Master Thesis

Indoor Air Quality and Health:

Study of Prevalence of Sick Building Syndrome and the Association of Perception of Indoor Air Quality and SBS among Workers in Offices in Hamburg

HAW HAMBURG

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Date: 03.09.2021 Maya Pradeep

Place: Hamburg, Germany

List of Abbreviations

AQG	Air Quality Guide
ASR	Ausschuss für Arbeitsstätten
BAuA	Bundesministerium für Arbeit und Soziales
CI	Confidence Interval
CO_2	Carbon dioxide
^0C	degree Celsius
df	Degrees of freedom
DGUV	Deutsche Gesetzliche Unfallversicherung e.V.
ECG	Electrocardiogram
EEG	Electroencephalogram
η	Eta
ETS	Environmental Tobacco Smoke
EU	European Union
FTZ-NK	Forschung und Transferzentrum ``Nachhaltigkeit und Klimafolgen Management``
H_0	Null Hypothesis
H_1	Alternative Hypothesis
HCHO	Formaldehyde
HSD	Honest Significant Difference
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
IFA	Institut für Arbeit Schutz
mg/m^3	milligram per cubic metres
$\mu g/m^3$	microgram per cubic metres

m^2	square metres
m/s	metres per second
n	number
n.d	not defined
PM	Particulate Matter
ppm	parts per million
p.n	Page Number
%	Percent
RH	Relative Humidity
r_s	Spearman Correlation Coefficient
SBS	Sick Building Syndrome
SD	Standard Deviation
Sig.	Significance
SPSS	Statistical Package for the Social Sciences
Std	Standard
TVOC	Total Volatile Organic Compounds
Tukey HSD	Tukey Honest Significant Difference
UBA	Umwelt Bundesamt
US-EPA	United States – Environment Protection Agency
VDU	Visual Display Unit
WHO	World Health Organization

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Abstract

Introduction - There were approx. 33.9 million office staff in Germany in 2019. Even though the internal air quality inside the office buildings are considered favourable for the health and productivity of its occupants, workers still report discomforts and dissatisfaction. The factors affecting the perception of IAQ are still not fully clear. The present study was conducted to assess the IAQ in offices, study the prevalence of SBS, the subjective perception of IAQ and SBS among workers in offices in Hamburg, Germany.

Materials and Method - A cross-sectional study was conducted in Summer 2019 (June-August) among office workers (n=40) in 5 offices in Hamburg. The IAQ parameters (CO2, Temperature, Air velocity, Relative Humidity) were assessed using Testo 480 instrument for climate measurements (Testo SE & Co KGaA) and the particulate matter was measured using multifunction air detector (Intelligent Air Detector). A questionnaire was developed for an online survey among office workers to collect data for assessment of prevalence of SBS and perception of IAQ.

Results - The study showed the prevalence of SBS with fatigue and tiredness as the most frequently experienced symptoms by the office workers every week. High temperature was highest perceived parameter (37.5%) during the study. The ANOVA test run in the study showed difference in the variables between the five buildings, and the Tukey HSD post hoc test for multiple comparison specifically identified the buildings that showed the difference. The Spearman's rho correlation showed a negative linear relationship between (a) the measured parameter and perception of IAQ and (b) perception of IAQ and SBS complaints. The independent sample t-test showed that female workers had higher SBS than males.

Conclusion - The results of the study should be considered with caution due to several limitations. The study corresponds to the summer season and cannot be projected to all seasons. Individual one to one assessment of the multiple factors impacting the worker perception of IAQ and SBS prevalence are needed in the future research.

Key words - Internal Air Quality, Office workers, Sick Building Syndrome, Office buildings, IAQ perception

1.Introduction

The Indoor Air Quality (IAQ) is an important public health concern for developing and developed industrialized nations. In developed countries, people spend 80-90% of their time indoors (Tarrafa Silva et al., 2016) (Deros et al., 2012) (Frontczak and Wargocki, 2011) mostly in offices. (Nezis et al., 2019) and people in Germany spends around 90% of their time indoors (UBA). WHO 2007 reports indoor air pollution as one among the ten most important risk factor for diseases (1.5 million deaths and 2.7% of the global burden of diseases) ("Indoor air pollution," n.d.). Hence it is a potential factor in determining the individual health of its occupants.

Most of the offices work eight hours and for five days per week, which implies that the workplace environment is significant to many for their health and well-being. Offices are one of the indoor environments defined as areas in buildings which are not subject to the ordinance on hazardous substances (UBA). Though the office environments are considered relatively non-hazardous, the vulnerable individuals are at a risk due to prolonged exposure to poor indoor environment. (DGUV, 2013)

An acceptable Indoor Air Quality (IAQ) is defined as the "air in which there are no contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority of the people exposed do not express dissatisfaction". (Adel, n.d.) IAQ in the workplace is important not only for psychological and physical health reasons but also for the productivity of the employee. (Al Horr et al., 2016) (Stefanovska Ceravolo et al., 2012) The activities in offices change with new technologies such as spatial concepts, new indoor environment management inputs, work methodology upscaling, paper free office concepts, so on and so forth. The shift from routine work, to work demanding concentration results in various dissatisfaction and complaints projecting to their health and wellbeing. The creation of an acceptable IAQ is challenging due to susceptibility boundaries of the occupants, acceptance, and perception of outside air flowing in.

The major health problems reported by office workers is termed `Sick Building Syndrome', which is a group of symptoms, which are usually not able to be associated with a definite cause and lasts until the person remains in the premises. (UBA, 2012) (Joshi, 2008) (Lyles et al., 1991) The symptoms of SBS may occur as single or a combination of one or more symptoms. For e.g., nasal, ocular, oropharyngeal, cutaneous, and general symptoms. It is observed that most of the causes of dissatisfaction are related to temperature, air quality and ventilation. (DGUV) They may also arise due to physical conditions indoors like lighting in the room, incoming noise from any source, due to chemicals like VOCs, CO_2, tobacco smoke, biological sources like moulds or other microbes and psychosocial factors like age, gender, stress factors, job related factors. (Joshi, 2008) Studies also showed that factors like lack of privacy, frequent sounds from office instruments and centralized air conditioning system also contribute to SBS. (Gül et al., 2007) The gender difference in the perception of IAQ and SBS prevalence, when women had more health complaints than men, are observed in many studies. (Zainal et al., 2019) (Brasche1 et al., 2001) (Stenberg et al., 1994) The probable reason suggested by the researchers is that a physical and psychological state combined with factors related to job and workplace could be the risk factors for women in perception of SBS.

A cross sectional study conducted in three buildings in Malaysia, where the indoor air quality had parameters within the acceptable limits and showed no presence of potential pollutants, however, shows prevalence of SBS, (Norhidayah et al., 2013) which indicates the influence of other stressors if any like psychosocial, ergonomic, environmental factors, or work-related factors.

The multidisciplinary project “ProKlimA”, the study conducted in 14 office buildings across Germany promoted by “Bundesministerium für Bildung und Forschung” in 1995-99, studied the exposure and health related impairments among workers in office building. The study shows that besides other variables of discomfort, the worker expectation factor for variables were diverse and they exhibited comfort preferences which had an impact on the prevalence of SBS. (Bischof et al., 2002)

The perceived IAQ is truly relevant in health complaint assessments and worth considering along with other factors for lowering the prevalence of SBS. (Thach et al., 2019) Besides the physical parameters that are commonly measured for assessing occupant satisfaction, it is observed that these parameters are not the sole factors unless they are extremely evident and proven to have impact on health.

