels of stress | 0.085 | 0.949 |

Extraction Method: Principal Component Analysis.
-Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

### 5.2.3. DEMOGRAPHICS

This section summarises the biographical characteristics of the respondents. Questions based around their age, gender, lifestyle and living conditions were presented to participants in order to investigate possible correlation or cofounders to SBS.

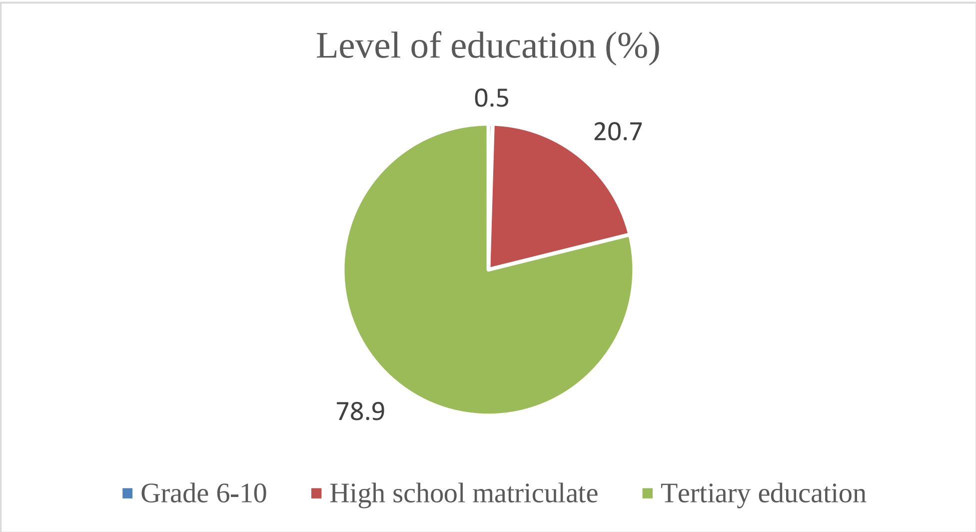



Figure 8: Level of education amongst sample group (%).

The majority of participants were literate as most had completed a tertiary education (78.9%), with 20.7% holding a matric. 0.5% of employees either completed grade 6 to 10.

Table 7: The overall gender distribution by age and gender.

| Age | | Gender: Male | Gender: Female | Total |
|---|---|---|---|---|
| 18 - 30 | Count | 38 | 88 | 126 |
| | % within Age | 30.2% | 69.8% | 100% |
| | % within Gender | 48.7% | 65.2% | 59.2% |
| | % of Total | 17.8% | 41.3% | 59.2% |
| 31 - 40 | Count | 26 | 35 | 61 |
| | % within Age | 42.6% | 57.4% | 100% |
| | % within Gender | 33.3% | 25.9% | 28.6% |
| | % of Total | 12.2% | 16.4% | 28.6% |
| 41 - 50 | Count | 6 | 10 | 16 |
| | % within Age | 37.5% | 62.5% | 100% |
| | % within Gender | 7.7% | 7.4% | 7.5% |
| | % of Total | 2.8% | 4.7% | 7.5% |
| 51 - 60 | Count | 5 | 2 | 7 |
| | % within Age | 71.4% | 28.6% | 100% |
| | % within Gender | 6.4% | 1.5% | 3.3% |
| | % of Total | 2.3% | 0.9% | 3.3% |
| 61 - 65 | Count | 3 | 0 | 3 |
| | % within Age | 100% | 0% | 100% |
| | % within Gender | 3.8% | 0% | 1.4% |
| | % of Total | 1.4% | 0.0% | 1.4% |
| Total | Count | 78 | 135 | 213 |
| | % within Age | 36.6% | 63.4% | 100% |
| | % within Gender | 100% | 100% | 100% |
| | % of Total | 36.6% | 63.4% | 100% |

Overall, the ratio of males to females is approximately 2:3 (36.6% : 63.4%) ($p < 0.001$). Within the age category of 18 to 30 years, 30.2% were male and 69.8% were female. Within the category of females (only), 65.2% were between ages of 18 to 30 years. This category of females between the ages of 18 to 30 years formed 41.3% of the total sample. Within both categories of 18 to 30 and 31 to 40, females accounted for 65.2% and 25.9% of the respondents. The smallest age group of participants were 61-65 and 51-60 which accounted for only three and seven participants respectively. The age distributions are not similar, as there are more respondents younger than 40 years (88%) ($p < 0.001$).

### 5.2.3.1. Lifestyle and living conditions

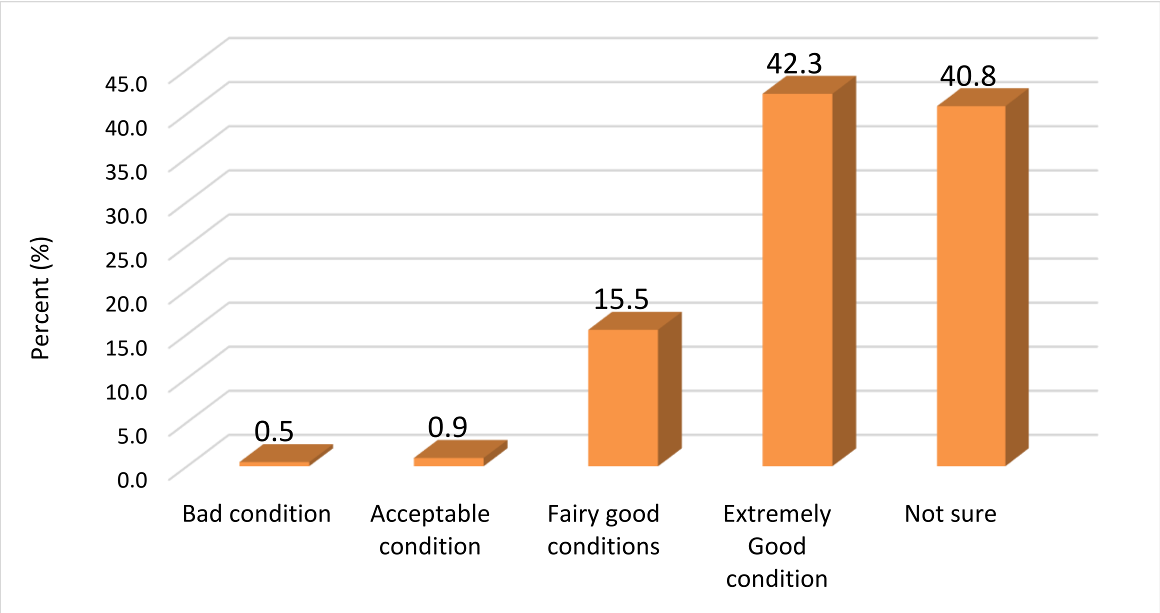



Figure 9: Participants view of the cleanliness/ housekeeping conditions in their place of living most of the week.

A significant number of participants viewed their living conditions as extremely good condition (42.3%; $p < 0.03$); however, 40.8% of participants were not sure and only 0.5% viewed their living conditions as bad ($p$ > 0.0.5). Overall, participants were unsure about their living conditions or stated it was in extremely good condition.

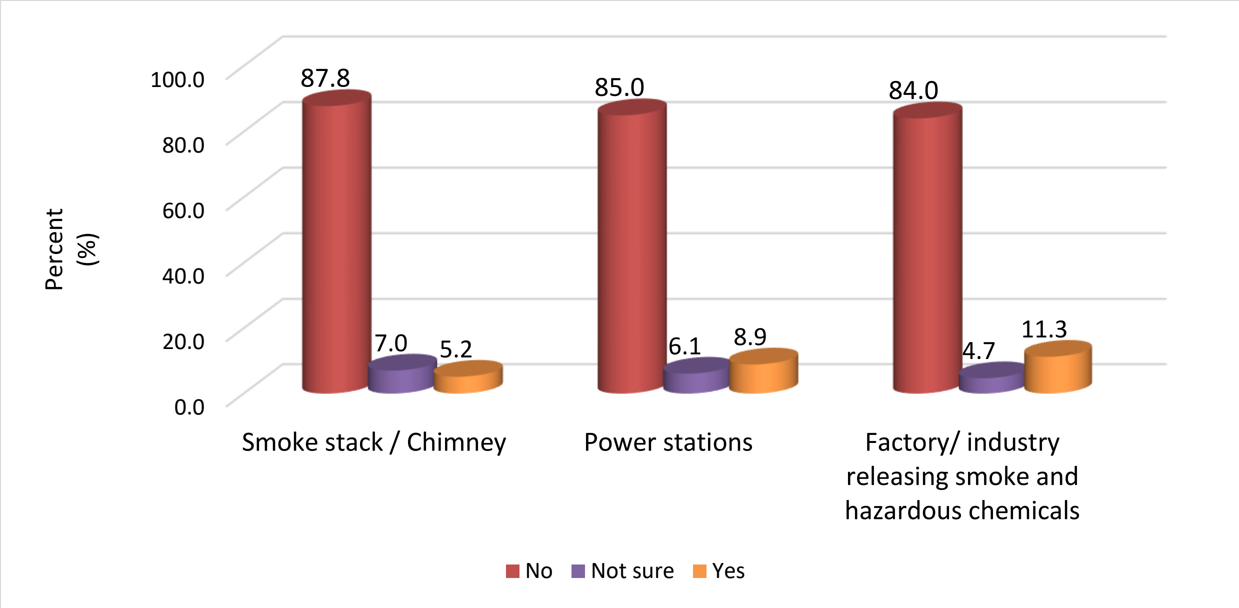



Figure 10: The industry types situated near participant's residence.

Participants were asked if any smoke stack/chimney, power stations, factories/ industries releasing hazardous chemicals were situated near or around their residence. The data set illustrated that a significant average of 85.6% ($p < 0.001$) participants stated that they did not reside anywhere close to any of the 3 categories; albeit, an average of almost 6% were unsure and 8.5% did reside near those categories.

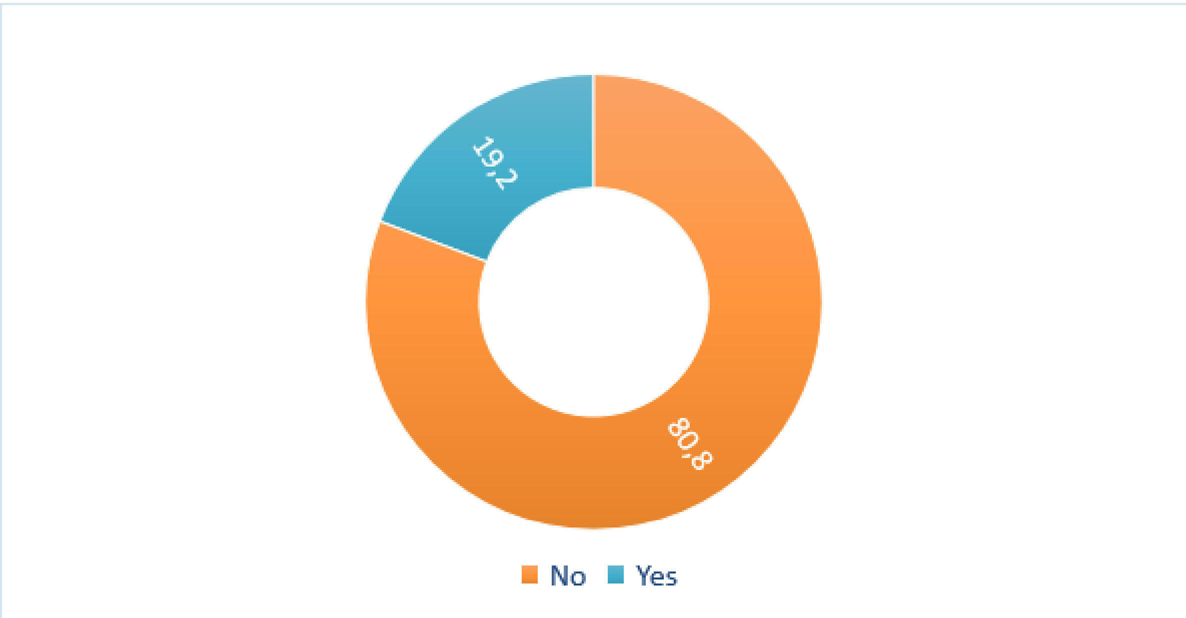



Figure 11: Participant who smoked (%).

The majority of participants (80.8%; $p < 0.001$) were non-smokers and only 19.2% were smokers. Of the participants who indicated that they did smoke, 85.4% of them stated that they smoked in designated smoking areas outside of the building, whilst the remaining 14.6% (n=6) did not smoke during working hours.

### 5.2.4. ENVIRONMENTAL STRESSORS AFFECTING PARTICIPANTS

Environmental factors such as the IAQ, level of comfort and control over indoor factors play a significant role in directly detecting SBS within the building. Indoor air or ventilation referred to air circulation/ air flow; air freshness; humidity; stuffiness and odour The perceptions of the effect that the environmental state has on participants are analyzed below. Figure 12 below highlighted the conditions experienced by the participants within the building.

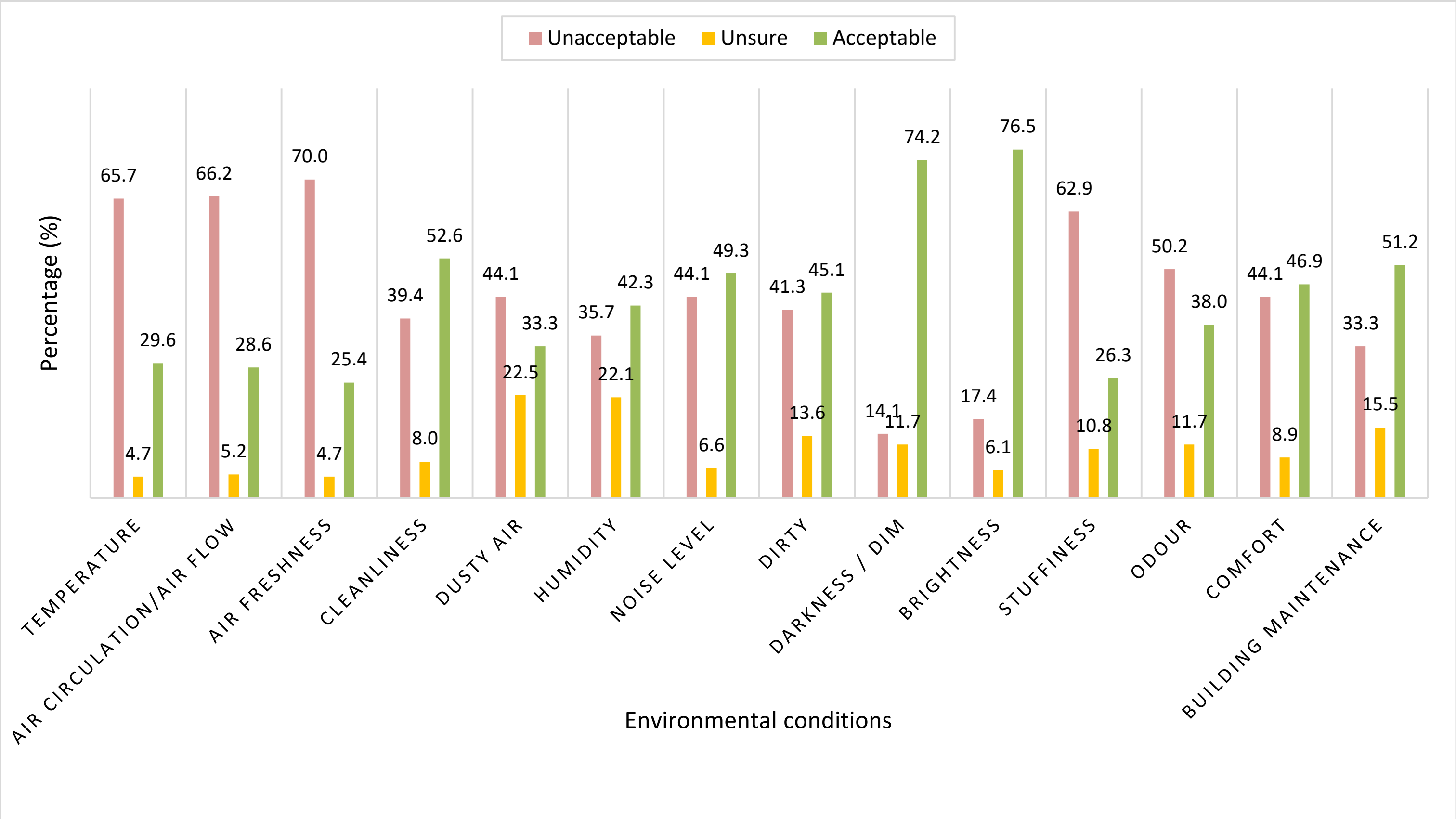



Figure 12: The working conditions experienced by participants

#### 5.2.4.1. Indoor air / Ventilation

According to Figure 12, 28.6% of participants felt the air flow to be acceptable. Approximately 66.2% of participants described the air circulation within the building to be unacceptable. This is more than half of the participants at the company ($p < 0.001$). Furthermore, 62.9% of employees experienced the air to be stuffy and 50.2% of participants experienced bad odours within their work environment. Approximately 70% (n=94) of employees found the indoor air freshness to be unacceptable and 55 participants stated it was completely unacceptable. More than half of the participants believed that the indoor air circulation (66.2%) and flow was unacceptable. The overall perception of occupants of these environmental factors in the workplace, was deemed unacceptable. This would suggest the building maintenance and management was not up to standard. Results of the perceived building maintenance revealed that 51.2% (n=109) of the respondents found maintenance and management acceptable and 33(n) were unsure.

#### 5.2.4.2. Temperature and humidity

The majority (65.7%; $p < 0.001$) of participants found the indoor temperature to be unacceptable, 4.7% were unsure and 29.6% of participants found the indoor temperature to be acceptable. According to Figure 12, humidity displayed no major significance ($p > 0.005$) between levels that were unacceptable (35.7%) and acceptable (42.3%).

#### 5.2.4.3. Perceived environmental cleanliness

When participants were asked their views on the cleanliness of the working environment, 52.6% found it to be acceptable. Similar to this, 45.1% of participants found their working environment to be unacceptable (not dirty) and 13.6% of participants were unsure. Dusty air was inconclusive due to the high number of participants who were unsure (22.5%).

#### 5.2.4.4. Other environmental stressors

Figure 11 also highlighted other results commonly related to SBS; indicating that factors such as illumination (Darkness/ dim and brightness) were acceptable (74.2% and 76.5%

respectively). Almost half of the employees found the noise and comfort level (46.9% and 49.3%) to be acceptable, while the rest of the respondents found these levels unacceptable.

#### 5.2.4.5. Level of control

As highlighted in chapter 2, the level of control that employees have on their immediate environment, such as access to fresh air, room temperature or workload have a direct effect on employees and also contributes to overall environmental satisfaction and good perceptions of their environment, as well as to psychological stress.

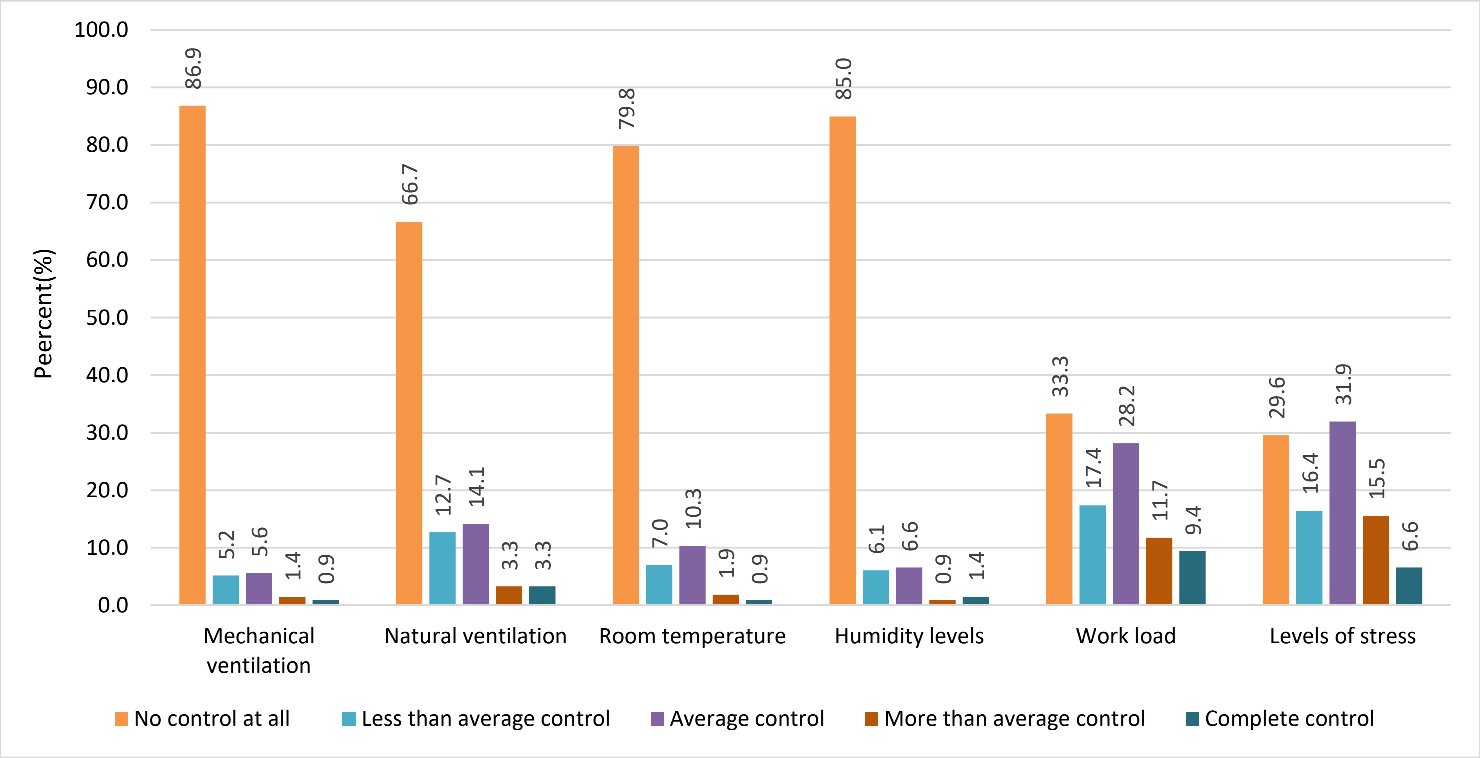



Figure 13: Level of control over different environmental stressors.

Participants were asked about the level of control they experienced over different environmental factors (Figure 13). Mechanical ventilation pertained to control over air-conditioning units whereas natural ventilation included factors such as open windows and doors. Figure 13 indicates that there were high levels of "no control" by the participants for mechanical ventilation (86.9%), natural ventilation (66.7%), room temperature (79.8%) and humidity levels (85.0%). Less than a third of the participants also had no control relating to work load and levels of stress, with a similar number indicating that they had average control.

### 5.2.4.6. Level of comfort

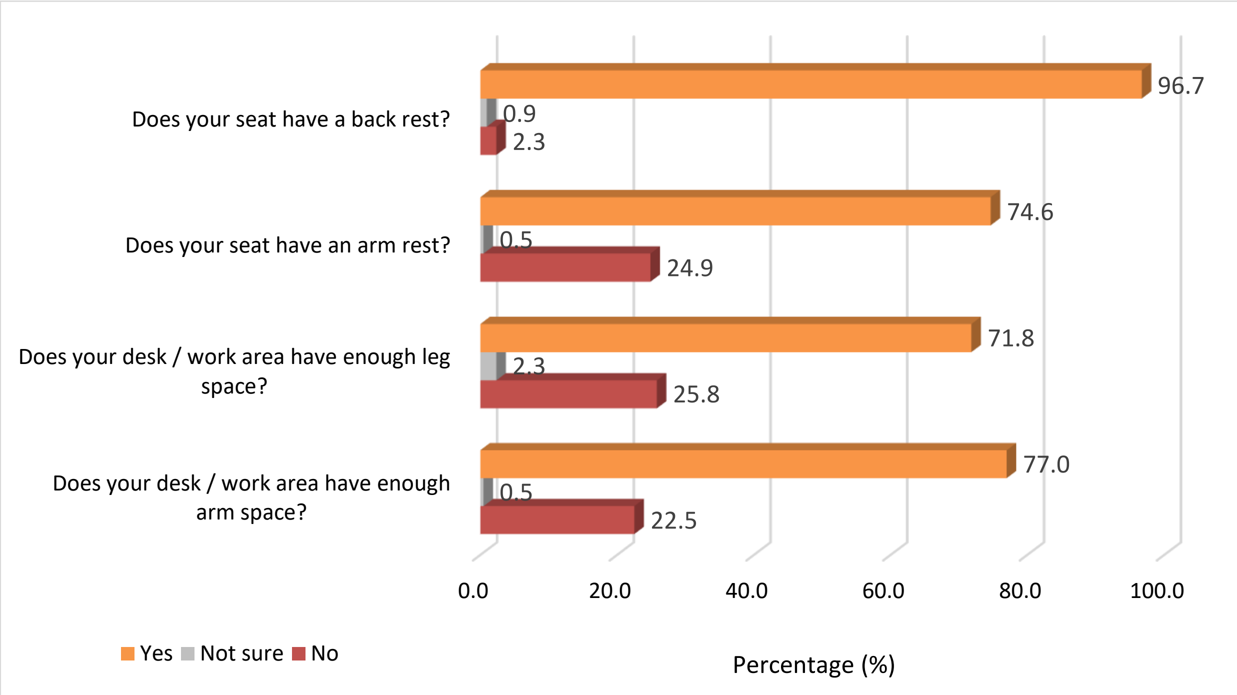



Figure 14: Ergonomic comfort experienced by participants.

Almost all participants (96.7%) had a back rest to ensure acceptable ergonomics. Only five participants (2.3%) stated that they did not have back rests. Almost 25% of participants did not have arm rests and 25.8% did not have enough leg space at their work station. There were between 70% and 77% of participants who did have leg and arm space at their work station. Overall, the majority of participants perceived their work stations to be comfortable (70.9%).

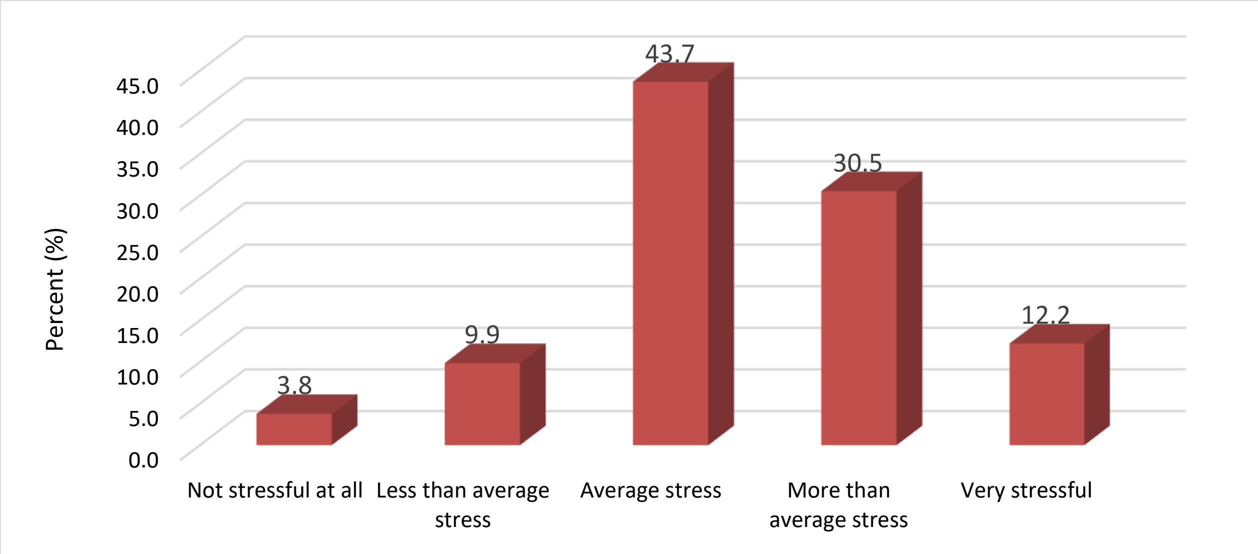



Figure 15: Levels of stress experienced in the workplace amongst participants.

Only 3.8% of participants (n=8) experienced no stress at all; whereas, 12.2% (n=26) perceived their work environment to be very stressful. Overall, the majority of participants at 43.7%, experienced average stress and the second highest percentage was noted in the more than average category of 30.5%.

Table 8: Water leaks around their work station within the last six months.

| | Frequency (n) | Percent (%) |
|---|---|---|
| No | 164 | 77,0 |
| Not sure | 29 | 13,6 |
| Yes | 20 | 9,4 |
| Total | 213 | 100,0 |

Table 9: Dampness of any building material, carpeting or furniture.

| | Frequency | Percent |
|---|---|---|
| No | 156 | 73,2 |
| Not sure | 43 | 20,2 |
| Yes | 14 | 6,6 |
| Total | 213 | 100,0 |

Almost 10% of participants stated that there were water leaks around their work station, while 77% (n=164) stated that they did not experience any water leaks around their work station. When participants were further asked (Table 9) if they had experienced any dampness of any building material, carpeting or furniture around their work station, 73.3% stated "no" and 20.2% stated they were not sure.

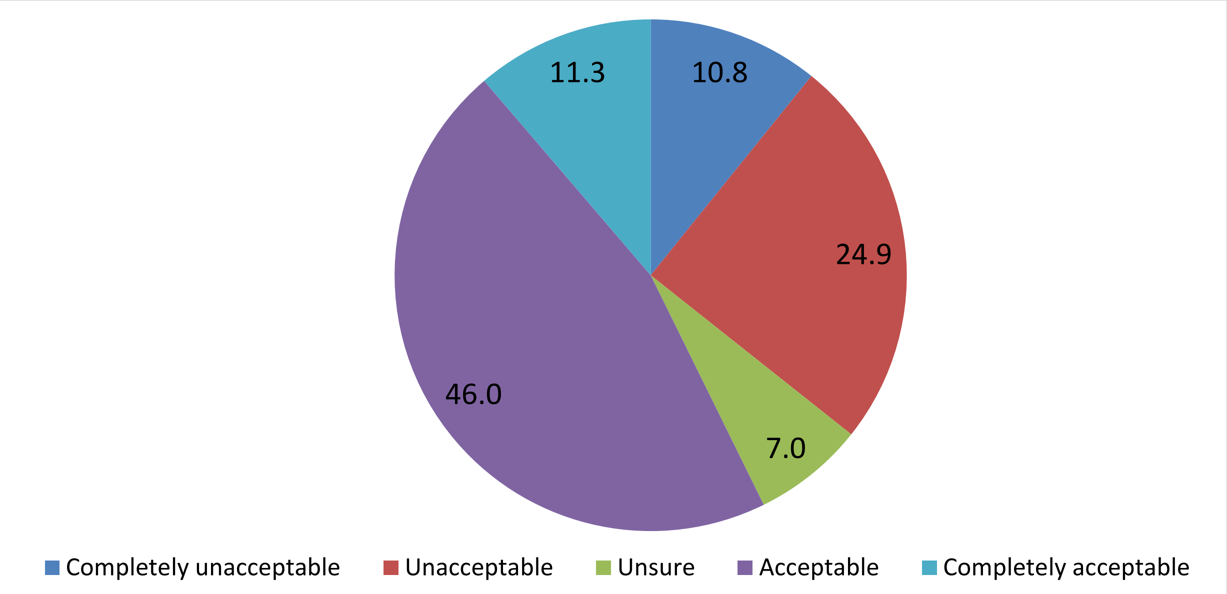



Figure 16: Participants perception of the cleaning effectiveness at their work station.

Almost half of the participants felt that the efficacy of cleaning services at their work was acceptable and 11.3% found it to be completely acceptable; however, 24.9% of participants found their workplace cleaning service to be unacceptable and 10.9% to be completely unacceptable. Overall, more participants found the cleaning services to be acceptable ($p < 0.001$) rather than unacceptable ($p > 0.005$). When participants were prompted further to confirm whether vacuuming in their offices was conducted often enough, almost half (51.2%) of participants stated that vacuuming was seldom conducted. Almost 35% stated that vacuuming was done often and 5.2% stated it was not conducted at all.

### 5.2.5. HUMAN HEALTH AND PERCIEVED SBS SYMPTOMS

Human health included the presence of chronic illness, other illnesses and symptoms while in the building of study. This gave the researcher a clear understanding of the symptoms related to SBS and the level of severity. The global definition of SBS highly depends of the symptoms presented in the building.