Two large field studies done, one in open plan and private offices in green and conventional buildings and second in open plan offices in conventional office buildings shows that the assumed predictors are not the only important factors for perception of IAQ and are not able to bring strong and consistent associations between physical factors and occupant satisfaction. (Leder et al., 2016) At this juncture the worker perception of the IAQ is an exigent indicator of health complaints raised. Hence a continued study for the newer circumstances created in workplace and continued effort to understand the underlying variables to resolve the IAQ issues and lower the prevalence of SBS in workplaces is demanded.

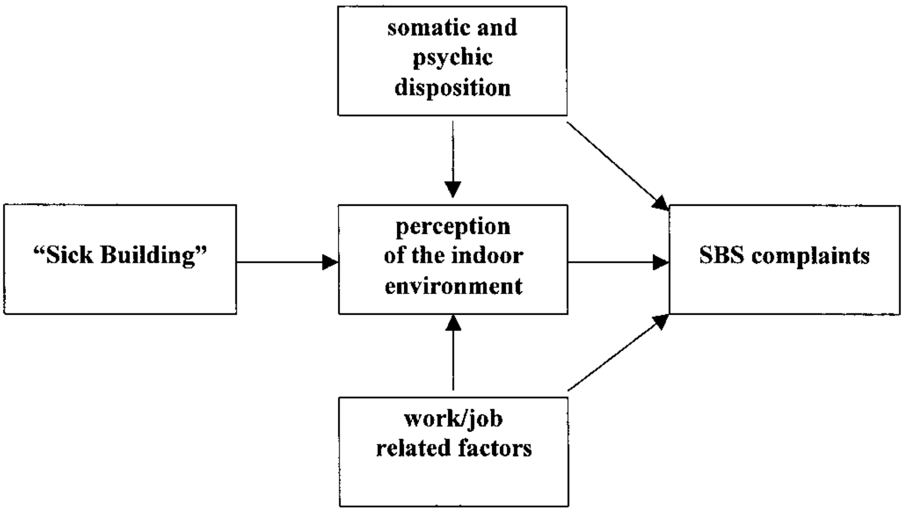

Fig.1 Model of the Pathway of SBS complaints
(Source: Brasche1 et al 2001)

2.Background

2.1 Indoor Air Quality in Offices

Indoor air quality (IAQ) refers to the air quality within the buildings and structures when it relates to the health and comfort of building occupants and the IAQ in offices are governed by factors like `source of pollutants, odours, workplace design, operation and maintenance of ventilation system, moisture and humidity, occupant perceptions and susceptibility` along with multiple factors affecting the comfort and perception of IAQ. (US-EPA). The quality of indoor air is a net result of interaction of many factors and the studies indicate that they are predominantly defined by factors like the temperature, humidity, air movement, CO_2, and particulate contamination. Studies show that a lack of awareness among occupants, improper or uncontrolled renovation, micro-organisms, ventilation rate are also factors contributing to IAQ problems. (Brągoszewska et al., 2018) (Fisk et al., 2009) (Hasegawa et al., 2009) The indoor pollutants are in higher concentrations than in outdoors which increases during working hours and becomes unsuitable due to inadequate dilution of the air. The infiltration of pollutants from outdoor air and the produces due to various indoor activity combinedly contribute to the quality of indoor air. (Cheng, 2017) IAQ problems scale parallelly with increased environmental pollution (ambient air). (Myers and Maynard, 2005) However, in an insulated room where the chance of infiltration is minimised, the air may become unsuitable due to emissions from indoor materials, the heating and cooling systems of the building, cleaning materials, human activity and from pets.

The IAQ of the offices lead to worker complaints termed as `Sick Building Syndrome`.

Studies on SBS among office workers in the earlier periods till the more current time shows that there are considerable improvements of worker comfort, but SBS is still prevalent among the office workers. (Skov et al., 1987) (Zweers et al., 1992) (Stenberg et al., 1994) (Kubo et al., 2006) (Gou and Siu-Yu, 2012) (Bluyssen et al., 2016)(Thach et al., 2019)

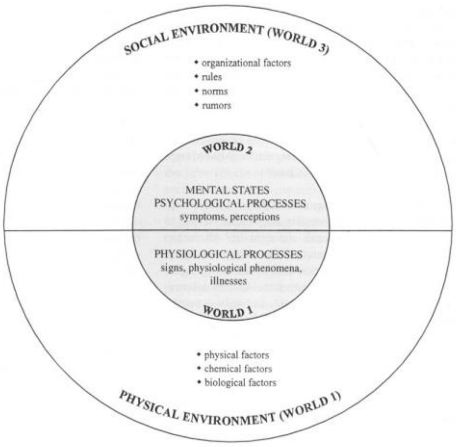

Fig.2 The office environment model
Source: (Jaakkola, 1998)

The absence of a clear etiological evidence in the research studies till date continues the skepticisms pertaining to the condition (SBS) itself and factors affecting perception of IAQ and reporting of SBS. An office environment model conceptualized by Jaakkola et al, 1998 (Fig.2) depicts the complex interaction of office worker and office environment. SBS is a constellation of symptoms caused due to IAQ (Joshi, 2008) (Burge, 2004) and usually do not cause major health problems like a clinical condition. The occupant may not report the same symptom on a subsequent exposure. This was an observation in a study of European office buildings (Bluyssen et al., 1996) where the assessment panel had an initial and a different subsequent perception of IAQ in the study buildings, which they termed as `adapted perception`, which the researchers observes to be expected from the office workers also. In Germany, SBS is prevalent in offices particularly in new office buildings. (DGUV) and the Office workers are an important class of people complaining SBS as they work in same place for a longer duration. The SBS symptoms include watery eyes, mucous membrane and skin irritation, fatigue, runny nose, joint pain and headache, irritation of eyes, upper respiratory symptoms, dry eyes, difficulty in concentrating lethargy, tiredness (Tsai et al., 2012) (Abdel-Hamid et al., 2013) (Bluyssen et al.,2016)

2.2 Air Temperature, Relative Humidity and Air Velocity

The occupants appreciate and perceive IAQ in the absence of unpleasant sensations, which is also subjective. The `room temperature` is the temperature perceived by humans and is determined by the air temperature and temperature of the surrounding surfaces and the air temperature is defined as the temperature of the air surrounding human body without heat radiation. ("BAuA - ASR A3.5," n.d.)

The present study, the office workers with light to medium workload alone are included. Based on the workload and posture the following limit values are to be maintained throughout the entire working time.

Table.1 Recommended minimum air temperature in indoor workplace

Predominant Posture	Workload		
	Light	Medium	Heavy
Sitting	+20^{0}C	+19^{0}C	-
Standing, Walking	+19^{0}C	+17^{0}C	+12^{0}C

Source: ASR A3.5 2010

The air temperature in office work areas shall not exceed a maximum of 26^{0}C as per DGUV, 2013. Deviation from the standard threshold values of temperature can affect the worker thermal comfort and productivity. SBS symptoms are observed to consistently increase with a rise in temperature above 23^{0}C by various researchers. (Seppänen and Fisk, 2006) (Skov et al., 1987)

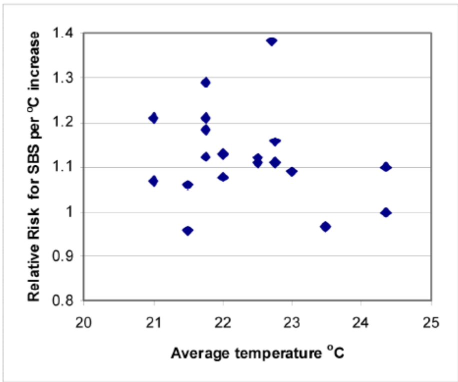

Fig.3 Relative risk of SBS symptoms per 1 °C increase in temperature versus average temperature of the assessment. (Source: Seppänen et al, 2006)

An experimental study was conducted in a low pollution office, where 7 workstations were identified within the office with a temperature regulatable setting (from 16^0C-32^0C). The air velocity was maintained below 0.1 m/s and with no controlled regulation of relative humidity. The study recruited 21 volunteers as participants. Measurements of physical parameters, physiological values (EEG & ECG), performance measurements, subjective measurements pertaining to thermal sensation votes (based on ASHRAE scales), mood states, wellbeing and motivation, task load index were carried out. (Lan et al., 2010) The study found that air temperature had significant effects on the overall workload (repeated measure ANOVA, P<0.05) (Fig.5) and the magnitude of perception of wellbeing was better at neutral temperature than in warmer temperature (Fig.4).

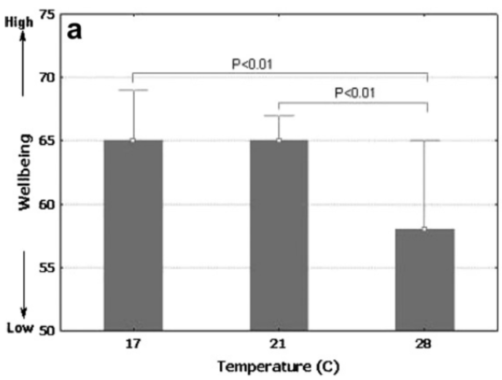

Fig.4 Change in perception of wellbeing with air temperature
(Source: Lan et al 2010)

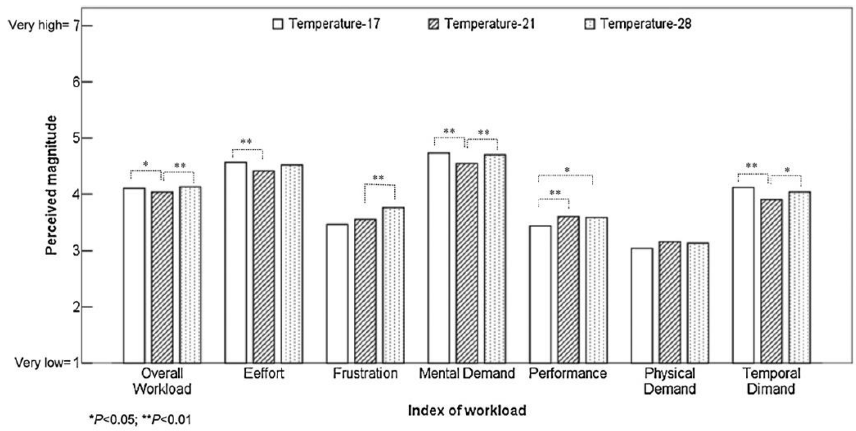

Fig.5 Change in overall workload and the six subscales with air temperature
(Source: Lan et al 2010)

The Relative Humidity is the amount of moisture content in air compared to the maximum moisture level that the air can hold at the same temperature and is expressed in percentage. ("BAuA - Klima am Arbeitsplatz," n.d.). The relative humidity is temperature dependant, and the recommended levels are shown in table 2.

Table.2 Recommended maximum relative air humidity in relation to air temperature

Air temperature in ^{0}C	Relative humidity in %
20	80
22	70
24	62
26	55

(Source: Based on DGUV, 2013)

There are no clear guide values for relative humidity, however based on technical aspects DGUV-2013 suggests a RH of 40% (22^{0}C) as Winter minimum and RH value of 60% (26^{0}C) as summer maximum. The common health complaints associated with humidity are irritation of eyes and upper respiratory tract. (Wolkoff, 2018) The study also observes that RH affects the resuspension of particles depending on the water affinity properties of particulate matter and the type of flooring in offices.

The air humidity around 40-45% is shown to decrease the perception of dry air and unpleasant odour (Nordström et al., 1994) and an indoor air humidity from 10%-40% does not play a role in the prevalence of SBS. (Sundell and Lindvall, 1993) The influence of RH on the perception may be due to the thermodynamic condition between temperature and humidity, along with the emission profiles of indoor contaminants. (Wolkoff and Kjærgaard, 2007)

Another important IAQ parameter which influence the perception of thermal comfort is the air velocity, the limit values of which depend upon the air temperature and air flow turbulence and is expressed in metres per second (m/s). Air flow turbulence is the air velocity administered over time. The air velocity is an important factor determining the draught in the workplace along with other factors of IAQ. A temperature of 20^0C, with a mean air velocity below 0.15m/s and 40% air turbulence shall experience no draught in the workplace. (DGUV, 2013) When there is a low air movement in the workplace, occupants perceived a poor IAQ. (Haghighat and Donnini, 1999)

A study in an experimental setting using climate chamber observes that the air velocity has effects on perception of thermal comfort, perceived air quality and humidity without causing subjective health effects like dry eyes in environments with high temperature and humidity in subjects wearing normal summer clothing. (Zhai et al., 2015)

2.3 Carbon Dioxide in Office Indoors

CO_2 is a bio effluent, a nontoxic gas which is always present in an occupied office building. Assessment of CO_2 levels in indoor spaces is adopted as a proxy for the efficiency of ventilation system in each office rooms or other spaces within the buildings. It is an indication for worker comfort of odour, developed or present in the indoors. (Wolkoff, 2013) CO_2 concentration and ventilation rate are indirectly proportional, (Turiel et al., 1983) which implies that a well ventilated office room have low carbon dioxide levels (Deros et al., 2012) and studies identified the ventilation rate as a vital factor for IAQ. The Ventilation System in workplaces may be natural or mechanical. The occupants in a naturally ventilated buildings expressed more satisfaction (70%) than those in mechanically ventilated buildings (59%). (Hummelgaard et al., 2007) The dissatisfaction due to the CO_2 (levels >800ppm) in the indoor office rooms resulted in SBS symptoms like tiredness of eyes, difficulty in concentrating and remembering (Tsai et al., 2012) and remarks that the ventilation rate can alter the exposure of indoor air contaminants.

The effect of indoor carbon dioxide on the task resolving ability of occupants show a decline with increasing levels of CO_2 exposure. (Satish Usha et al., 2012)

Since the toxic level knowledge for CO_2 is deficient, the guide values for CO_2 in indoor air are constructed for the purpose of assessment, (Abelmann, 2013) (Table.3) and as a general rule suggesting that the CO_2 level shall not exceed 1000 ppm or 1800mg/m^3. ("BAuA - ASR A3.6," n.d.) The ventilation requirements are recommended based on the guide values.