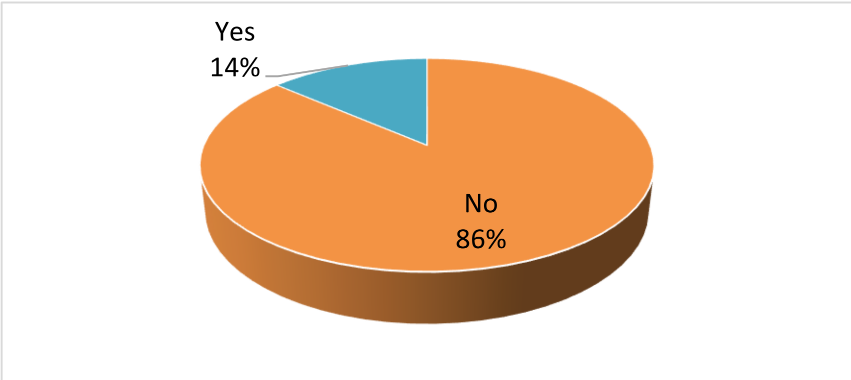



Figure 17: Participants who had chronic illnesses.

Only 14% of participants presented chronic with illnesses, whereas a significant number of participants (86%) stated they did not have chronic illnesses.

Table 10: Symptoms experienced by participants.

| | 1-3 times a week | | Almost every day | | Everyday | | Chi Square |
|---|---|---|---|---|---|---|---|
| | Count | Row N % | Count | Row N % | Count | Row N % | *p*-value |
| Aching joints | 10 | 17,9% | 9 | 16,1% | 5 | 8,9% | 0,001 |
| Back pain | 24 | 23,5% | 18 | 17,6% | 7 | 6,9% | < 0.001 |
| Chest congestion | 8 | 27,6% | 2 | 6,9% | 1 | 3,4% | 0,003 |
| Chest pains | 7 | 26,9% | 1 | 3,8% | 0 | 0,0% | 0,003 |
| Contact lens problems | 14 | 45,2% | 1 | 3,2% | 0 | 0,0% | 0,002 |
| Watery eyes | 34 | 39,5% | 15 | 17,4% | 5 | 5,8% | < 0.001 |
| Disorientation | 4 | 21,1% | 2 | 10,5% | 1 | 5,3% | 0,199 |
| Dizziness | 16 | 36,4% | 3 | 6,8% | 2 | 4,5% | < 0.001 |
| Dry and burning eyes | 36 | 37,5% | 17 | 17,7% | 6 | 6,3% | < 0.001 |
| Fatigue/ tiredness | 39 | 26,2% | 61 | 40,9% | 13 | 8,7% | < 0.001 |
| Drowsiness/ | 29 | 30,5% | 39 | 41,1% | 5 | 5,3% | < 0.001 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| lethargy | | | | | | | |
| Headaches | 53 | 33,5% | 42 | 26,6% | 15 | 9,5% | < 0.001 |
| Sinusitis | 44 | 34,4% | 29 | 22,7% | 16 | 12,5% | < 0.001 |
| Blocked / stuffy nose | 33 | 31,7% | 31 | 29,8% | 5 | 4,8% | < 0.001 |
| Runny nose | 19 | 31,7% | 11 | 18,3% | 4 | 6,7% | 0,001 |
| Excessive sneezing | 18 | 23,4% | 21 | 27,3% | 9 | 11,7% | 0,030 |
| Nasal congestion | 18 | 32,1% | 12 | 21,4% | 3 | 5,4% | 0,004 |
| Nausea | 12 | 22,6% | 10 | 18,9% | 1 | 1,9% | 0,002 |
| Nose bleeds | 1 | 8,3% | 2 | 16,7% | 0 | 0,0% | 0,062 |
| Palpitations | 2 | 40,0% | 1 | 20,0% | 0 | 0,0% | 0,819 |
| Skin irritations | 20 | 28,2% | 18 | 25,4% | 6 | 8,5% | 0,001 |
| Sore dry throat | 8 | 21,6% | 3 | 8,1% | 2 | 5,4% | < 0.001 |
| Insomnia | 7 | 30,4% | 4 | 17,4% | 2 | 8,7% | 0,148 |
| Unusual taste | 5 | 55,6% | 0 | 0,0% | 0 | 0,0% | 0,739 |
| Ear problems | 3 | 23,1% | 0 | 0,0% | 2 | 15,4% | 0,092 |
| Dry skin | 14 | 28,0% | 15 | 30,0% | 1 | 2,0% | 0,002 |
| Flu like symptoms | 22 | 22,7% | 12 | 12,4% | 1 | 1,0% | < 0.001 |
| Anxiety | 9 | 26,5% | 9 | 26,5% | 2 | 5,9% | 0,199 |
| Nervous conditions | 7 | 35,0% | 5 | 25,0% | 1 | 5,0% | 0,092 |
| Asthma | 3 | 18,8% | 3 | 18,8% | 0 | 0,0% | 0,392 |
| Difficulty breathing | 9 | 26,5% | 5 | 14,7% | 1 | 2,9% | 0,063 |

Participants were asked to rate each symptom that they may or may not have recently experienced from seldom, 1-3 times a month, 1-3 times a week, almost every day or every day. The option for seldom and 1-3 times a month displayed minimal significance and was therefore removed from the above table.

Participants perceived symptoms such as watery eyes, dizziness, dry and burning eyes, fatigue/ tiredness, drowsiness/ lethargy, headaches, sinusitis, blocked /stuffy nose, runny nose, skin irritations, sore dry throat and flu like symptoms, which were statistically significant ($p < 0.01$) in all three categories of frequencies. The most significant symptom ($P < 0.001$) symptom perceived by participants were headaches in all three categories of 1-3 times a week (33.5%), almost every day (26.6%) and every day (9.5%). While headaches (n=15) and sinusitis (n=16) were most significant every day, only 2.3% (n=5) of participants stated that they experienced no symptoms.

As highlighted in Table 10, there was statistical significance ($p < 0.01$) between participants who felt fatigued or tired at different frequencies. Sixty-one participants (40.9%) felt fatigued or tired almost every day and 26.2% of participants felt fatigued or tired 1-3 times a week. Therefore, statistical significance ($p < 0.01$) displayed 30.5% of participants felt drowsy or lethargic 1-3 times a week and 41.5% of participants and almost every day.

Table 11: Time of the day participants felt inexplicably tired/ drowsy.

| | Frequency | Percent (%) |
|---|---|---|
| Morning | 12 | 7,6 |
| Afternoon | 54 | 34,4 |
| Evening | 91 | 58,0 |
| Total | 157 | 100,0 |

Participants were asked if they felt unexplainably tired/ drowsy during working hours. 73.7% of participants said yes. Those participants who said yes, specifically felt unexplainably tired/ drowsy in the evening (58%) and afternoon (34.4%). Only 7.7% of participants felt unexplainably tired/ drowsy in the morning (Table 11).

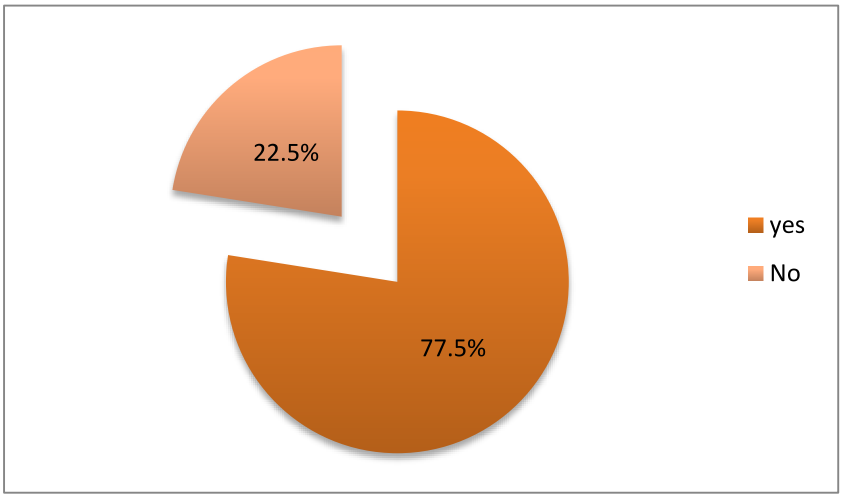



Figure 18: Participants who felt or did not feel SBS symptoms clear up within a few hours (1-3hrs) after leaving the building.

Participants were asked if the symptoms they selected above in table 10 cleared after a few hours (1-3hrs) after leaving the building and 77.5% (n=165) of participants responded with yes; whereas, 22.5% of participants said no.

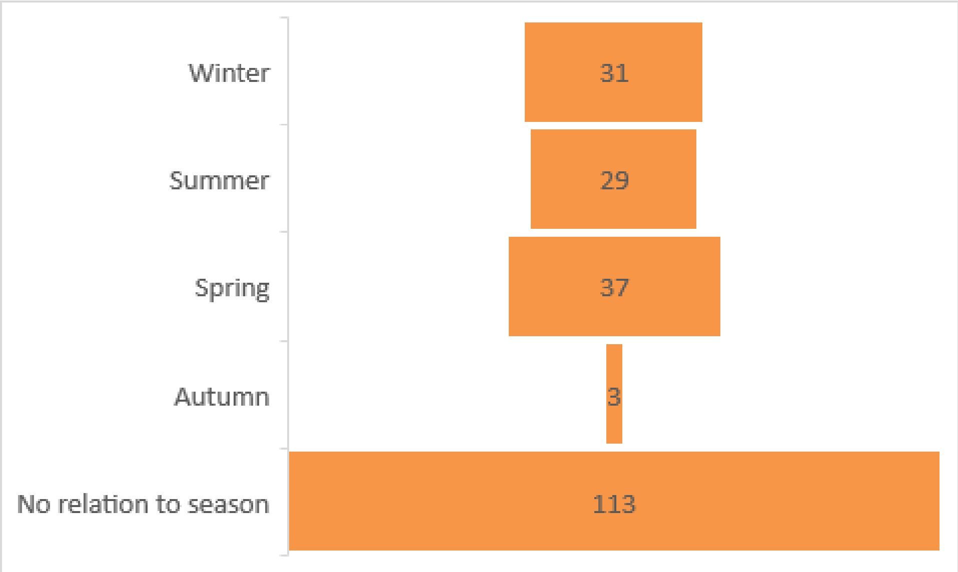



Figure 19: Seasons in which participants (%) felt that symptoms bothered them more during working hours.

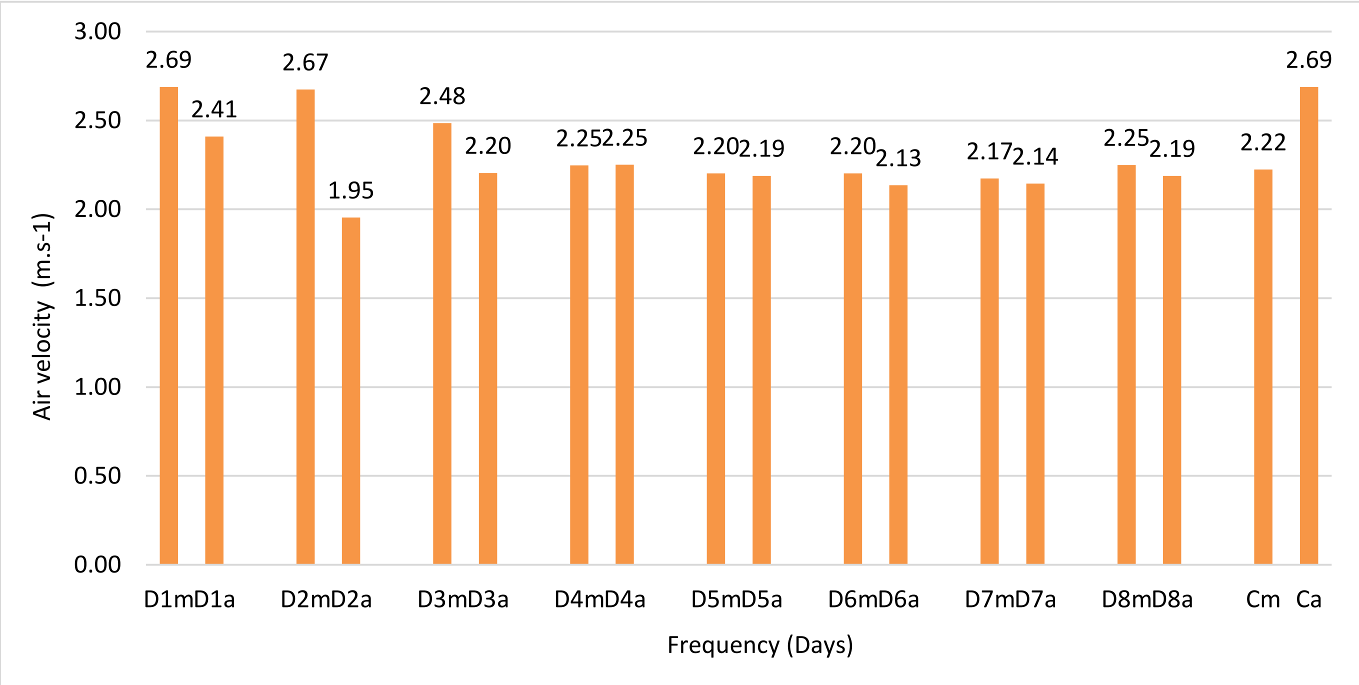
The majority of participants (n=113; 51.3%) stated that the symptoms experienced in table 10 had no relation to a season; however, Spring (n=37; 17.4%) and Winter (n=31; 14.6%) showed a few participants who displayed SBS symptoms in those seasons; whereas, Autumn had only 3 participants (1.4%) whom experienced SBS symptoms, which showed no significance.

### 5.3. PHASE 2: OBJECTIVE SAMPLING ANALYSIS

Indoor air velocity, temperature and $CO_2$ were sampled in various locations of the office building. The data from the surveys were captured onto Excel, namely; air ventilation rate, CO2 levels and temperature sampling readings. The checked and coded Excel sheets were transferred onto IBM® SPSS® Statistics Version 26.0 (Release August 2018) and Statgraphics Centurion 15.1 (2006) software statistical package. Objective sampling was important to further validate the positive results from the questionnaire (perceived environment).

The floor plan in Appendix E illustrated all the sampling locations taken on all two levels of the ground and first floor. The areas that do not have keyed symbols of $CO_2$, airflow velocity and temperature sampling locations were either deemed a singular office, vacant office, boardroom, kitchen or lavatory. Three samples were taken in each sample location each day to collect and average over the time period.

### 5.3.1. Airflow rates




Key : D1m = Day 1 morning; D1a = Day 1 afternoon; Cm = Control morning; Ca = Control afternoon

Figure 20: Mean values of air velocity over 8 days in the morning and afternoon.

Days 1, 2, 3, 6, 7 and 8 indicate significant higher flow rates in the morning compared to the afternoon ($p < 0.001$). The afternoon readings are somewhat similar, but lower than the morning readings. A pairwise comparison between the morning and afternoon readings revealed that the difference between the morning and afternoon readings for each day.

Other comparisons to the standard morning and afternoon readings are shown in the Paired Samples Test table, with the significant differences highlighted in Appendix G.

It was important to ensure that the airflow rate was calculated in $l.s^{-1}$ to compare it to the SANS 10400 and ASHRAE standard. To determine the airflow rate in $l.s^{-1}$ the measurement of the air velocity from each diffuser was taken. The below Continuity Equation calculation was used to determine the l/s per person (Meyer 1995: 102-103).

The number of people calculated was the theoretical number of people that should be in the building with adequate fresh airflow rate per person. This theoretical number of people was subtracted from the actual number of people in the building to prove adequate or inadequate fresh airflow rate per person.

**Calculation of airflow rate at each diffuser:**

$Q: Airflow\ rate\ at\ diffuser\ (m^3.s^{-1})$

$A: Cross\ sectional\ area\ of\ circular\ diffuser\ (m^2):\ A = \pi r^2$

$V: air\ velocity\ (m.s^{-1})$

$$Q = A.V$$

Convert airflow rate $(m^3.s^{-1})$ to $(l.s^{-1})$

$$1\ m^3 = 1000\ l$$

Therefore: $Flow\ rate\ (l.s^{-1}) = Q\ (m^3.s^{-1}) \times 1000$

(Meyer 1995: 102-103).