Table.3 Hygienic Guide Values for CO_2 for indoor air

CO_2 Concentration (ppm)	Hygienic Assessment	Recommendation
<1000	Hygienically safe	No action
1000-2000	Hygienically noticeable	Ventilation (outdoor air flow rates or rather increasing air change) proof of ventilation habits and improvement
>2000	Hygienically unacceptable	Proof for options of ventilation, proof for further measures

(Source: UBA,2012)

2.4 Particulate Matter

The health problems that may arise due to exposure to dust are based on the assessment of the that fractions which can be breathed in termed as ``respirable dust`` or ``alveolar dust``(DGUV). They are referred to as Particulate Matter (PM2.5 and PM10) with diameters 2.5 and 10 µm respectively. Particulate matter levels in indoors arise from various sources, both within the indoors as well as from outdoors. It is a heterogenous mixture of particles, solid or liquid present suspended in the air that varies in size and composition in space and time (US EPA, 2016). An exposure can cause immediate to delayed health problems to the occupants especially to susceptible individuals with predisposed health conditions. (Wolkoff, 2013) The exposure to fine particles (PM2.5) is shown to have association with cardiopulmonary mortality predominantly than the total mortality. (Chen et al., 2017)The source of indoor particulate matter varies from carpets, pets, environmental tobacco smoke (ETS) (Nezis et al., 2019) to office equipment like photocopiers, printers which generate particles. (Kagi et al., 2007) (He et al., 2007)

A Research (Literature Review) conducted to assess the role of carpets in the IAQ, and occupant health found that the carpets can hold the particulates owing to the porosity of material of construct and allow resuspension of particles depending upon the size, physical property of the particle and the relative humidity in the room. The resuspension of the coarse particles (PM 10) is higher (3-4 times) than the fine particles (PM2.5). (Becher et al., 2018) The outdoor PM level also impact the indoor particulate matter levels. (Cheng, 2017) (Saraga et al., 2017) The PM can enter the respiratory system and the rate of penetration depends on the size, hence PM2.5 can travel into the bronchus and PM10 is more likely to be limited in the upper respiratory tract. (Kim et al., 2015)

The SBS complaints associated with PM concentration are generally irritation of eyes, dry throat, runny nose, cough, tiredness, irritability, difficulty in concentrating, headache, dizziness, and skin irritation. (Nezis et al., 2019)

No threshold for particulate matter has been identified below which there are no health effects. The WHO AQG values are the recommended values considered representing an ´acceptable and achievable target values to minimise the health effects in the context of local constraints, capabilities, and public health priorities`. The indoor guide value for PM2.5 is 25µg/m^3 which is the 24 hrs mean value applying only for clean indoor spaces with absence of relevant air sources of dust (tobacco smoke or any other combustion) (UBA, 2008) which is also the value assigned by WHO. No guide value for indoor PM10 is defined since the levels of this fraction is found to be higher in the indoors than in the outdoors implying that their sources are to be identified within the indoor space. However, the fraction is required to be maintained below 50µg/m^3 as per the EU dust limit for tropospheric air.

Table.4 Air quality guidelines (UBA, 2015)

	EU limit/ target values*	WHO recommendation**
PM10		
Annual Mean	40µg/m^3	20µg/m^3
Daily Mean Value	50µg/m^3 (35 Exceedances permitted)	50µg/m^3 (3 Exceedances permitted)
PM2.5		
Annual Mean	25µg/m^3 (Stage 1) 20 µg/m^3 (Stage 2)	10µg/m^3
Daily Mean Value	-	25µg/m^3 (3 Exceedances permitted)

**EU limit according to the EU Directive 2008/50/EG and 2004/107/EG*

***WHO recommendations for protection of human health according to Air Quality Guideline for Europe 2nd edition, 2000*

2.5 Occupant Perception as a determinant of IAQ and prevalence of SBS

The occupant perception of IAQ and comfort is a complex phenomenon. Generally, the basic focus of an IAQ is the impact of humidity, temperature, contaminant level, air movement and the ventilation system. The acceptable levels identified by the occupants varies with individuals.

The outcome of a literature survey, the study carried out to examine how the indoor environmental factors like temperature, light, sound, and air quality are related to the occupant comfort level (in homes, schools, offices, and experimental climate chambers), observes that temperature was the most prominent factor influencing the occupant perception compared to light, sound and air quality. It was also observed that the individual characteristics of occupants like educational status, professional relationships, time pressure had an influence on the perception of thermal comfort and other factors like gender, health, age, work stress or duration of working hours did not affect the perception of thermal comfort. The country of origin was a factor affecting the acoustic comfort in a few studies, regardless of the gender difference. The observations made in the study were diverse and the responses of occupants in studies lacked consistency to give precise conclusions. (Frontczak and Wargocki, 2011)

A cross-sectional study conducted in three buildings by objective parameter measurement and a comprehensive survey using questionnaire for subjective appraisal of work area, worker health assessment, and evaluating worker wellbeing in the office room reported that the workers in mechanically ventilated office buildings had better perception of IAQ. The measured air quality and thermal parameters were relatively good however, had poor perception of air quality and thermal comfort. (Butala and Muhič, 2007)

The study in two mechanically ventilated buildings in heating and cooling seasons, factors like the air velocity within the workplace, an open-plan workspace, and the job satisfaction influenced the worker perception. The study explored the rating of occupants for ten SBS complaints and found a gender difference in the perception of symptoms where dry skin and headaches were frequent among females and sore throats and eye irritation were frequent among male workers. Sore throat increased as age increased, and fatigue and sleepiness decreased with age. The symptoms exhibited a seasonal pattern. Dry skin, nose irritation and sore throat was more in winter and symptoms like sleepiness and headaches in summer. A low air velocity led to poor perception of IAQ which was however associated with the temperature at the time. The preference for higher air velocity at higher temperature was statistically correlated. The study also showed that the job satisfaction imparted a good perception of IAQ however a dissatisfaction with job showed no relationship with the SBS complaints. Another observation was the possibility to control their environment had some influence in the health complaints of occupants. (Haghighat and Donnini, 1999)

An observation in the study to assess the air velocity preferences in office buildings, (Zhang et al., 2007) is that higher air velocity improved the perception of IAQ in cool climate in contrast to the observations in many other studies where a high air velocity produces an IAQ perception in warm climate.

The study by Toressin and colleagues, found that the occupants' 'personal attitude', 'mood', or 'past events' had a prominent role in the perception of IAQ. In a moderately acceptable indoor environment, perception of an unacceptable IAQ could be a result of a totality of indistinctive factors that were present indoors whereas when there existed a very unacceptable indoor factor, it takes over as the prominent factor and the low prominent factors go underestimated. The analysis of each factor separately should give better evidence regarding the perception of IAQ of the occupants. (Torresin et al., 2018)

2.6 Gender and SBS

The gender as a factor for the prevalence of SBS is found extensively in the investigations of SBS. In the multidisciplinary study 'ProKlima' performed among office workers in different office buildings in Germany where the questionnaire survey assessed their health symptoms, asked for the rating of well-being indicators, appreciation of work environment, satisfaction with their socio-economic status, it was observed that women had more probability of making health complaints than men. In women the working condition imparts a crucial role in lowering their threshold for satisfaction with indoor environment. Figure 6(a) and 6(b shows the risk of sensory irritations in females and male workers respectively, in the study. The stress at the workplace along with psychosocial and indoor factors like air-conditioning influenced their well-being. (Bullinger et al., 1999)

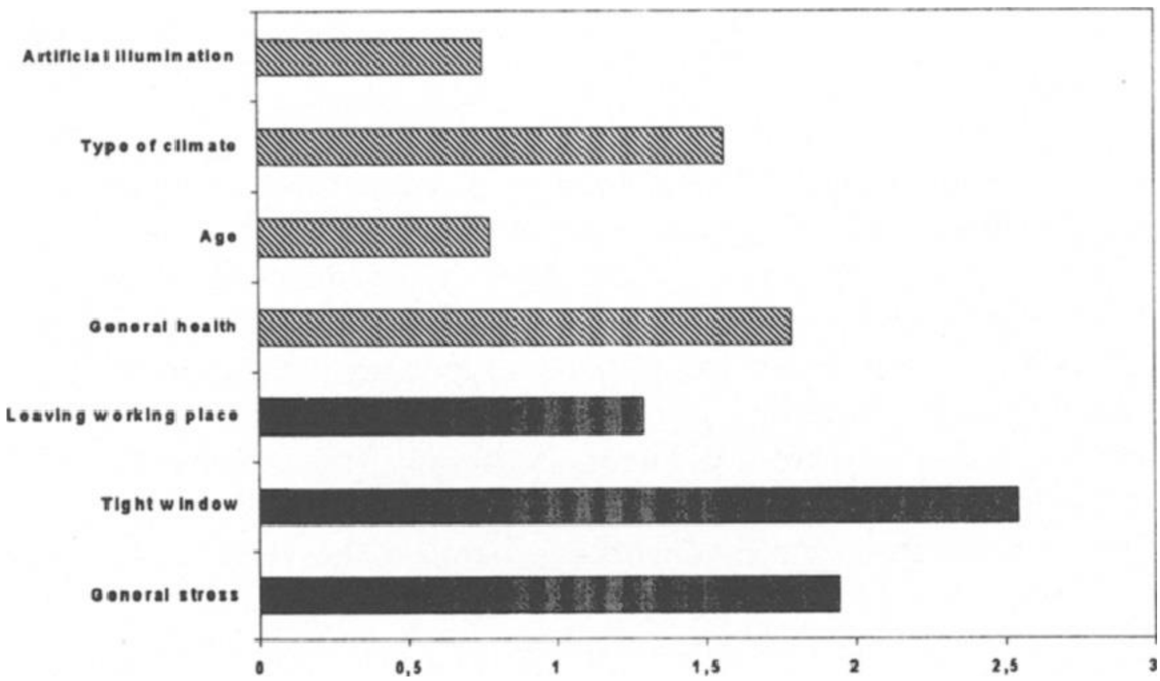

Fig: 6(a) Risk of increased sensory irritation (OR); Women (N=1998)

Source: Bullinger et al 1999

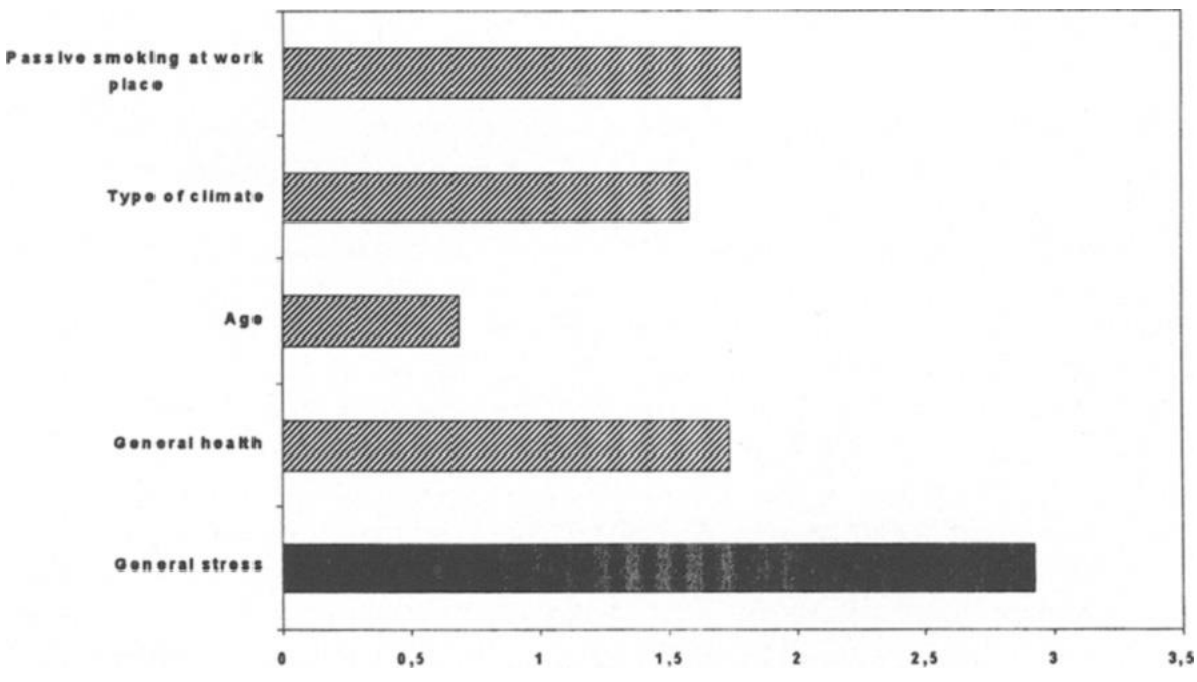

Fig: 6b) Risk of increased sensory irritation (OR); Men (N=1721)

Source: Bullinger et al 1999

3. Research question

Aims:

1. To assess the indoor air quality in the offices in Hamburg, Germany.
2. To assess the prevalence of health complaints among office workers.

Objectives:

1. To assess the IAQ by measuring the parameters like temperature, humidity, air velocity, carbon dioxide and particulate matter.
2. To study the prevalence of health complaints (SBS)
3. To compare the differences in IAQ parameters between the offices
4. To assess whether the objective measurements agree with the subjective perception.
5. To test the Hypotheses

A: H_0 - There is no association between perception of IAQ and SBS.

H_1-There is an association between perception of IAQ and SBS.

B: H_0 - There is no association between the gender of the office worker and SBS.

H_1 - There is an association between the gender of the office worker and SBS.

4. Instruments and Method

4.1 Study Design

A cross sectional study was performed during summer season in 2019 in five office buildings in Hamburg, Germany. The IAQ parameters (CO_2, temperature, relative humidity, air velocity and particulate matter) were measured during the month of July-August 2019 and the survey conducted in August-September 2019.

The study was designed in two parts. In the first part, the objective instrumental measurement of indoor air quality parameters was carried out and in second part the subjective perception assessment done using survey questionnaire. The parameters like CO_2, temperature, humidity, and air velocity were measured using `Testo 480` instrument for climate measurement and the particulate matter was measured using multifunction air tester (Intelligent air detector). The present study codes the office buildings as B1, B2, B3, B4 and B5. The office buildings were more than 10 years old except B3 which was completed and occupied in 2013. 16 sampling points were identified in the five office buildings and measured according to the IFA-DGUV, 2013 reports which is the procedure recommendation for the investigation of the work environment-indoor workplaces.

Pic.1 Google map of office building location in Hamburg

4.2 Sample Population

In the present study, the sample is a non-probability convenience sample of office workers from five offices in Hamburg, Germany. The sample group was selected in a non-random manner where not each member of sample population has a chance to participate in the study therefore no inclusion criteria was identified prior to selection of subjects.

The offices were contacted for willingness to participate in the present study with the support of HAW, and five offices were selected which were in Altona (1), Bergdorf (2), Tiefstack (1), and Wilhelmsburg (1) in Hamburg, Germany. The disadvantage of selection bias cannot be excluded in this study due to chances of nonuniformity of sample distribution. (ref). However, the offices with workers engaged in duties (administrative functions) were selected and workers engaged in duties requiring physical exertion was excluded, to minimise any confounding factors which may arise due to difference in the work nature. The offices consisted of single and multi-personal working spaces.