**Calculation of required airflow rate per person:**

- $Average\ Total\ flow\ rate$ : $Sum\ of\ total\ flow\ rate\ from\ each\ vent\ outlet\ in\ the\ building.$
- $Fresh\ air\ total\ flow\ rate: Total\ flow\ rate\ (l.s^{-1}) \times 30\%$ (30% fresh air supplied by the HVAC designed).
- *ASHRAE Standard* = $10\ l.s^{-1}$ ($10\ \mathrm{l.s^{-1}}$ was chosen compared to $7.5\ \mathrm{l.s^{-1}}$ from the SANS code 10400 as $10\ \mathrm{l.s^{-1}}$ would depict the maximum of airflow rate per person required).

$$Number\ of\ people\ \times ASHRAE\ Standard\ (l.s^{-1}) = Fresh\ air\ total\ flow\ rate(l.s^{-1})$$

$$Number\ of\ people\ = \frac{Fresh\ air\ total\ flow\ rate}{ASHRAE\ Standard\ (10\ l.s^{-1})}$$

(Kosonen *et al.* 2011: 76; Abu Eleinen, Elries and Elnahas 2018: 7; 2017 cited in Mora and Bean 2018: 41 and Turpin 2014: 17)

The total air flow velocity was calculated by adding all of the flow velocity out of each diffuser to sum a total air flow velocity. The velocity of air was taken in the morning and afternoon and the average velocity was utilized in the calculation. The cross sectional radius of the air diffuser is 0.14 m

**Day 1 - Morning air flow rate:**

$\boldsymbol{Q = A.V}$

$A = \pi r^2$

$A = \pi(0.14)^2$

$A =$ 0.06157 $m^2$

Sum of velocity of air from each diffuser (for day 1) = 161.32 $m.s^{-1}$

Q = 0.06157 $m^2$ x 161.32 $m.s^{-1}$

Q = 9.93 $m^3.s^{-1}$

Q = 9.93 $m^3.s^{-1}$ x 1000

Q = 9930 $l.s^{-1}$ x 30%

Q = 2979 $l.s^{-1}$

**Day 1 - Afternoon air flow rate:**

$\boldsymbol{Q = A.V}$

$A = \pi r^2$

$A = \pi(0.14)^2$

Air flow rate on day 1

$A = 0.06157$ m$^2$

Sum of velocity of air from each diffuser (for day 1) = 144.60 $m.s^{-1}$

Q = 0.06157 m$^2$ x 144.60 $m.s^{-1}$

Q = 8.90 $m^3.s^{-1}$

Q = 8.90 $m^3.s^{-1}$ x 1000

Q = 8900 $l.s^{-1}$ x 30%

Q = 2670 $l.s^{-1}$

Average air flow rate for day 1 = $\frac{Morning\ air\ flow\ rate + afternoon\ air\ flow\ rate}{2}$

= 2824.50 $l.s^{-1}$

$$Number\ of\ people\ = \frac{Fresh\ air\ total\ flow\ rate}{ASHRAE\ Standard\ (10\ l.s^{-1})}$$

= $\frac{2824.50\ l.s^{-1}}{10 l.s^{-1}}$

= 282.45 people (This is maximum number of people the building can hold according to the ventilation rate of the system for this specific day)

The excess number of people currently in the building :

Total number in building – required maximum number of people

= 410 – 282.45

= 124.55

Therefore, there are approximately 125 people in excess in the building. This calculation was applied to all days on Excel and displayed in Figure 20 below.

**Day 1 - The actual air flow rate per person:**

$$Number\ of\ people\ \times actual\ air\ flow\ rate\ per\ person\ (l.s^{-1})$$
$$= Fresh\ air\ total\ flow\ rate (l.s^{-1})$$

$$actual\ air\ flow\ rate\ per\ person\ (l.s^{-1}) = \frac{Fresh\ air\ total\ flow\ rate(l.s^{-1})}{Number\ of\ people}$$

$$actual\ air\ flow\ rate\ per\ person\ (l.s^{-1}) = \frac{2824.5}{410}$$

$$actual\ air\ flow\ rate\ per\ person\ (l.s^{-1}) = 6.88\ l.s^{-1}\ per\ person$$

Therefore, each person (410) received 6.88 $l.s^{-1}$ on day 1. This is 3.11 $l.s^{-1}$ less than what is required by the ASHRAE Standard and the SANS code 14001.

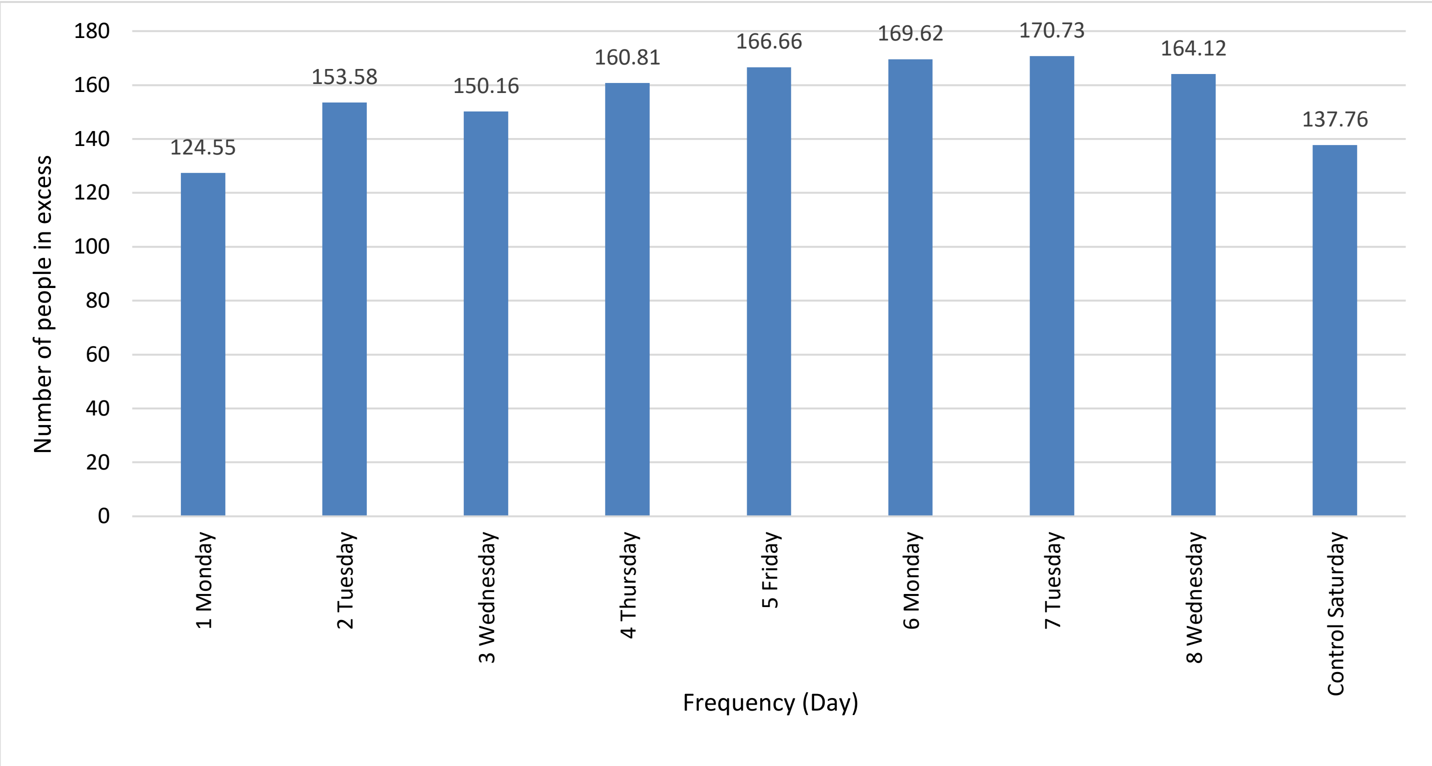
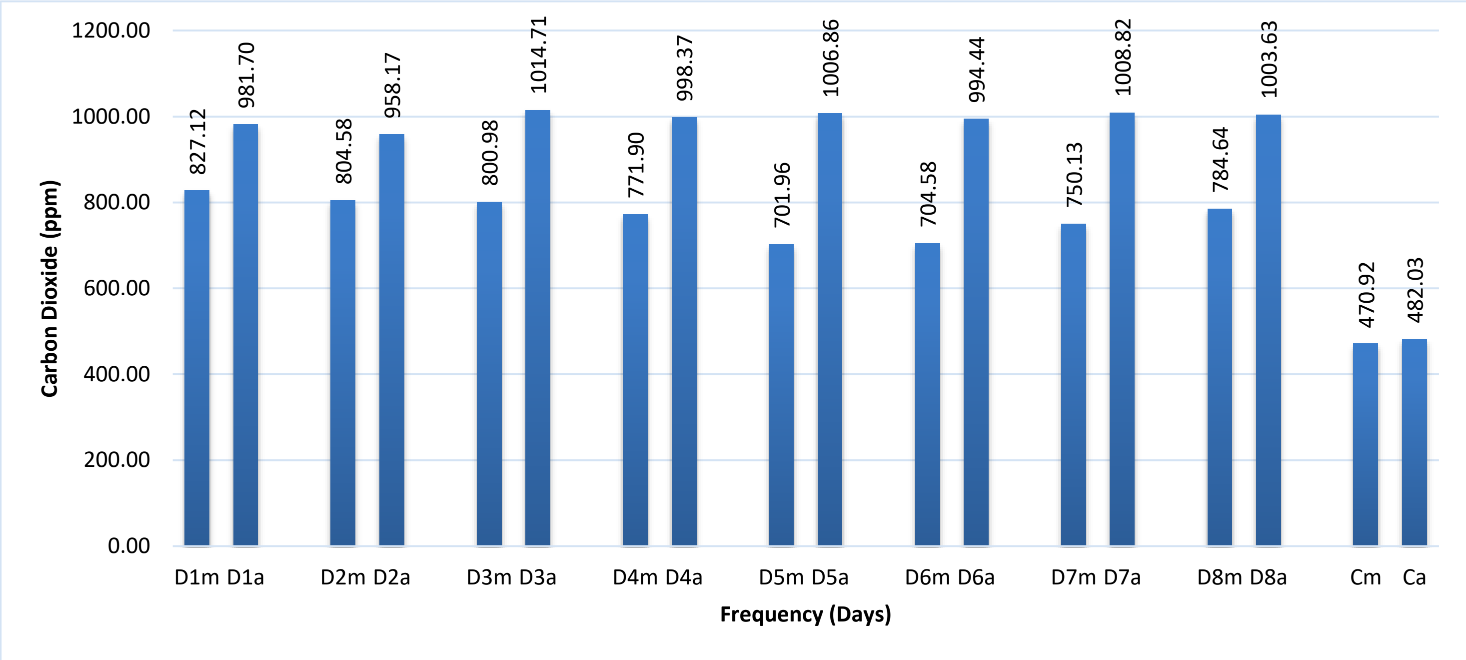



Figure 21: The excess number of people in the building according to the ventilation rate of the air-condition system for each day.

Figure 21 illustrated the number of people that are in excess of the required specification of the building size and air-conditioning system. As per the calculation above for day 1 there were approximately 124 people in excess of the building. The same calculation was applied on Excel for the other 8 days. Day 7 highlighted the highest number of people in excess, with 170 which suggests all 410 people in the building were receiving significantly less than 10 $l.s^{-1}$ as per person. Overall, on all days there was insufficient air per person due to the high number of excess people in the building.

### 5.3.2. Carbon dioxide

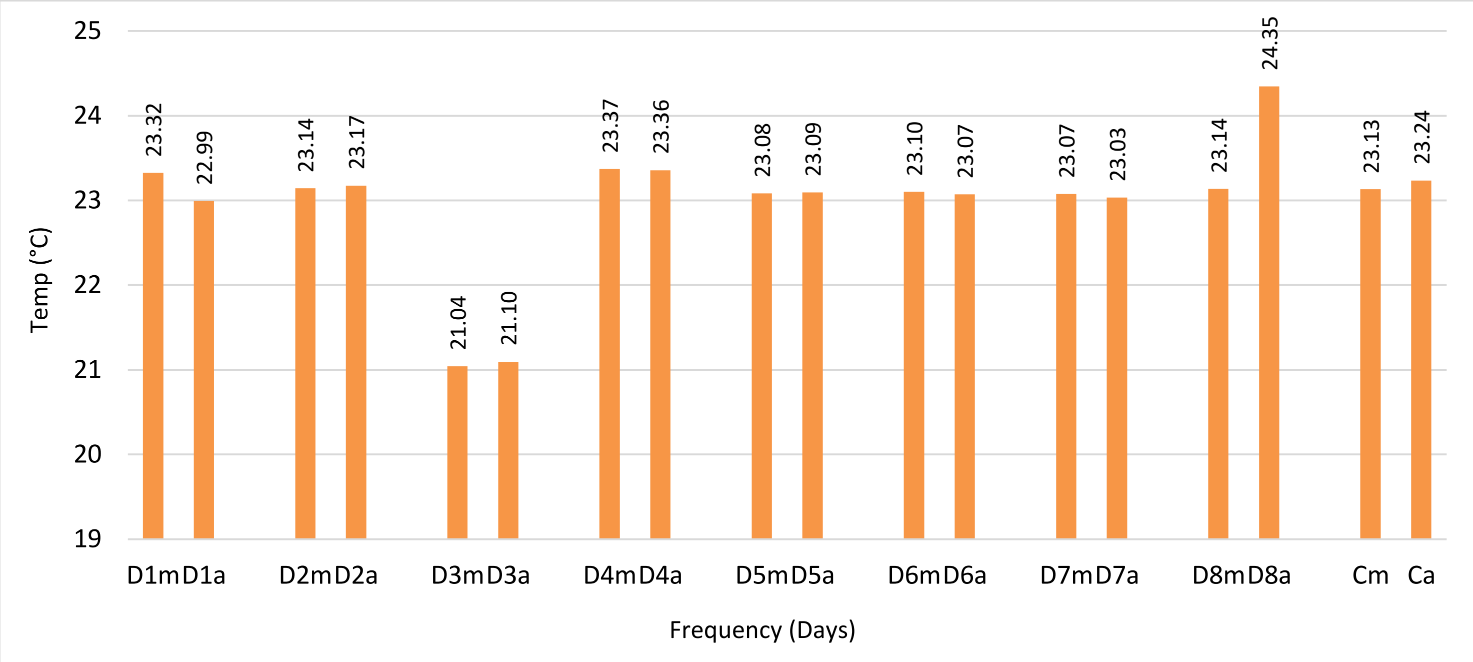



Key : D1m = Day 1 morning;  D1a = Day 1 afternoon; Cm = Control morning; Ca = Control afternoon

Figure 22: Mean values of carbon dioxide over 8 days in the morning and afternoon.

As per Figure 22 demonstrating the levels of $CO_2$ (in ppm), there is a significant increase of $CO_2$ in the afternoon as compared to the morning. The collective mean value for the morning was 768,24 ppm whereas, the afternoon mean value was 1000,84 ppm. There was an approximate mean of 232.60 ppm increase from the morning. The visual illustrated in Figure 22 clearly demonstrated the lower values in the morning and the higher values in the afternoon every day for the 8 day. These mean values do not include the control values that were collected. The control values for both morning and afternoon were approximately the same (Approximately 470 ppm - 480 ppm) and no significant difference ($p>0.005$), as seen with the other 1 to 8 days. Overall, there has been a clear pattern of lower values in the morning and higher values in the afternoon as per Figure 22.

### 5.3.3. Temperature




Key : D1m = Day 1 morning; D1a = Day 1 afternoon; Cm = Control morning; Ca = Control afternoon

Figure 23: Mean values of temperature over 8 days in the morning and afternoon.

The average temperatures were taken at each diffuser outlet over eight days with the ninth day being a control as presented in Figure 23. The morning and afternoon on day 3 presented a significant decrease in temperature compared to every other day. Day one to nine presented figures in approximately 23°C with no significant changes, while day three reached approximately 21°C. On day eight however, there was a slight increase of approximately 1.21°C.

## 5.4. GENERAL FACTORS

Secondary data was obtained from the company. A wellness day was held late during 2020. All employees who worked at this office building was required to participate. Medical data related to blood pressure, cholesterol test, sugar test, HIV test and BMI monitoring was obtained and conducted by professional medical practitioners. The data was then collated and given to the company in the form of a report with graphs, charts and basic statistics. Significant data related to this study was extracted. The report illustrated that 80.2 % of employees visited the general practitioner for upper respiratory tract infections. The highest in-hospital claim of 83% stemmed from signs, symptoms and disorders from the lungs and/ or air passages. Influenza, sinusitis, upper respiratory tract infections, signs and symptoms of a general disorder, dermatitis and eczema were the top ranked reasons for general practitioner (GP) visits with the highest cost of approximately R35 000 to R40 000. This was ranked the top number of visits as well as the highest claims paid for the year.

Furthermore, general observations of the building, through a walkabout, was made whilst objective sampling was conducted. Observations of the diffusers or vents revealed approximately 10 diffusers were stuffed with paper, 5 were completely closed, and 2 were damaged. The windows of the buildings were of good conditions as no breakage and damages were observed. The thermostat located in the air-conditioning unit room displayed a temperature of 25℃ in the building.

### 5.5. CONCLUSION

The results have shown that the employees inside the building of study do suffer from SBS. The interpretation, as well as the WHO’s definition of SBS has been fulfilled through common symptoms presented in the time frame. Although, there were several reasons for possible causes of SBS: temperature, ventilation and $CO_2$ levels were of uncommon or illegal limits. Chapter 5 results were further discussed in chapter 6. Thereafter, possible recommendations to eliminate or alleviate the syndrome from the environment were discussed in the ensuing chapters.