4.3 IAQ Parameter Measuring Devices

Testo-480 Device for Climate Measurement

It measures climate related parameters, used for the comfort level measurements for the workplace evaluation and flow measurements in and at ventilation and air-conditioning systems. (“Testo SE & Co. KGaA,” 2017) The parameters like temperature, humidity, flow- velocity, pressure, carbon dioxide and lux can be measured in a measuring cycle of 0.5s and an operating temperature of 0 - +40^{0}C with an accuracy of ±0.5^{0}C (EU Directive-2014/30/EC). The present study do not measure the illuminance.

The device has three probes namely the `comfort probe`, `indoor air quality probe` and the `globe thermometer`. The air velocity, temperature and indoor air turbulence are measured by the comfort probe in accordance with DIN EN 13779. The draught risk is determined based on the air turbulence which is the level of fluctuations in air velocity over time. The indoor air quality probe measures relative air humidity, carbon dioxide, air temperature and absolute pressure (DIN EN ISO 9001). The globe thermometer (thermocouple type K) measures the radiant heat by detecting the significant temperature difference between the ambient and globe temperature. This accounts for the high solar radiation through ventilations. The measurement accuracy for Testo 480 corresponds with the recommendations from ASR A3.5 (2010, p.3) (Testo SE & Co. KGaA, 2017).

Testo-480 Climate Measuring Device

Testo-480 Device Mounted on Tripod for measurement

Pic.2(a) and 2(b) Testo 480 device for climate measurement

Table.5 The parameters measured using Testo 480 in the study

	Comfort probe		Indoor air quality probe		
Measured parameters	**Air temperature (°C)**	**Air velocity (m/s)**	**Air temperature (°C)**	**Relative humidity(%)**	**CO2 (ppm)**
Measuring range	**0 to +50 °C**	**0 to +5m/s**	**0 to +50 °C**	**0 to +100**	**0 to +10000 ppm**
Accuracy	**± 0.5 °C**	**± 0.03 m/s**	**± 0.5 °C**	**± 1.9 %**	**± 105 ppm**

Source: Based on Testo SE & Co. KGaA, 2017

b. Multifunctional Air Detector (Intelligent Air Detector)

The device can measure pollutants like HCHO, TVOC, temperature, humidity in the room along with PM2.5 and PM10 using laser scattering detection technique. The air detector scatter light is based on particle size with sensor detection and an algorithm determining the count and size of particles. The sampling time required is 3 seconds and has a detection range of 0-999 micrograms/m^3. The Intelligent air detector device was appropriate because the product was suggested for measurement in low density to high density environments like rooms in house and office spaces. The device is calibrated before use and the monitor read and display the pollutant levels and air quality at the time of measurement. The device do not save measurement values, hence needed to be recorded manually.

The Multifunctional Air Detector is used to measure the particulate matter (PM2.5 and PM10) in the present study.

Pic. 3 Intelligent Air Detector

4.4 The Questionnaire

A self-administered questionnaire was developed through literature search, based on the study objectives to assess the occupant perception of IAQ and SBS in the office.

The Miljömedicin (MM) 040 questionnaire (Reijula and Sundman-Digert, 2004), was the first standardised questionnaire (Örebro University Hospital 1985) for assessments of indoor workplaces released in 1989 after testing the validity and reliability. The questionnaire contained several questions to assess the SBS and perception of indoor climate. The sections of MM questionnaire asking questions to assess noise perception, work condition and the complementary questions were excluded based on the needs of the present study. The English questionnaire `MM 040 office` for studying Indoor climate in office however had limited questions, hence demanded appropriate modification in the questionnaire by including the missing items.

A new questionnaire was developed based on literature search consisting of 24 questions (including the sub-items). The sources for the synthesis of the questionnare for measuring the worker satisfaction factor were searched in the following reference materials.

`Proklima Project` - `Bundesministerium für Bildung und Forschung` 1994-1999, (Raw, 1996) (Moosbrugger and Kelava, 2012) and (Young, 2015). The questions for measuring the satisfaction pertaining to the life qualities like health, work, activities, personal judgements of indoor environment are drawn from the 'Proklima Project'. The questionnaire (the scales and subscales) was shown to obtain good internal consistency in the study. (Bischof, 2003 p.n 53-58)

Though the MM questionnaire (“The MM Questionnaires,” n.d.)and the questionnaire of the 'ProKlima Project' (Bischof, 2003 p.n 284-295) were validity and reliability tested, the new questionnaire developed from them was not tested for internal consistency which was a limitation of the study. And test re-test reliability assessment was also not performed due to resource limits. The recall period of three months was brought down to two months in the present study to minimise a recall bias.

The questionnaire consisted of four sections as detailed below-

First section aimed at obtaining general data of the workers (age, gender, educational qualification, smoking habits, use of contact lens, rearing of pet animals). The question in this section were dichotomous (only two answers, e.g., yes, or no) or multiple choice where respondents could select the applicable from the defined answers.

The second section was to assess the workplace design (type of workplace like single occupied or multi-personal, type of air flow regulation, provision for natural ventilation) and workplace activities (period of employment in the present office, hours of work per week, professional responsibilities, self-assessed physical activity score, hours spent per day using the monitor, methods, and frequency of cleaning the workplace).

The third section was to assess how the occupants perceived the workplace by asking them questions like, defining the space of workplace, (the respondents were given answers to select from, like `most spacious`, `adequately spacious`, `less spacious`, and `least spacious`), perception of air quality in the workplace, subjective experience of indoor conditions like high room temperature, dry air, respiratory irritability, unpleasant odour, question to assess the frequency with which they experienced not good physical and mental condition in last two months in the workplace and if they were relieved of the condition when leaving the premises.

In the fourth section, the questions were to assess their perception of personal health status and the factors in an indoor workplace that they consider as detrimental to their health.

They were asked to recollect the number of days of absence from office in the last two months due to a health reason and asked for any pre-existing health conditions like allergy or chronic diseases. They were also asked to score the various factors affecting their psychosocial wellbeing (Health, Job challenges, income/financial security, cleanliness of office, furnishing at the workplace, relationship with colleagues and superior officials) on a 5-level rating scale like `not important`, `little important`, `quite important`, `very important` and `extremely important`), followed by their current satisfaction score of well-being in the present workplace (4-level rating scale like `dissatisfied`, `quite dissatisfied`, `quite satisfied`, `very satisfied`). The health complaints in the past two months experienced by the staff working in the present workplace were asked for, by listing out prevalent health complaints, selected from studies through literature search, like itching/ burning/irritation of eyes, dryness of throat/hoarseness of voice, cough (dry and allergic), irritation of skin/scalp or around the ears, dry hands/reddening of skin on hands, tiredness or fatigue, headache/heaviness of head (with or without nausea)/difficulty concentrating/dizziness, change in smell and taste sensation, difficulty in breathing. Finally, the questionnaire asks how the employee personally think of his/her role in their own wellbeing.

The survey questionnaire was prepared utilizing the cloud based online survey development software ``Google Forms ``

The self-administered online questionnaire was pilot tested among 5 peers in FTY-NK office and 2 experts in field of teaching and research. They answered the questionnaire and gave recommendations and suggestions for improvement. Phrasing errors were looked over and very personal questions like information on pregnancy to the female respondents, were excluded in the final version. The initial questionnaire had 24 questions and reconstructed into the final version containing 33 questions based on the recommendations and feedback of the pilot study.