# CHAPTER 6

# DISCUSSION

## 6.1. INTRODUCTION

This study investigated the association between perceived indoor environmental conditions, indoor carbon dioxide levels, air flow rate, indoor temperature and the prevalence of SBS contributing to the health and wellbeing of employees in an administrative office building in Durban, KwaZulu-Natal. This study derived data from quantitative results in 2 phases. The 1st phase was to assess the perceived environmental, psychophysical and psychosocial stressors experienced amongst employees via a questionnaire administered by the researcher. The 2nd phase described carbon dioxide level, air flow rate and indoor temperature affecting employees in the building of study using occupational hygiene instruments. Phase 1 was analysed to depict, by the objective survey results in Phase 2, employee perceptions that were further validated or proved to have no association. Results from the questionnaires in Phase 1 were analysed in conjunction with the results from Phase 2 objective sampling. The organisation's existing health and safety management was directly observed during the investigation. Due to the COVID-19 global pandemic, the researcher was unable to include micro biological sampling of ambient fungi and bacteria in the air as originally planned as the laboratory which supplied the mediums and microbiological analysis was inundated with COVID-19 samples. This did not limit the study significantly, as the major factors were sampled and analysed. The cross-sectional field study results were discussed below.

## 6.2. DEMOGRAPHICS

The questionnaire response rate of 85% in this study was found to be much higher than the acceptable goal of 60% as mentioned by Fincham (2008: 1). There was no definitive reason for the high response rate. Truter (1993: 14), on the other hand, informed that a response rate of over 80% was common and especially achieved with self-administered questionnaires. In addition, a study on the association of SBS with indoor air parameters yielded a response rate of 94.3% among office employees of a similar study on SBS (Jafari *et al*. 2015: 55). Overall, the response rate for this study was more than was initially required.

Due to the nature of the work, almost all participants were English speaking with tertiary educations or held a matric. The company policy included all participants to remain under their designated medical aid scheme. The predominant age group was found to be between 18 and 40 years, with females being the predominant sex. This phenomenon may have been due to an office-based environment where women are commonly the predominant sex. This demographic was synonymous with several other studies globally (Zamani-Badi *et al.* 2019: 423; Zainal *et al*. 2019: 130; Jafari *et al.* 2015: 55; Turpin 2014: 19; Gomzi *et al.* 2007: 153; Gale *et al.* 2005: 10; Skyberg 2003: 246 and Helsop 2002: 434).

A considerably large body of studies conducted in different environments such as a university, hospital and office environment revealed a significant rate of symptoms reported by women rather men (Zamani-Badi *et al.* 2019: 423; Zainal *et al*. 2019: 130; Gale *et al.* 2005: 10; Gomzi *et al.* 2007: 153, Skyberg 2003: 246; Jafari *et al.* 2015: 55 and Helsop 2002: 434; Turpin 2014: 19). Conversely, Kayvani *et al*. (2017: 19-22) and Nopiyanti *et al.* (2019: 367) found no significant relation to gender and SBS. Gale *et al.* (2005: 10) and Edvardsson (*et al*. 2008: 806) indicated that the phenomenon of women being more prone to SBS was still unexplained and needs further research into the reasoning. More recent studies by Zamani-Badi *et al.* (2019: 427), Nopiyanti *et al.* (2019: 367) and Nakayama *et al.* (2019: 6), listed possible reasons for such a phenomenon, such as: 'risks of biological hereditary, genes and hormones, differences in the impact of risk factors that women encountered in the working environment, leisure time and lifestyle, a strong feeling of repulsion and sensitivity towards odors and environmental conditions". Other reasons, such as women often have a smaller body size and muscle strength than that of men, were highlighted.

This study illustrated a significant number of participants lay between the ages of 18 and 30 with the second highest age group of 31 to 40. These two age groups were relatively young, which was synonymous with several other studies. Many studies focused specifically on older and younger age groups and its association to SBS as mentioned below. A recent research in an office setting highlighted that younger employees reported more symptoms of SBS than elder employees (Zainal *et al*. 2019: 131). Nopiyanti *et al.* (2019: 368) argued that younger employees frequently experience more SBS symptoms than elder employees due to them having a stronger immune system and higher levels of stamina. As younger employees are healthier, they were able to feel simpler symptoms, compared to older aged, who seldom pay attention to milder symptoms. At variance with the findings Nopiyanti et al.(2019:368), a large office cross-sectional study conducted in thirteen different office buildings, reported to have elder employees report more frequently with more types of symptoms than younger employees (Skyberg *et al*. 2003: 250). While this phenomenon was still unexplained, Van Marken Lichtenbelt *et al.* (2017: 823) suggested that elderly people were at risk for other or enhanced ailments and conditions which could skew the data. There was no definitive reason and for the high number of females of a younger age in this study due to the several explanations in research.

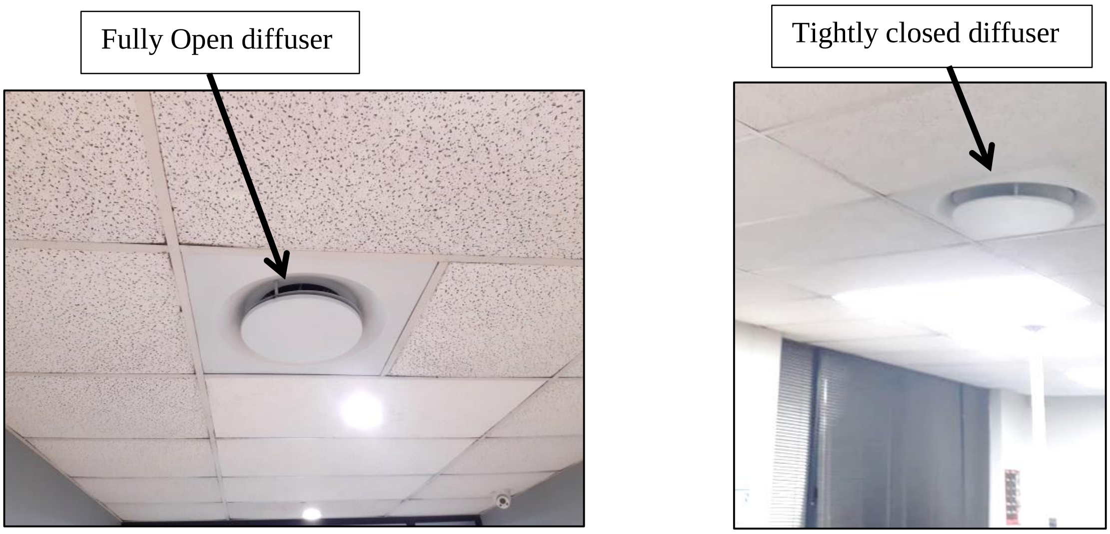



Figure 24: Opened and closed central air conditioning diffuser in the building.

**6.3. VENTILATION**

The lack of air circulation, air flow, stuffiness, bad odour and unacceptable air freshness described by most participants suggested that participants were not satisfied with their environment causing an uncomfortable working condition. This finding has been presented in several studies to depict a “sick” building (Forooraghi, Wallbaum, and Ryd 2019: 2; Jun, Hamzaha and Anuaa 2017:1). Due to the high number of dissatisfied participants with regards to IAQ, the level of satisfaction does not meet the ASHRAE requirement of 80% employee satisfaction to be deemed free of SBS.

As presented in the previous chapter, nearly all participants stated they had no control at all over the central air-conditioning system or natural ventilation to fresh air such as open doors and windows. Shadwell (1995: 1) highlighted that the lack of control over employee surroundings caused employees to feel anxious and uneasy, even frustrated and therefore negatively change their perceptions of the environment.

The perception of the ventilation within the building may be viewed as bias due to the personal perceptions received of the work environment. Therefore, ventilation air flow rates were objectively sampled using instruments. On the days sampled, including the control day, the minimum number of people in the building was continuously exceeded on all nine days. Consequently, this led to less than the required amount of fresh air received of approximately 7-10 $l.s^{-1}$ per person. The SANS code 10400 required 7.5 $l.s^{-1}$ as a minimum and ASHRE standard required 10 $l.s^{-1}$. The ASHRAE Standard was chosen in this study as the comparison limit as it would reflect the worst-case scenario of the highest required standard. The ventilation rates received in this study over all days sampled was less than what was required by both the ASHRAE standard and SANS code.

As per Figure 24 some diffusers were physically closed by employees. The air velocity was approximately $2.2m.s^{-1}$ because employees manually blocked the diffuser with paper or closed the diffuser, therefore possibly resulting in reduced air flow. Two diffusers were broken and bent. This manual act hinders the required flow of air being received into the office; revealingly, this may also suggest that the temperatures were not acceptable for comfort levels. Furthermore, the ASHRAE Standard 55-2017 stated that the common air flow rate was 0.8 $m.s^{-1}$ (Jasman, Nasaruddin and Tee 2019: 4). This was significantly lower than the air flow rate sampled, including the control day. The air velocity may have been increased significantly to compensate for the overcrowding as well as the poorly maintained air conditioning system.

Air velocity readings were irregular on day two; air velocity was higher in the morning and much lower in the afternoon. On other days it was irregular. On most days the airflow in the morning was consistent with the readings in the afternoon. The airflow readings on the first day was very irregular. The reason for this sudden irregularity was not explained. The inefficiency of the air-condition system may have resulted from a poor maintenance and air flow monitoring schedule which may or may not have existed. Poor building management had proved to be an important medium in which pollutants created harmful conditions for human health. Buildings determine the exposure of outdoor air supply by either facilitating entry of outdoor pollutants or acting as a barrier through filtration. Undoubtedly, the type of building management and structural design could cause harm to human health or improve work morale, productivity, efficiency and employee wellbeing (MacNaughton *et al*. 2017: 178).

Furthermore, insufficient fresh air has been known to reduce productivity and work efficiency. One study argued that when office employees received less fresh air employees exerted less work effort and typed 6.5 % fewer words with more errors on the computer (Rashid and Zimring 2008: 12 and Wargocki 1999: 176). Conversely, when there was an increase in ventilation up to 30 liters/sec/person, there was a direct increase in thinking, typing faster and increased work performance, including an increase in perceived IAQ and a decrease in sick leave amongst employees (Maula *et al*. 2017: 1141; Bennett 2012: 309; Seppänen and Fisk 2006: 4-5; Burge 2004:188 and Heerwagen 2000:8).

The study building was designed for 250 people where the airflow rate would have been adequate if 7 $l.s^{-1}$ was provided per person; however, 410 people were not adequately receiving fresh air as there was an excess of approximately 125 people on any given day, maybe more, due to visitors. Furthermore, as per appendix E, there was one department which was under construction whilst this study was conducted. The office was to be occupied from September 2020. This additional department in the building accounted for approximately 20 more employees which would have brought the total from 410 to 440 including new intakes from other departments. The increase in staff overcrowding would result in a further decrease of air flow rate per person. Overcrowding has a direct link to illness and absenteeism in the workplace. Overcrowding within the office space demonstrated a direct increase in the amount of $CO_2$ and bacteria; thus, leading to a decrease in the amount of adequate fresh air per person, consequently causing a decrease in work performance and wellbeing (Maddalena 2015: 361). In addition, indoor overcrowding facilitates provided easy transmission of bacteria and even some viruses, such as the influenza virus and the Corona Virus-19 through close transmission of particle droplets from sneezing and coughing (Peci *et al.* 2019: 2).

The predominant number of participants who felt unexplainably tired and drowsy at the end of the day, may be directly associated with the insufficient air received per person in the building. Furthermore, the significant high levels of $CO_2$ in the afternoon may also be contributing to the inexplicable tiredness/ drowsiness experienced by participants at the end of the day due to the lack of fresh air being received.

### 6.4. CARBON DIOXIDE

The levels of $CO_2$ in the morning fluctuated between a mean of 768,24 ppm and 1000,84 ppm. The morning readings were considered as typical levels of $CO_2$ in an office environment (Bonino 2016: 46-48). Contrary to these findings; the levels of $CO_2$ were above the legal limits off 1000 ppm in the afternoon, during sampling hours of 15h00 and 16h00.

There has been no study to date, which highlighted this phenomenon related to SBS, which cannot be explained without further investigation of the air-conditioning and extraction system. Furthermore, the results of the control samples clearly demonstrated the same levels of $CO_2$ in the morning and afternoon. The single difference between the sample results and control samples was the absence of employees therefore it can be said that the extreme $CO_2$ levels in the afternoon may be caused by employees. The increased levels towards the end of the day suggest several other reasons. This may be due to the ventilation extraction systems not working adequately causing an accumulation of $CO_2$ at the end of the day. Moreover, several diffusers were closed around the building, which hindered the amount of air flow being pushed into the building. This phenomenon was validated by the lack and outstanding maintenance records for the extraction systems.

A significant number of employees felt unexplainably tired/drowsy. Chapter 2 details the biological human effects of being exposed to high levels of $CO_2$ leading to haemoglobin oxygen deprivation causing the body to feel tired and dizzy (Lu *et al.* 2015: 3842 and Kapalo *et al*. 2018: 62). From the 73,3% of employees who felt tired/drowsy, more than half (58%) of employees specifically felt unexplainably tired/drowsy at the end of the day, as opposed to the morning. This further validated the accumulation of $CO_2$ at the end of the day. There were no other studies found with the similar findings and phenomenon which may be contributed to SBS.

Another reason for employees feeling tired/ drowsy at the end of the day could be there relationship between the accumulation of $CO_2$ and overcrowding in the building, which housed the current number of 410 employees, in contradiction with the built specification. Conclusively, there were several contributing factors for the high $CO_2$ levels, from overcrowding and poor maintenance to inadequate functioning of the extraction system. Carbon dioxide was used as an indicator of inadequate ventilation, poor odour control and overcrowding indoors in several studies (Ram 2019: 231; Jafari *et al.* 2018: 83; Gall *et al*. 2016: 59; Szczurek *et al.* 2015: 2193; Meintjies 2013: 25 and Brits 2011: 39). It can therefore be said there was inadequate ventilation and overcrowding within the building of study which did not meet South African and international standards.

## 6.5. TEMPERATURE

Approximately more than half of the participants believed that the temperature indoors was unacceptable. Several other studies have yielded similar results (Mavrogianni *et al.* 2013: 361 and Boerstra *et al.* 2015: 316). The unacceptable temperatures may be explained by the physical closure of diffusers around the building as per Figure 24. This initiative taken by employees was not highlighted in any other study. Furthermore, the manual closure of diffusers suggested that the temperatures were too low and therefore, by closing the diffusers, employees received less cold air.

The average reading coming out the diffuser was 22°C to 23°C at over 2 $m.s^{-1}$ , which was significantly above the recommended air flow velocity. The ASHRAE standard 2017 required temperatures between 20°C to 25.5°C; however, the previous version of the standard in 2015 required 23.8°C to 26.9°C in summer, which is when this study took place. Nevertheless, the indoor temperature was slightly lower than the required ASHREA standard required. Moreover, the temperature reading in the control room panel displayed 25°C, which was not the actual case; suggesting that the air-conditioning system may be compromised or not maintained.

On the third day of sampling, the temperature dropped significantly. There was no reason for this; however, this does indicate poor monitoring which could possibly lead to poor maintenance. Nevertheless, this was not conclusive as more than half of the participants viewed the building as well maintained, according to the data received. The specifications of building maintenance were not detailed in the questionnaire and therefore the question regarding building maintenance and infrastructure conditions may have been viewed as only superficial building maintenance, such as structural damages and not viewed to include the air-conditioning system or extraction systems.

## 6.6. LEVEL OF COMFORT

Skyberg *et al*. (2003: 251) highlighted that different types of factors are good indicators for reported symptoms of SBS, such as allergies, passive smoking, computer work and psychological load. Cleanliness within the office also had an impact on reported SBS symptoms. In one study, it was noted that when cleaning was performed once a week, there was an increased prevalence of reported symptoms, whereas, when cleaning was conducted three to four times a week, minimal complaints were reported. Bluyssen *et al*. (2016: 315) critiqued that cleaning processes undertaken in the evening rather than in the morning before employees arrive at work, have increased the prevalence of SBS and overall discomfort and office satisfaction in the workplace. Bluyssen *et al.* (2016: 315) argued that this occurrence was due to the cleaning activities being completed before ventilation was switched on, before employees began their work. This was not the case in this study as the ventilation was switched off every afternoon at 18h00 and started back up in the morning at 6h00. The cleaning services began work at only 19h00. The level of cleanliness was perceived to mostly be acceptable; nevertheless, after brief discussions with a few participants, it was concluded that certain areas were cleaned and vacuumed regularly, whereas others were not and were not on a schedule for cleaning, resulting in a buildup of dust, dirt and bad odour from old food.