The questionnaire contained an informed consent to apprise the participants regarding the purpose of research, outcome of research, guarantee of anonymity and privacy policy. The consent clearly stated that `the participation is voluntary, and refusal does not involve any penalty or loss of benefits to which the participant would otherwise be entitled, and the participant may at any time decide to discontinue participation without penalty ` (European Commission., 2013) . The questionnaire was served to the participants through the contact person in individual offices. No individual personal identification data was collected, and verbal explanation was given regarding `the procedures adopted to guarantee the participant's privacy: the confidentiality, the measures to protect the data, the duration of the storage of the data and what will happen with the data` to the contact person in the offices prior to distribution of questionnaire.

4.5 Sample Size

As on 30th June 2019, the number of office workers in Germany is 33407262 and in Hamburg is 996031. ("Statistisches Bundesamt Deutschland," 2021)

The sample size calculation for studies can be done using `open epi` the open-source software version 3.01, updated on 6th April 2013. Fig shows a calculated sample size (n) of 101 based on the finite population of office workers in Hamburg with a hypothesised prevalence of SBS of 7% (Abdel-Hamid et al., 2013) at a confidence interval (CI) of 95%, which implies the study requires a minimum of 101 survey responses for the assessment of SBS in the study population. (Sullivan et al., 2009) However, in the present study it is a non-probability convenient sample of office workers from five offices in Hamburg who agreed to participate in the study.

Sample Size for Frequency in a Population

Population size(for finite population correction factor or fpc)(*N*):	996031
Hypothesized % frequency of outcome factor in the population (*p*):	7%+/-5
Confidence limits as % of 100(absolute +/- %)(*d*):	5%
Design effect (for cluster surveys-*DEFF*):	1

Sample Size(*n*) for Various Confidence Levels

ConfidenceLevel(%)	Sample Size
95%	101
80%	43
90%	71
97%	123
99%	173
99.9%	282
99.99%	395

Equation

Sample size $n = [DEFF*Np(1-p)]/ [(d^2/Z^2_{1-\alpha/2}*(N-1)+p*(1-p)]$

Fig.7 Calculation of sample size

(Source: https://www.openepi.com/SampleSize/SSPropor.htm)

4.6 Data Collection

The indoor air quality parameter measurements were taken during working hours of the office and with the usual attendance of staff. The door and ventilations were maintained as per the usual manner during their occupancy. A single measuring point was identified at each workspace. The recommendation of measurement at hourly intervals could not be fulfilled in order not to disturb the normal functioning of the office and for the short time frame of study obtained by appointment from the authorities for each measuring point. A one-hour continuous measurement was taken at each measuring point. No outside measurements were carried out to avoid too much interference in the organisational properties which may discourage the active co-operation of workers including participation in the questionnaire survey.

The Testo 480 device continuously measured the parameters every second for a duration of one hour. The data can be stored internally in testo 480 device and was then transferred to computer and saved as excel spread sheet for subsequent statistical analysis. However, the multifunction air tester device does not save the measurements internally and had to be manually recorded through the one-hour measurement for PM2.5 and PM10. For particulate matter, the device takes measurement every second, but value was recorded in every five minutes interval for each measuring point using stopwatch. The mounting of instruments and positioning were observed as per DGUV, 2013 recommendations.

4.7 Statistical Analysis of Data

The data collected were subjected to statistical analysis using SPSS software program (IBM Corp., version 24). The statistical tests were selected based on the data and objectives of the study.

Descriptive statistics was performed for the assessment of the IAQ parameters in the office buildings and to study the prevalence of health complaints among the office workers.

The Spearman`s rho correlation (non-parametric test) was used to assess whether the subjective perception of IAQ concur with their reported health complaints. The hypotheses testing of association between perception and SBS was also assessed using Spearman`s rho correlation. (One tailed test with alpha (α) = 0.05) This method of correlation analysis using ranked data is suggested for data with outliers and for small samples. (Field, 2017 p.n 344)

A one-way between-groups analysis of variance (ANOVA) was performed to investigate the IAQ parameter differences between different office buildings followed by Tukey HSD Post Hoc multiple comparisons test for a statistically significant difference in the mean score between the office buildings.

An independent-samples t-test was conducted to study the association between SBS and genders.

5.Result

5.1 Office Building and Workplace Characteristics

As mentioned earlier, the study used five office buildings in different locations of Hamburg, Germany and the environmental parameters were measured at sixteen office rooms. The buildings were in Altona, Bergdorf, Wilhelmsburg and Tiefstack. Table.6 shows the characteristics of office buildings and the 16 measuring points.

Table.6 Office building and workplace characteristics

City of Office building	Room number	Number of occupants in office room	Total Number of Employees in the office	Geographic location of room	Type of air regulation	Floor characteristics	Approx. area
Bergedorf B1	1	1	150	South	Natural	Non-carpeted	10 m^2
	2	2		South	Natural	Non-carpeted	10 m^2
	3	1		North	Natural	Carpeted	10 m^2
	4	2		East	Natural	Non-carpeted	12 m^2
Bergedorf B2	1	3	75	North	Natural	Non-carpeted	15 m^2
	2	3		North	Natural	Non-carpeted	24 m^2
	3	1		South	Natural	Non-carpeted	16 m^2
Wilhelmsburg B3	1	1	800	South	HVAC	Carpeted	12 m^2
	2	1		North		Carpeted	12 m^2
	3	1		South		Carpeted	12 m^2
Altona B4	1	1	10	South	Natural	Carpeted	33 m^2
	2	3		South	Natural	Carpeted	84 m^2
	3	3		East	Natural	Carpeted	60 m^2
Tiefstack B5	1	3	10	North	Natural	Carpeted	35 m^2
	2	3		South	Natural	Carpeted	40 m^2
	3	3		South	Natural	Carpeted	30 m^2

The measurements were taken during the normal working hours of office based on prior permission and convenience of the individual office administration.

All office buildings had manually operable windows with windowpane shades for naturally regulating the air flow and light in the room. However, office building B3 had HVAC for the regulation of air flow in the building and the workspaces. All offices had temperature regulatable heaters installed in working rooms. All the buildings are older than 10 years except the building B3 which is relatively new and was informed to have been occupied in 2013. Office building B3 had single person office spaces well separated by walls, on the other hand, rest of the offices were a mix of single and multi-person shared office rooms. Some of the workspaces in buildings other than building B3 were either single space fully separated or multi-personal office separated as a single room. Workspaces with incomplete separation also existed in one of the offices which were transformed to a workspace based on the arise of spatial demands in the office. However, this was an exception. The floors were either carpeted or non-carpeted. The non-carpeted office room floor was paved with wooden material. The area of office rooms ranged from approximately $10m^2$ to $84m^2$ and the number of employees in the office buildings varied from a low number of 10 to as high as 800. The choice of geographic location for measurements was dependant on the convenience and co-operation of the occupants in the office room obtained on request and appointment from authorities.

5.2 Respondent Characteristics

As mentioned before the choice of respondents was not a possible option in the present study and conduction of survey was mediated through the contact person in the individual offices. Of the possible 1045 employees in the offices only 40 numbers participated in the self-administered online survey. (Respondents-3.8%)

The demographic data is summarized in Table.7.