Other factors such as odour control was deemed unacceptable by more than half of employees. Odour has a significant impact on overall comfort, as several other studies have investigated the positive relationship between odours and SBS (Kim *et al.* 2019: 633 and Wang *et al.* 2013: 2); This is in contrast to Rostron's (2008: 293) argument that sensory irritations, such as taste and smell of odours were not considered symptoms of SBS but rather environmental perceptions unique to specific individuals; therefore, bad odours were not a major investigation focus of this study.

Furthermore, comfort levels highly depend on physical comfort such as good ergonomics. The majority of participants felt overall comfort from their seating and work stations, as a significant number of participants stated they had backrests, leg room, arm rests and enough space to work on their desks. Musculoskeletal disorders can occur in any area of the body including the neck, shoulders, wrists, back, legs, knees and feet (Wiguna *et al.* 2020: 8). Poor ergonomics is known to result in back and body aches, headaches, which were also mentioned in other studies as a SBS symptom. To this end, ruling these symptoms out had given further clarification as to what the prominent causes of SBS were.

## 6.7. SICK BUILDING SYNDROME SYMPTOMS

Almost 90% of participants stated they did not suffer with any chronic illnesses; however, there was a significant number of participants suffering with watery eyes, dizziness, dry and burning eyes, fatigue/ tiredness, drowsiness/ lethargy, headaches, sinusitis, blocked /stuffy nose, runny nose, skin irritations, sore dry throat and influenza like symptoms which was confirmed by several other studies investigating SBS in buildings (Vafaeenasab *et al*. 2015: 247; Lu *et al.* 2015: 3841; Tsai, Lin and Chan 2012: 345; Bonino 2016: 46-48 and Azuma *et al*. 2018: 51). The most significant of all the symptoms was the headaches and sinusitis, which occurred more frequently and in more participants.

There was no relation to season and occurrence of these symptoms, as it was evident from the data that symptoms were not more or less prominent in any specific season. There was, however, significant relation to time of day in which symptoms were more prominent, and that was towards the end of the day, which was possibly explained in the reason above, given for the $CO_2$. The association between SBS and symptoms in different seasons was therefore ruled out as a confounding factor. This was contradictory to a study by Azuma *et al. (*2017: 2) who evidently highlighted how strong irritants in the air during the summer months, rather than other months, are known to cause severe skin and upper respiratory irritation.

The listed SBS symptoms mentioned here correlates to that of the common definition by WHO (Amouei *et al.* 2019: 2). Furthermore, the defining factor of SBS was decided if the symptoms disappear after a few hours of leaving the building. Almost all participants stated that this was true. Various other studies determined the prevalence of SBS by this factor (Yildiz 2020: 210; Lu *et al*. 2017:2; Orosa and Oliveira 2011: 482; Edvardsson *et al*. 2007:805 and Truter 1993: 11). Moreover, several studies mentioned WHO's definition of SBS as an occurrence when an average of 25% or more of employees complain of symptoms of SBS (Murniati 2020: 279, Gladyszewska-Fiedoruk 2019: 1; Thach *et al.* 2019: 2; Jun, Hamzah and Anua 2017: 8; Jafari *et al*. 2015: 55 and Jansz 2011: 3). In this study more than 25% of participants suffered with symptoms which were relived after they had left the building. Conclusively, due to the definition being fulfilled, it can be said that the study building was "sick".

The company of study participated in an annual wellness day held by the company's designated medical aid. The findings were of significant value as it highlighted important statistics with regards to medical interactions and health status for the year. The report illustrated that 80.2 % of employees visited the general practitioner for upper respiratory tract infections. This finding may be strongly linked to SBS symptoms. Due to the significant number of employees who visited the GP for flu like symptoms, skin conditions and upper respiratory tract infections may be related to the building of study. These are also the top symptoms presented in the common SBS definition above. The findings were profound in consolidating the results yielded from the researcher.

## 6.8. CONFOUNDING FACTORS

Participants were presented with a series of questions related to their life style, residing conditions and stress level. This was done to eliminate confounding factors so as to reach a conclusive result in investigating the prevalence of SBS in the office building of study. There have been no recent studies within the South African context which investigates the prevalence of SBS and eliminates the confounding factors.

Participants revealed their living conditions in terms of cleanliness and housekeeping to be mostly ‘extremely good’ and ‘fairly good’; however, half of the respondents were unsure; therefore, no conclusive result can be elicited from this. Cleanliness and housekeeping were pertinent factors to consider. Environmental conditions at home such as building dampness leading to the fungal and bacterial exposure, may possibly result in asthma and other respiratory illnesses (Adams *et al*. 2020: 1). Participants were further asked if they were exposed to water leaks or dampness at their work stations and the majority conceded that they had not. A thorough investigation ensured that all confounding factors were eliminated. Another example would be the prevalence of industries nearby. Almost all (90%) participants stated they do not live near smoke stack or chimneys, power stations or factories releasing smoke and hazardous chemicals. Exposure to such gas/chemical emissions have been known to results in cancers and other respiratory. Chemical emission from surrounding industries in the south Durban basin where school pupils were exposed to various chemicals leading to coughing, wheezing, chest tightness or heaviness, and shortness of breath (Kistnasamy *et al.* 2008: 366). Factors such as these may possibly mask or imitate the same symptoms as SBS.

Stress and workload have been widely known to cause a range of symptoms which can be misconstrued as SBS symptoms such as headaches and chest pains (Carrer and Wolkoff 2018: 6; Bluyssen *et al.* 2016: 299 and Runeson *et al.* 2006: 446). The level of control over employee workload has significant effects on overall satisfaction in the work environment and in turn, productivity and efficiency (Brauer and Mikkelsen 2010: 639 and Shadwell 1995: 1). In this study more participants leaned towards having no control to average control over their work load as well as their level of stress.

Confounding factors were easily identified, therefore resulting in more accurate and reliable results. In this study, the confounding effect of smoking was modest as almost 81% stated that they did not smoke or did not smoke at work. Those who did, smoked in designated smoking areas outside and away from the building. One study positively correlated smoking behaviour with exacerbated SBS symptoms. The elimination of this factor resulted in more accurate true results. Sulistyanto *et al.* (2020:1468) highlighted how smoking lowers the lung capacity and changes the structure and functioning of the respiratory tract and lung tissue making an individual more susceptible to SBS symptoms.

## 6.9. LIMITATIONS OF THE STUDY

The study design is similar to that of studies conducted internationally; however, this study did have certain limitations. A limitation to this study was the elimination of VOC exposure sampling, such as aliphatic hydrocarbons, aldehydes, acetone, and formaldehyde. This may have been a contributing factor towards the prevalence of SBS but it was never monitored; nevertheless, there were no major indicators to suggest these factors as possible causes.

Indoor environmental perceptions were self-reported by employees. This yielded recall bias as a result of inherent defects, as the strong association between the self-reported results and the objective monitoring cannot be explained by recalled bias (Sun *et al.* 2019: 118). Furthermore, individual responses to their perceptions of the environment were yielded. This may be a bias, or not a complete representation of the environment, as every individual experiences comfort and sensors differently.

Another major limitation to this study is the lack of sick leave data, medical boarding and retirement data due to ill health that was not used. Due to the company's policy, the researcher was unable to obtain this type of data. This data would've been beneficial to corroborate the findings of this study and possibly further validate what other studies have mentioned.

## 6.10. CONCLUSION

The study results strongly indicate that the office environment promotes both ill health and discomfort, resulting in several dissatisfied employees if selection bias and confounders can be excluded. The ASHRAE standard 62.1 (ASHRAE Standing Standard Project Committee 2016: 3) highlighted that an environment will be deemed satisfactory when 80% of the occupants' express satisfaction. This was not fulfilled. The common theme presented in these findings was poor maintenance and operation of the buildings systems; which was similar to the findings of Nopiyanti *et al.* (2019: 363). To summarise, low temperatures and high velocity rates did not compensate for the overcrowding and closed diffusers around the building, possibly leading to the high $CO_2$ levels in the afternoon. Added to this is a lack of air extraction due to the poor maintenance and operation of the system; consequently leading to SBS symptoms experienced by many employees. These results may have changed due to the skeleton staff working in the building because of the COVID-19 restrictions being put in place.

# CHAPTER 7

# RECOMMENDATIONS AND CONCLUSIONS

## 7.1 INTRODUCTION

In the previous chapter, the results of the findings were analysed and discussed. This chapter summarises the main findings and concludes with on a way forward to improve the working environment within the building. Although this study provides recommendations for an office-based environment, the improvements below may be applied to all buildings including medical facilities and schools. Very few studies have implemented or recommended remedial action after environmental measurements and results were taken after investigations were noted, more especially in a South African context (Brits 2011: 40-42; Turpin 2014: 18, 19 and Feit 2018: 20). This study hoped to provide evidence in aiding to close that gap locally. Although the study was not conclusive on the etiology of SBS, there were significant correlations between environmental conditions resulting in SBS symptoms, which fulfilled the common SBS definition used around the world. Nevertheless, several recommendations were suggested to improve the working environment according to the hierarchy of controls, as well as the identification of opportunities for future research. Finally, a summary was presented in conclusion of the study.

## 7.2. IMPROVING THE WORKPLACE ENVIRONMENT

The hierarchy of control steps are applied to ensure prevention of indoor environmental factors as reasonably practicable, with the elimination stage being the first and most important step to begin with and PPE being the least important (Turpin 2014: 18-19; Brits 2011: 40-42; Rostron 2008: 293 and Feit 2018: 20). This concept has been adopted in several countries nationally and internationally and is commonly used in the field of OHS (Ahmad and Hassim 2015: 169).

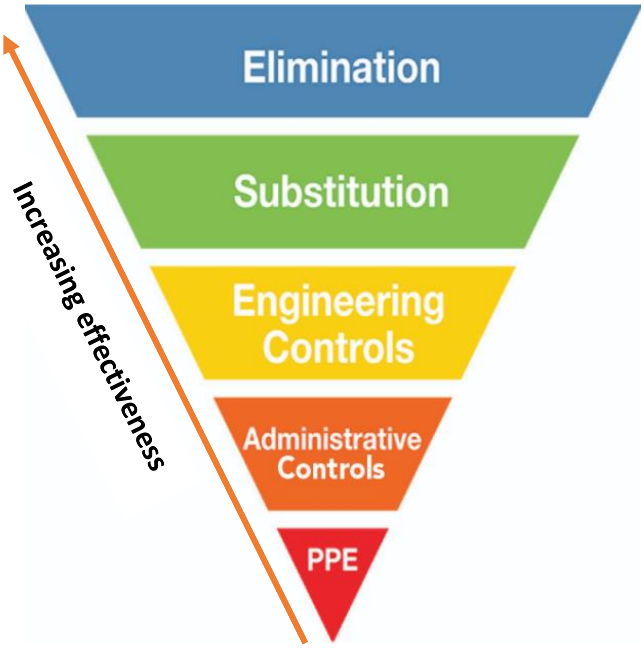



Figure 25: Hierarchy of controls (Druley 2018: 1).

**7.2.1. Elimination controls:**

The complete elimination of factors contributing to SBS was difficult; notwithstanding that there are limited ways to eliminate certain factors, such as unsatisfactory temperatures by avoiding too high or too low indoor temperatures through adhering to guideline limits stated in the ASHRAE standard 55 – 2017, Thermal Environmental Conditions for Human Occupancy (ANSI Approved) (Turpin 2014: 18). Another factor which may possibly be contributing to SBS and calls for possible elimination may be the removal of carpeting or flooring material that accumulates dust (Turpin 2014: 19). This may be substituted with tiles which are more hygienic and easier to clean more often.

**7.2.2. Substitution controls:**

Substituting one hazardous factor with something less negatively impactful, has been identified through substituting building materials with good quality building materials such as tiling, water resistant paint on ceilings and walls and treated furniture (Brits 2011: 40). Wet stains were identified in areas around the building and therefore, substituting wet stained ceiling tiles or carpeting with new dried ones will ensure carpet and building dampness is not a factor contributing to SBS as presented in many other studies (Brits 2011: 40).

### 7.2.3. Engineering controls:

There were several possible engineering controls identified to ensure a better working environment. The main engineering control, which may be costly, but may make a significant difference, would be redesigning the mechanical ventilation system according to legal standards and guidelines, such as the ASHRAE Standard 62- 2017 (Rostron 2008: 293 and Akinwale *et al.* 2019: 22). This may compensate for the larger number of employees working in the building. The redesigning process may include installing more operable windows (Rostron 2008: 293) or venting indoor polluted sources into outdoor locations away from sources of pollutants (Brits 2011: 40). Another important factor would be to ensure adequate local exhaust ventilation at sources of indoor air pollutants, odours and moisture generation (Feit 2018: 20). The accumulation of air pollutants, odours and moisture can be eliminated by the installation of air cleaners, in addition to the existing mechanical ventilation system (Brits 2011: 41 and Akinwale *et al.* 2019: 22). Ideally, extending the building structure to avoid overcrowding would be the best option; however, this is costly. Engineering controls would require permission from the estate as well as the landlord for the building.

### 7.2.4. Administrative controls:

It was found that the management was generally committed to environmental, health and safety; however, once complaints or findings were raised, management were more reactive rather than proactive in ensuring the health, comfort and wellbeing of employees. Platforms such as safety health committee meetings may be used to raise employee concerns via safety health environmental representatives (SHE) within the building. Upskilling these SHE Representatives will provide more thorough findings when they conduct monthly building and SHE inspections in their designated areas. Another platform whereby employees may raise their concerns is directly through the building maintenance team.

Good communication between management, building maintenance/ utilities and employees should exist. Wellness days or group emails sent to the entire building may be utilized to include SBS awareness and ways in which controls can be implemented to ensure that a healthy, comfortable and satisfactory working environment is achieved (Rostron 2008: 299; Akinwale *et al.* 2019: 22 and Brits 2011: 42). The wellness days may include items such as ergonomic information on how to identify poor postural positions at their work stations and how to improve this. Platforms should be created via which employees may report hazardous, uncomfortable environments and incidents such as water leaks, which can lead to dampness and mold/ fungal growth.

The company should exert more effort into developing concrete cleaning schedules for the entire office. This includes scheduled deep cleaning of carpets, chairs and surfaces. If resources are not adequate, the company should invest in additional workers or services. Regular maintenance and cleaning of the ventilation system is important as, regular cleaning or replacements of filters are important to ensure a clean, healthy environment (Turpin 2014: 18; Brits 2011: 40 and Ahmad and Hassim 2015: 168). It is important to note when painting, cleaning, waxing floors or any other pollutant generating activities is being conducted that ventilation rates should be increased before and after such activities (Feit 2018: 20). Furthermore, regular monitoring tests of the mechanical ventilation system against design values and regulations or standards should be arranged (Turpin 2014: 18).

The mechanical system was designed to supply a recommended number of occupants, anything over this will generate IAQ problems (Brits 2011: 40). Therefore, prevention of overcrowding is vital, not only for employee health and comfort but also to ensure the COVID-19 pandemic restrictions are maintained. Maintaining a work space of $2.5m^2$ per person is adequate to ensure legal and comfort compliance. Given that the company does not own but rather rents out the building, moving half the employees over to another building in the estate may be another option to ensure adequate spacing.

#### 7.2.5. Green buildings:

The aim of 'green' buildings is to reduce the environmental footprint through intelligent design buildings with green designs, operations and maintenance. A simple example would be to include more plants around the office stations. These controls lower several key pollutants, such as volatile organic compounds (VOC's) and allergens. 'Green' buildings strictly adhere to guidelines and standards for ventilation and filtration of the building; making them efficient, successful and desired. Moreover, it has been said that 'green' buildings were associated with low indoor pollutants, resulting in fewer complaints and incidents of SBS (Al Horr *et al*. 2016: 385; Allen *et al.* 2016: 805-806 and Pelser 2013: 5). Patel *et al.* (2019: 1435) demonstrated how green buildings resulted in occupants feeling less stressed, less depressed with lower anxiety levels. Likewise, Wang (2019: ii, D5) acknowledged that combined energy efficient methods used in buildings were strongly associated with improved health, less asthma, allergies, SBS and improved respiratory symptoms; consequently, reducing absenteeism, improving productivity and reducing staff turnover. It was noteworthy that no research has been done in 'green' buildings where surveys were given out to employees who were oblivious of their building condition, such as the aspect of bias where participants are unaware of the green building control (Allen *et al.* 2016: 805-806 and Pelser 2013: 5). Furthermore, no research on green buildings within the South African context has been completed.

## 7.3. FUTURE RESEARCH

This study can be expanded by including all sampling factors such as bacterial and fungi in the workplace environment. Other factors include, VOC's, noise, ergonomics, dust and humidity. Objective sampling of these factors in conjunction with the questionnaire, including several office buildings as part of the study and medical examinations of participants will fully cover all aspects of SBS and therefore a solid and more conclusive etiology for SBS may arise.

International studies have abundant research on SBS, yet there has been a severe lack of research on SBS in South Africa. The last most comprehensive SBS study was conducted in 1993 (Truter 1993:1). Given that this study, that has included both a subjective questionnaire and objective sampling, will be the most recent research within South African, more specifically KwaZulu- Natal, it will provide other researchers with a point of departure to continue fill this research gap within South Africa.

A more recent study by Wang (2019: D5) highlighted the nine foundational elements to a healthy building, which was based on previous rated green buildings. "The nine foundational elements of healthy buildings included indoor air quality, ventilation, thermal health, water quality, as well as dampness and mold, dust and pests, noise, light and views, safety and security". Previous research had not explored the nine foundational elements and therefore further investigation into these nine elements may contribute to South African research as a whole in the future.

Furthermore, South Africa has extremely limited research on green buildings and improvements towards becoming a green building. Green buildings results highlighted that participants in 'green; certified buildings had better environmental perceptions, 30%

reduction in SBS symptoms, 26,4% higher cognitive function and 6,4% better sleep quality score compared to participants in the normal commercial building. It was suggested that sleep quality was influenced by environmental factors during working hours. These results confirm how well maintained and efficiently operating buildings had a positive effect on employee health and even reduce incidences of SBS (MacNaughton *et al*. 2017: 178-183).

### 7.4. CONCLUSION

In summary, research has been completed over many years on SBS and indoor work environments. To date, there still is no specific one etiology for SBS. This study has identified more than one possible contributing factor to the prevalence of SBS, namely; poor ventilation; high $CO_2$ concentrations, lack of building maintenance and low temperatures. The key is for companies to manage all building related operations, maintenance and functioning to ensure a healthy working environment free from causing any illness or hazards. Literature reviewed highlighted and is supported by this research, which confirms that SBS is caused by a number of factors. After investigations through objective sampling and perceptions of the environment, significant correlations were achieved between factors and SBS through symptoms displayed which defined SBS.

Old and new buildings are here to stay, therefore companies need to ensure better care of their employees and buildings as it could result in a knock-on effect. As an example, a poorly maintained building which traps pollutants inside, may result in unforeseen building and maintenance costs, ill employees who cannot work due to their symptoms which results in less productivity and efficiency as well as business loss. This may also lead to increased sick leave days and law suits filed against the company. Law suits against companies of this nature may not yield a positive outcome as the South African international labour declarations and constitution calls for decent and humane work environments.

In summary, building maintenance of the ventilation system, including the extraction and air-conditioning system, contributed to the accumulation of pollutants within the environment, resulting in SBS symptoms experienced by participants. The main objectives of this study have been achieved and it can be concluded that SBS does exist in the office building of study where most participants highlighted their concerns of their unsatisfactory work environment. The SBS definition has been fulfilled and with the implementation of recommendations such as scheduled building maintenance and management, SBS may be alleviated. More studies are required to provide reliable investigation in finding the etiology of SBS which could lead to effective preventative strategies.

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**APPENDIX A** **QUESTIONNAIRE**

**INSTRUCTIONS**

**Cross (X)** the option(s) that applies to you in the appropriate box. Please answer all questions. Additional spaces are provided for you to enter details as you feel necessary.
Please note all information below will be anonymously disclosed so please answer as truthfully as possible.

**Questionnaire number** ______________

## A. Personal and demographic data

1. Gender

| | |
|---|---|
| Male | 1 |
| Female | 2 |
| Other | 3 |

2. Age

| | |
|---|---|
| 18 - 30 | 1 |
| 31 - 40 | 2 |
| 41 - 50 | 3 |
| 51 – 60 | 4 |
| 61 - 65 | 5 |

3. Level of education

| | |
|---|---|
| No schooling | 1 |
| Primary schooling | 2 |
| Grade 6-10 | 3 |
| High school matriculate | 4 |
| Tertiary education | 5 |

4. Marital status

| | |
|---|---|
| Single | 1 |
| Married | 2 |
| Widowed | 3 |
| Living with a partner | 4 |
| Not sure | 5 |

5. Employment status at the office

| | |
|---|---|
| Part time (a few times a week / hourly) | 1 |
| Full time employment (5-7 days a week) | 2 |
| Not sure | 3 |

## B. Residential Status

1. What is your view of the cleanliness/ housekeeping conditions in your place of living most of the week?

| | |
|---|---|
| Extremely bad condition | 1 |
| Bad condition | 2 |
| Acceptable condition | 3 |
| Fairly good conditions | 4 |
| Extremely Good condition | 5 |

2. How long have you been living here?

| | |
|---|---|
| Under 1 year | 1 |
| More than 1 year. Please state below. | 2 |
| | |

3. Do you live within two kilometers of any of the following?

| | No | Not sure | Yes |
|---|---|---|---|
| Smoke stack / Chimney | | | |
| Power stations | | | |
| Factory/ industry releasing smoke and hazardous chemicals | | | |

## C. Health Status

1. Do you have any chronic illness/es?

| | |
|---|---|
| No - Answer question **2** | 1 |
| Yes - Answer question **1.1 and 1.2** | 2 |

1.1. What chronic illness/es do you have?

______________________________________________

______________________________________________

______________________________________________

1.2. Do you take chronic medication every month?

| | |
|---|---|
| No | 1 |
| Yes – Answer question **1.3** | 2 |

1.3. Name the type of chronic medication do you take?

______________________________________________

2. Do you smoke cigarettes?

| | |
|---|---|
| No – Answer Question **2.3** | 1 |
| Yes - Answer questions **2.1** & **2.2** | 2 |

2.1. Please indicate approximately how many cigarettes do you smoke a day?

_______________________________________________

2.2. Where do you smoke during working hours?

| | |
|---|---|
| In a designated smoking section outside the office | 1 |
| In your office space | 2 |
| In the office building | 3 |
| A far distance away from the office building | 4 |
| I do not smoke during working hours | 5 |

2.3. Does anyone in your immediate working vicinity smoke?

| | |
|---|---|
| No | 1 |
| Not sure | 2 |
| Yes | 3 |

3. Do you suffer from any allergies?

| | |
|---|---|
| No | 1 |
| Yes (Specify below) | 2 |
| | |
| | |

## D. Job and office environment

1. . How long have you been employed at this company?

| | |
|---|---|
| Under 1 year | 1 |
| 1-2 years | 2 |
| 3-5 years | 3 |
| 5-10 years | 4 |
| more than 10 years | 5 |

2. What is the average time you spend daily traveling to and from work?

| | |
|---|---|
| 0 - 15 minutes | 1 |
| 16 - 30 minutes | 2 |
| 31 - 60 minutes | 3 |
| 61 - 120 minutes | 4 |
| More than 120 minutes | 5 |

3. Approximately how many days a week do you work in your office?

| | |
|---|---|
| 1 day a week | 1 |
| 2-4 days a week | 2 |
| 5 or more days a week | 3 |

4. Are any of the following items regularly used at your work station?

| | |
|---|---|
| Portable cooling fan | 1 |
| Portable air filter / cleaner | 2 |
| Portable heater | 3 |
| Portable humidifier | 4 |
| None | 5 |

5. Please cross **all** condition(s) below that best describe your current work area (during 2019)

| | Completely unacceptable | Unacceptable | Unsure | Acceptable | Completely acceptable |
|---|---|---|---|---|---|
| Temperature | | | | | |
| Air circulation/air flow | | | | | |
| Air freshness | | | | | |
| Cleanliness | | | | | |
| Dusty air | | | | | |
| Humidity | | | | | |
| Noise level | | | | | |
| Dirty | | | | | |
| Darkness / dim | | | | | |
| Brightness | | | | | |
| Stuffiness | | | | | |
| Odour | | | | | |
| Comfort | | | | | |
| Building maintenance | | | | | |

6. Does your desk / work area have enough arm space?

| | |
|---|---|
| No | 1 |
| Not sure | 2 |
| Yes | 3 |

7. Does your desk / work area have enough leg space?

| | |
|---|---|
| No | 1 |
| Not sure | 2 |
| Yes | 3 |

8. Does your seat have an arm rest?

| | |
|---|---|
| No | 1 |
| Not sure | 2 |
| Yes | 3 |

9. Does your seat have a back rest?

| | |
|---|---|
| No | 1 |
| Not sure | 2 |
| Yes | 3 |

10. Is your work station comfortable?

| | |
|---|---|
| No (please specify why below) | 1 |
| Yes | 2 |
| | |
| | |

11. Do you work with a computer / laptop?

| | |
|---|---|
| No – Answer question **12** | 1 |
| Not sure | 2 |
| Yes - Answer **11.1; 11.2; 11.3** | 3 |

11.1. How many hours a day do you work with a computer/laptop

| | |
|---|---|
| 1-2 hours | 1 |
| 2-5 hours | 2 |
| 5-8 hours | 3 |
| If more, please specify | 4 |
| | |

11.2. Do you experience glare from the computer/ laptop?

| | |
|---|---|
| No | 1 |
| Not sure | 2 |
| Yes | 3 |

11.3. Do you use an anti-glare screen?

| | |
|---|---|
| No | 1 |
| Not sure | 2 |
| Yes | 3 |

12. Are there windows/doors that you can open in your office to receive fresh air?

| | |
|---|---|
| No | 1 |
| Not sure | 2 |
| Yes | 3 |

13. In the past month has your office been –

| | No | Not sure | Yes |
|---|---|---|---|
| Refurbished / refitted | | | |
| Repainted | | | |
| Carpeted | | | |
| Relocated | | | |
| Steam cleaned | | | |

14. To what extent are you satisfied with your job?

| | |
|---|---|
| Very unsatisfactory | 1 |
| Dissatisfied | 2 |
| Satisfied | 3 |
| Very satisfied | 4 |
| Completely satisfied | 5 |

15. What amount of control do you have over your workload?

| | |
|---|---|
| No control at all | 1 |
| Less than average control | 2 |
| Average control | 3 |
| More than average control | 4 |
| Complete control | 5 |

16. In your opinion, how stressful is your job?

| | |
|---|---|
| Not stressful at all | 1 |
| Less than average stress | 2 |
| Average stress | 3 |
| More than average stress | 4 |
| Very stressful | 5 |

17. What level of control do you have over the following factors in your office?

| | No control at all | Less than average control | Average control | More than average control | Complete control |
|---|---|---|---|---|---|
| Mechanical ventilation | | | | | |
| Natural ventilation | | | | | |
| Room temperature | | | | | |
| Humidity levels | | | | | |
| Work load | | | | | |
| Levels of stress | | | | | |

18. Does one or more of the above mentioned conditions affect your ability to work? Which one and how?

______________________________________________

______________________________________________

______________________________________________

______________________________________________

19. Are there any indoor environmental or occupational factor/s hindering your work efficiency at work, name them?

______________________________________________

______________________________________________

20. Have there been any water leaks around your work station in the last 6 months?

| | |
|---|---|
| No | 1 |
| Not sure | 2 |
| Yes | 3 |

21. Is there dampness of any building material, carpeting or furniture around you?

| | |
|---|---|
| No | 1 |
| Not sure | 2 |
| Yes | 3 |

22. Did you notice any of these strange odors around your work station?

| | |
|---|---|
| Bitter | 1 |
| Burning substance | 2 |

| | |
|---|---|
| Sweet | 3 |
| Hydrocarbon / solvent | 4 |
| Excessive perfume | 5 |
| Tabaco smoke | 6 |
| None | 7 |

23. How effective are the cleaning services at your office?

| Completely unacceptable | Unacceptable | Unsure | Acceptable | Completely acceptable |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

24. How often is vacuuming conducted at your office space?

| | |
|---|---|
| Not at all | 1 |
| Seldom | 2 |
| Unsure | 3 |
| Often | 4 |
| Always (everyday) | 5 |

25. How often do you take sick leave in a month?

| | |
|---|---|
| Less than 1 day a month | 1 |
| 1 day a month | 2 |
| 2- 4 days a month | 3 |
| 5 or more days a month | 4 |

26. What are the general reasons for you taking sick leave?

______________________________________________________________________________

______________________________________________________________________________

27. Do you feel unexplainably tired/ drowsy during working hours?

| | |
|---|---|
| No –Answer **section E** | 1 |
| Yes – Answer question 2**8 next** | 2 |

28. During which part of the day do you feel tired/ drowsy?

| | |
|---|---|
| Morning | 1 |
| Afternoon | 2 |
| Evening | 3 |

## E. Medical history

1. Cross the following episodes, **if any**, that you may feel are related to your working conditions or have experienced **at work** in the last **3 months**.

| Symptoms and conditions | Seldom | 1-3 times a month | 1-3 times a week | Almost every day | Everyday |
|---|---|---|---|---|---|
| Aching joints | | | | | |
| Back pain | | | | | |
| Chest congestion | | | | | |
| Chest pains | | | | | |
| Contact lens problems | | | | | |
| Watery eyes | | | | | |
| Disorientation | | | | | |
| Dizziness | | | | | |
| Dry and burning eyes | | | | | |
| Fatigue/ tiredness | | | | | |
| Drowsiness/ lethargy | | | | | |
| Headaches | | | | | |
| Sinusitis | | | | | |
| Blocked / stuffy nose | | | | | |
| Runny nose | | | | | |
| Excessive sneezing | | | | | |
| Nasal congestion | | | | | |
| Nausea | | | | | |
| Nose bleeds | | | | | |
| Palpitations | | | | | |
| Skin irritations | | | | | |
| Sore dry throat | | | | | |
| Insomnia | | | | | |
| Unusual taste | | | | | |
| Ear problems | | | | | |
| Dry skin | | | | | |
| Flu like symptoms | | | | | |
| Anxiety | | | | | |
| Nervous conditions | | | | | |
| Asthma | | | | | |
| Difficulty breathing | | | | | |
| **None (answer Section F next)** | | | | | |
| **Other (specify)** | | | | | |

2. Do the above ticked symptom(s) clear up within a few hours (1-3hrs) after leaving the building?

| | |
|---|---|
| No | 1 |
| Yes | 2 |

3. Are you aware of other people with your similar symptoms / concerns?

| | |
|---|---|
| No | 1 |
| Yes (Specify how many people below) | 2 |
| | 3 |

4. Have you noticed any other events (such as weather, temperature, odor or humidity changes) in the building that tend to occur around the same time as your symptoms? Please explain.

________________________________________

________________________________________

________________________________________

5. Which of the below seasons are you bothered more by the symptoms listed above during working hours?

| | |
|---|---|
| Winter | 1 |
| Summer | 2 |
| Spring | 3 |
| Autumn | 4 |
| No relation to season | 5 |

6. In the past two months, has your health - (tick one)

| | |
|---|---|
| Deteriorated | 1 |
| Improved | 2 |
| Remained the same | 3 |

## F. General

1. Is there anything else you would like to add about your work environment, please discuss below (for example, evidence of pest infestation, mold growth etc).

| |
|---|
| |
| |
| |
| |
| |
| |

**Thank you so much for your participation in this study**

**Appendix B**

**LETTER OF INFORMATION**

Warm Greetings!

My name is Demi Moodley and I am currently doing my Masters of Health Science in Environmental Health at Durban University of Technology. I would appreciate your participation in this study. Below covers more information regarding the study.

**Title of the Research Study:**

**An evaluation of Sick Building Syndrome amongst administrative employees in an office environment in Durban, KwaZulu Natal.**

**Principal Investigator/s/researcher:**
Demi Moodley (Master of Health Science: Environmental Health 2019)

**Co-Investigator/s/supervisor/s:**
Supervisor- Ivan Niranjan (Dr); Co-supervisors – Shanaz Ghuman (Dr) and Naadiya Nadesen (Masters).

**Brief Introduction and Purpose of the Study:**
When considering the health and wellbeing of employees, building designs and management are vitally important aspects and are roots of productivity and efficiency at the workplace. The majority of office employees spend between 5-8 hours of their day, 5 days a week in an office environment. For this reason, much attention over the years has been placed on indoor physical environments and occupant's health with recommendations to improve the work environment; however, there is a paucity of research investigating the association of the physical environment and Sick Building Syndrome in the South African context.

**Outline of the Procedures:**
The study will employ a method of multi-disciplinary triangulation whereby I will conduct physical monitoring, namely; air ventilation rates, temperature and humidity levels. Chemical monitoring of $CO_2$ levels and finally, biological monitoring of airborne fungal and bacterial concentrations will be conducted. The results yielded will be validated using a self-administrative questionnaire handed to 250 employees at their desk. There will be 14 sections of the open plan layout where both male and females

will be chosen to participate in the study. An information and consent form (Appendix B) will be required of you to fill out. On completion, will you be able to participate in the questionnaire. Your name is not required so please answer all questions as truthfully as possible. The questionnaire will require 15-20 minutes of your time to fill out during any part of the day. If you would like to know what the final study outcomes are, inform the researcher on that.

**Risks or Discomforts to the Participant:**
No adverse effects are anticipated from this research.

**Benefits:**
There will be no benefits given to you. Researchers may use this data to extend their existing knowledge on Sick Building Syndrome within the South African context.

**Reason/s why the Participant May Be Withdrawn from the Study**
If you do not agree to sign the letter of information and consent form. You may also be withdrawn from the study if you display negative reactions at any time during the study.

**Remuneration:**
There will be no incentives paid to you. All participants will give voluntarily consent to be a part of the study.

**Costs of the Study:**
There are no costs involved for participating in this study.

**Confidentiality:**
Confidentiality of all the information given towards the research will be assured at all times. No names will be attached to the questionnaires and only the researchers will have access to this data. None of your individual responses will be made available to the company. The company will only receive an overall outcome after the data has been statistically analysed.

**Research-related Injury:**
The study does not have potential to cause any injury or harm to you.

**Persons to Contact in the Event of Any Problems or Queries:**
Please contact me (084 628 0119), my supervisor (Dr. Ivan Niranjan - 031 373 2034) or the Institutional Research Ethics Administrator on 031 373 2375. -
Complaints can be reported to the DVC: Research, Innovation and Engagement Prof S Moyo on 031 373 2577 or moyos@dut.ac.za.

**General:**
Your participation is voluntary, and the approximate number of participants will be disclosed. A copy of the information letter will be issued to you.

## CONSENT

**Statement of Agreement to Participate in the Research Study:**

I hereby confirm that I have been informed by the researcher, Demi Moodley (name of Researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: IREC 125/19

- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study,
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

| ______________________ | ___________ | ______ | ________________ |
|---|---|---|---|
| **Full Name of Participant** | **Date** | **Time** | **Signature/Right Thumbprint** |

I, Demi Moodley Herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

| **Demi Moodley** | ___________ | _____________________ |
|---|---|---|
| **Full Name Researcher** | **Date** | **Signature** |

***Please note the following:***

If you make a mistake completing this document e.g. a wrong date or spelling mistake, a new document has to be completed. The incomplete original document has to be kept in your file and not thrown away, and copies thereof will be issued to you.

**APPENDIX C**

## Questionnaire Evaluation Form

Please mark one box only

1. What is your opinion of the subject presented in this questionnaire?

| | |
|---|---|
| Extremely interesting | |
| Interesting | |
| Average | |
| Boring | |
| Very boring | |

2. Do you think the topics raised in this questionnaire were adequately covered?

| | |
|---|---|
| Yes | |
| No | |

3. What is your opinion about the Letter of Information?

| | |
|---|---|
| Very clear | |
| Clear | |
| Adequate | |
| Unclear | |
| Needs revising<br>How ? | |

4. How would you describe the instructions accompanying each of the questions?

| | |
|---|---|
| Very clear | |
| Clear | |
| Adequate | |
| Unclear | |
| Needs revising.<br><br>How ? | |

5. Do you think the questionnaire is too long?

| | |
|---|---|
| Yes | |
| No | |

6. What is your opinion of the wording of the questionnaire?

| | |
|---|---|
| The meaning of all questions is absolutely clear | |
| The meaning of most questions is clear | |
| There is too much chiropractic/medical jargon | |
| The questions will not be understood by laypersons | |
| The questionnaire needs to be revised because it is unclear | |

7. If you had any difficulty answering any question/s, please write the number/s of the question/s in the space below with a suggestion on how the question/s can be improved?

| |
|---|
| |
| |

Thank you for your most valuable time in helping me with my research project. Please be reminded that the topics discussed above are strictly confidential
(Levy 2016: 92).

**APPENDIX D: PERMISSION LETTER TO INSTITUITIONAL MANAGEMENT**

Miss Demi Moodley

Durban University of Technology

Department of Community Health Studies

Durban

4000

June 2019

To whom it may concern

Dear Sir

**RE: REQUEST FOR PERMISSION TO CONDUCT A STUDY**

I am a currently registered as a Master student in Environmental Health of Health Sciences at the Durban University of Technology (DUT). The title of the proposed study is: “An evaluation of Sick Building Syndrome amongst administrative employees in an office environment in Durban, KwaZulu Natal”.

The objectives of the study are:

1. To determine perceived environmental, psychophysical and psychosocial stressors experienced amongst employees at an administrative office in Durban during 2019-2020.

2. To determine indoor air ventilation rates, carbon dioxide, air temperature levels and relative humidity affecting employees at an administrative office site in accordance to the ASHRAE standards.

3. Using microbiological methods, this study will aim to determine the levels of bacterial and fungal contamination in the air at preselected locations of the office.

My study will be multidisciplinary to achieve the most accurate results. This study will firstly include a self-administered anonymous questionnaire handed to 250 employees. Secondly, occupational hygiene surveys will be conducted in the open plan office spaces.

The company name will be kept anonymous at all times during and after the study has been conducted. Results of the study may be published in an accredited medical journal to create further awareness among the administrative office industry. No research regarding Sick Building Syndrome has been published at DUT and very few within the South African context. This study will not only be beneficial to the company but to the occupational hygiene industry in South Africa.

I hereby request your permission to conduct a research study at your company.

Please find attached my research study proposal and ethics clearance certificate. Your permission to conduct the study at your facility will be sincerely appreciated.

Yours Sincerely,

Miss D.Moodley
Researcher ---------------------------------------------------------
Master of Health Science
Student
084 6280119
demimoodley@gmail.com

I.Niranjan (Dr)
Supervisor
031 373 2034 ---------------------------------------------------------
ivann@dut.ac.za

S. Ghuman (Dr)
Co-Supervisor
031 373 2807 ---------------------------------------------------------
shanazg@dut.ac.za

**Gatekeeper's permission**

Date: ______________________

Signature ________________________________

**APPENDIX E: FLOOR PLANS**

| KEY<br>Ground level and First level floor plan | |
|---|---|
| ▲ (green triangle) | Carbon dioxide sampling location |
| ● (red circle) | Air flow and temperature sampling locations |

## APPENDIX E: FLOOR PLANS


FIRST FLOOR PLAN — PARTITION LAYOUT

# APPENDIX F :IREC Approval letter

**Institutional Research Ethics Committee**
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

**www.dut.ac.za**

4 September 2019

Ms D Moodley
[redacted]

Dear Ms Moodley

**An evaluation of Sick Building Syndrome amongst administrative employees in an office environment in Durban, KwaZulu-Natal.**
**Ethical Clearance number IREC 125/19**

The Institutional Research Ethics Committee acknowledges receipt of your final data collection tool for review.

We are pleased to inform you that the data collection tool has been approved. Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the IREC acknowledges receipt of your gatekeeper permission letter.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely,

Professor J K Adam
Chairperson: IREC

DUT DURBAN UNIVERSITY OF TECHNOLOGY
2019 -09- 04
INSTITUTIONAL RESEARCH ETHICS COMMITTEE

## APPENDIX G: Paired Samples Test Table

| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Lower | Upper | | | |
| Pair 1 | D1m - D1a | 0,27872 | 0,56679 | 0,07317 | 0,13231 | 0,42514 | 3,809 | 59 | 0,000 |
| Pair 2 | D2m - D2a | 0,72056 | 0,60214 | 0,07774 | 0,56501 | 0,87611 | 9,269 | 59 | 0,000 |
| Pair 3 | D3m - D3a | 0,27944 | 0,46309 | 0,05978 | 0,15982 | 0,39907 | 4,674 | 59 | 0,000 |
| Pair 4 | D4m - D4a | -0,00372 | 0,18044 | 0,02329 | -0,05033 | 0,04289 | -0,160 | 59 | 0,874 |
| Pair 5 | D5m - D5a | 0,01411 | 0,16114 | 0,02080 | -0,02752 | 0,05574 | 0,678 | 59 | 0,500 |
| Pair 6 | D6m - D6a | 0,06767 | 0,11421 | 0,01474 | 0,03816 | 0,09717 | 4,589 | 59 | 0,000 |
| Pair 7 | D7m - D7a | 0,02994 | 0,11273 | 0,01455 | 0,00082 | 0,05906 | 2,058 | 59 | 0,044 |
| Pair 8 | D8m - D8a | 0,06167 | 0,11120 | 0,01436 | 0,03294 | 0,09039 | 4,295 | 59 | 0,000 |
| Pair 9 | D1m - Cm | 0,46467 | 0,66746 | 0,08617 | 0,29224 | 0,63709 | 5,392 | 59 | 0,000 |
| Pair 10 | D1a - Ca | -0,27806 | 3,91155 | 0,50498 | -1,28852 | 0,73240 | -0,551 | 59 | 0,584 |
| Pair 11 | D2m - Cm | 0,44983 | 0,62641 | 0,08087 | 0,28801 | 0,61165 | 5,562 | 59 | 0,000 |
| Pair 12 | D2a - Ca | -0,73472 | 4,09760 | 0,52900 | -1,79325 | 0,32380 | -1,389 | 59 | 0,170 |
| Pair 13 | D3m - Cm | 0,26006 | 0,50382 | 0,06504 | 0,12991 | 0,39021 | 3,998 | 59 | 0,000 |
| Pair 14 | D3a - Ca | -0,48339 | 4,02548 | 0,51969 | -1,52328 | 0,55650 | -0,930 | 59 | 0,356 |
| Pair 15 | D4m - Cm | 0,02239 | 0,25620 | 0,03308 | -0,04379 | 0,08857 | 0,677 | 59 | 0,501 |
| Pair 16 | D4a - Ca | -0,43789 | 4,11955 | 0,53183 | -1,50208 | 0,62630 | -0,823 | 59 | 0,414 |
| Pair 17 | D5m - Cm | -0,02144 | 0,15161 | 0,01957 | -0,06061 | 0,01772 | -1,096 | 59 | 0,278 |
| Pair 18 | D5a - Ca | -0,49956 | 4,11444 | 0,53117 | -1,56243 | 0,56332 | -0,940 | 59 | 0,351 |
| Pair 19 | D6m - Cm | -0,02139 | 0,15821 | 0,02042 | -0,06226 | 0,01948 | -1,047 | 59 | 0,299 |
| Pair 20 | D6a - Ca | -0,55306 | 4,11160 | 0,53081 | -1,61520 | 0,50908 | -1,042 | 59 | 0,302 |
| Pair 21 | D7m - Cm | -0,05028 | 0,17171 | 0,02217 | -0,09463 | -0,00592 | -2,268 | 59 | 0,027 |
| Pair 22 | D7a - Ca | -0,54422 | 4,11588 | 0,53136 | -1,60747 | 0,51902 | -1,024 | 59 | 0,310 |
| Pair 23 | D8m - Cm | 0,02522 | 0,18876 | 0,02437 | -0,02354 | 0,07398 | 1,035 | 59 | 0,305 |
| Pair 24 | D8a - Ca | -0,50044 | 4,11843 | 0,53169 | -1,56435 | 0,56346 | -0,941 | 59 | 0,350 |

**APPENDIX H: Delta Ohm Thermometer calibration certificate**

**RUNRITE ELECTRONICS** (PTY) LTD

REG NO 2016/537256/07
ESTABLISHED 1996
VAT NO 4340162256

Unit 2, 17 Caversham Road, Pinetown, Kwa-Zulu Natal, Republic of South Africa

P.O. Box 208, Sarnia, 3615 • Tel: +27 (0) 87 806 5570 • info@runrite.co.za • Fax: +27 (0) 86 010 7601 • www.runrite.co.za

## CALIBRATION CERTIFICATE

Calibration REF No: O2018399

**Company :** **Durban University of Technology**

Instrument Model: **HD2303.0 AnemoMeter**

Instrument Serial No: **12028190**

The Calibration of this instrument has been checked in accordance with the manufacturer's instructions using the below reference which itself has been certified under Certificate of

**Delta Ohm Thermometer S/N# 12009900**

and the instrument was found to be within the manufacturer's specification.

This certificate is issued without alteration and the calibration was correct at time of issue.

Recalibration should be performed after a period of 12 months, which has been chosen to ensure that under normal circumstances, the instruments accuracy remains within the desired limits.

NEXT CALIBRATION DUE: **12-March-2021**

Signed:

Date: 12-March-2020

Customer Signature:

**Digital Test Equipment For A Safer Work Environment**

## APPENDIX I: Drager Gas monitor calibration certificate

# Calibration Certificate

Dräger

| | | | |
|---|---|---|---|
| Customer | Drager Rental | Next Service | 2020/08/12 |
| Order number<br>Dräger Order No.<br>(calibration certificate No.) | SMO14022020_02 | Issue date of Certificate | 2020/02/14 9:38:13 PM |

| | | | |
|---|---|---|---|
| **Instrument** | X-am 5600 | **Instrument part number** | **Software version** |
| **Serial number** | ARMF-0014 | 8321373 | V7.6 |
| **Configuration** | Datalogger : yes | | |

| | IR-Sensor Channel No. 1 | IR-Sensor Channel No. 2 | EC-Sensor Channel No. 3 | EC-Sensor Channel No. 4 | EC-Sensor Channel No. 5 | EC-Sensor not installed |
|---|---|---|---|---|---|---|
| Displayed gas | CO2 | ch4 | Cl2 | H2S | SO2 | |
| Part number | 6811960 | 6811960 | 6810890 | 6811525 | 6810885 | |
| Serial number | 01MJ0438 | 06MJ0438 | 01MF0014 | 02MF0014 | 03MF0014 | |
| Measuring range | 5,00 Vol% | 100,00 %LEL | 20,00 ppm | 100,00 ppm | 100,00 ppm | |
| Last calibration | 2020/02/14 | 2020/02/14 | 2020/02/14 | 2020/02/14 | 2020/02/14 | |
| Calibration gas | CO2 | ch4 | Cl2 | H2S | SO2 | |
| Calibration gas concentration | 2,00 Vol% | 57,00 %LEL | 10,00 ppm | 15,00 ppm | 10,00 ppm | |
| Alarm level A1 | 0,50 Vol% | 10,00 %LEL | 0,50 ppm | 5,00 ppm | 0,50 ppm | |
| Alarm level A2 | 1,00 Vol% | 20,00 %LEL | 1,00 ppm | 10,00 ppm | 1,00 ppm | |
| Hygiene Evaluation Mode | inactiv | inactiv | inactiv | inactiv | inactiv | |
| Mean Value Period | 0 min | 0 min | 0 min | 0 min | 0 min | |
| STEL | 0,50 Vol% | 0,00 %LEL | 0,50 ppm | 5,00 ppm | 8,00 ppm | |
| TWA | 0,50 Vol% | 0,00 %LEL | 0,50 ppm | 5,00 ppm | 1,00 ppm | |
| Shift length | 0 min | 0 min | 0 min | 0 min | 0 min | |

**Results of zero point calibration (Date/Time) (2020/02/14 9:13:32 PM)**

| | | | | | | |
|---|---|---|---|---|---|---|
| Gas cylinder | Fresh Air | Fresh Air | Fresh Air | Fresh Air | Fresh Air | - |
| Calibration gas serial no. | | | | | | - |
| Set Value | 0,00 Vol% | 0,00 %LEL | 0,00 ppm | 0,00 ppm | 0,00 ppm | - |
| Isvalue (before) | -0,06 Vol% | 0,00 %LEL | 0,00 ppm | 0,00 ppm | 0,00 ppm | - |
| Isvalue (after) | 0,00 Vol% | 0,00 %LEL | 0,00 ppm | 0,00 ppm | 0,00 ppm | - |
| Result | OK | OK | OK | OK | OK | - |

**Results of span calibration (Date/Time) (2020/02/14 9:30:22 PM)**

| | | | | | | |
|---|---|---|---|---|---|---|
| Gas cylinder | 20.02.2020 | 20.02.2020 | 10.06.2020 | 20.02.2020 | 13.08.2021 | |
| Calibration gas serial no. | WO166026-7 | WO166026-7 | WO220972-12 | WO166026-7 | WO217800-2 | |
| Set Value | 2,00 Vol% | 57,00 %LEL | 10,00 ppm | 15,00 ppm | 10,00 ppm | - |
| Isvalue (before) | 2,80 Vol% | 59,00 %LEL | 8,20 ppm | 15,40 ppm | 12,80 ppm | - |
| Isvalue (after) | 2,02 Vol% | 57,00 %LEL | 10,10 ppm | 15,00 ppm | 9,90 ppm | - |
| Result | OK | OK | OK | OK | OK | - |

The device has been checked and the measured values correspond to the specifications. The measuring equipment used for the calibration is regularly adjusted and traceable to the national standards. If measuring method corresponds with the current technical regulations and standards.

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Service engineer
Signature


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