Table.7 Demographic Profile of Respondents (n=40)

Variables		Frequency	Percent
Sex	Male	19	47.5
	Female	21	52.5
Age group	Under 30	7	17.5
	31-35	10	25.0
	36-40	10	25.0
	41-45	5	12.5
	46-50	1	2.5
	51-55	6	15.0
	Over 55	1	2.5
Level of Education	Secondary School	1	2.5
	Skilled worker Qualification	3	7.5
	Bachelor	14	35.0
	Master	21	52.5
	Doctoral	1	2.5
Smoking Habit	No	31	77.5
	Yes	9	22.5
Rear pet animals	No	30	75.0
	Yes	10	25.0
Since when working in current place (years)	Less than 2	12	30.0
	2 - 5	12	30.0
	5 -10	9	22.5
	10 -15	5	12.5
	More than 15	2	5.0
Use of contact lenses	Yes	3	7.5
	No	37	92.5

The data shows that 52.5% of the respondents were females and 47.5% were males falling in age group range from less than 30 years (17.5%) to more than 55 (2.5%) and 90% respondents had an education level of bachelor's or higher degrees. 77.5% were non-smokers and 75% did not rear pets. There were workers working for less than 2 years (30%) to those working for more than 15 years in the offices (5%). 92.5% of respondents did not use a contact lens (n=37).

5.3 Workplace Design and Activities of Office Workers

The workplace design and activities related to the professional responsibilities are given in table.8. Majority of respondents worked around 30-40 hrs/week (67.5%) and 95% of the respondents had either preassigned duties (62.5%) or performed duties upon instruction of the superior officials (32.5%). Among the 40 respondents 32 employees found their work as sedentary or with minimal activity and 95% of office workers worked with VDU for more than 4hrs/day. 62.5% of respondents worked in a workspace where the air flow was regulated by centralized air flow regulation system and 35% workers utilized fan to regulate air flow in the room. All workplaces had manually operable windows (except in one of the workplaces) and 92.5% of the employees used the facility to control the IAQ of the workplace. The employees informed that cleaning of the premises was done manually or are vacuum cleaned. However, four workers said that they do not know how often their workplaces were cleaned and how it was cleaned. 82.5% of workers believed that their office was adequately spacious and 17.5% felt that they were in working in a less spacious workplace.

Table.8 Workplace design and activities of office workers

		Frequency	Percentage
Professional position in the office	Activities as per instruction of the manager	13	32.5
	Pre-assigned work with limited responsibilities for others	25	62.5
	Comprehensive tasks and decision-making powers	2	5
	Others	0	0
Weekly working hours	Up to 20 hrs/week	4	10
	20 – 30 hrs/week	4	10
	30 – 40 hrs/week	27	67.5
	Over 40 hrs/week	5	12.5
Score of the physical activity during work	Sedentary	9	22.5
	Minimal activity	23	57.5
	Good physical activity	7	17.5
	Don’t know	1	2.5

Duration of work with VDU	< 3 hrs/day 3 – 4 hrs/day More than 4 hrs/day	0 2 38	0 5 95
Type of workspace	Single occupied Multi-personal Others	13 24 3	32.5 60 7.5
Type of air regulating system in workplace	Fan Air conditions Centralized air flow regulation	14 1 25	35 2.5 62.5
Presence of a manually operable windows	Yes No	39 1	97.5 2.5
If yes, how often is it used to naturally ventilate the workplace	Frequently Sometimes No I don't know	20 17 0 3	50 42.5 0 7.5
Frequency of cleaning the workplace and the method	Manually - More than twice a week Once weekly Once in two weeks Once in a month Don't know Vacuum cleaning – More than twice a week Once weekly Once in two weeks Once in a month Don't know	 18 12 2 3 5 2 29 1 2 6	 45 30 5 7.5 12.5 5 72.5 2.5 5 15
Defining space at the workplace	Most spacious Adequately spacious Less spacious Least spacious	0 33 7 0	0 82.5 17.5 0

5.4 The Understanding and Appreciation of IAQ by the Office Workers

Table.9(a-f) illustrates the workers` understanding of the indoor air quality in the workplace. Asked for the rating of IAQ in the workplace, less than half of the respondents rated the IAQ as good and 22.5% rated it as fair. Majority (37.5%) of workers experienced high temperature very often (every week). 17.5% felt a low temperature and 10%

experienced dry air and unpleasant odour very often in the workplace. 7.5% of the respondents reported that they had some bad physical or mental health condition occurring very often. 27.5% of them found that the symptoms were relieved when they moved out of the workplace. 25% of occupants agreed and 42.5% did not rule out the possibility of a detrimental effect of room environment on their health. 47.5% of the employees said they have availed sick leave in the past two months.

Table.9a.

Question	Excellent	Good	Fair	Neutral	Not so good	Poor	Total
How do you rate the IAQ in your workplace?	1	17	9	4	7	2	40

Table.9b.

Have you experienced one or more of the following conditions in last 2 months?	High room temperature	Very low room temperature	Dry air	Respiratory irritability	Unpleasant odour
Yes, very often (every week)	15	7	4	1	4
Yes, sometimes (1-3 times per month)	19	14	21	16	14
No, never	6	19	15	23	22
Total	40	40	40	40	40

Table.9c.

How often have you felt physically or mentally not in good condition in the last 2 months?	All the time	Very often (3-4 times/week)	Often (3-4 times/month)	Seldom (once in a month)	Never
	0	3	7	25	5

Table.9d.

Do you feel relieved when you move out of your workplace?	Yes, often (more than 3 experiences)	Yes, sometimes (1-3 experiences)	No, I am not relieved after moving out of the premises	I am not sure
	11	23	3	3

Table.9e.

Do you think that the room environment is detrimental to your health?	Yes	No	Maybe
	10	13	17

Table.9f.

How many days were you absent from the office in the past 2 months for health reasons?	1-3 days	4-6 days	7-10 days	Not absent
	16	2	1	21

5.5 Worker Rating of Own Health and the Determinants of Well-being

The office workers` assessment of their own health and how they considered various factors could be responsible for their good health in the workplace is shown in Table.10(a-c). None of the respondents felt that they had poor general health. Ventilation of the office room and smelling pollution were the top-rated indoor factors for the well-being by the respondents followed by room temperature, air movement and humidity. Air conditioning of the workplace was rated as the lowest significant factor, however 45% of the staff found air conditioning very important for their well-being. (Table 10b) For the psychosocial well-being, more than 62.5% of the occupants found the given factors (health, job challenges, income and financial security, cleanliness of office, furnishings at the workplace, relationship with colleagues and superior officials and independence at work) as very important and health was the factor highly valued (97.5%) among them. (Table 10c) 70%-80% of the occupants expressed quite satisfaction and 12.5%-25% occupants were very satisfied with these factors at the current point of time.

Table.10a

Question	Excellent	Very good	Good	Not that good	Bad
How would you describe your general health status?	5	22	13	0	0

Table.10b

Which of the following indoor factor do you think is important for your well-being?	Not important	Slightly important	Quite important	Very important	Extremely important	Total
Ventilation	0	1	5	21	13	40
Humidity	1	4	7	22	6	40
Room temperature	0	3	4	28	5	40
Air movement	0	3	8	23	6	40
Smelling pollution	1	2	3	25	9	40
Air conditioning of workplace	9	6	7	18	0	40

Table.10c

Q. Which of the following determinant factor do you feel is important for your psychosocial well-being?	Health	Job challenges	Income and financial security	Cleanliness of office	Furnishings at the workplace	Relationship with colleagues and superior officials	Independence at work
Not important	0	0	0	0	0	0	0
Little important	1	2	2	1	4	0	1
Quite important	0	9	8	4	11	2	7
Very important	19	25	24	27	20	26	28
Extremely important	20	4	6	8	5	12	4
Total	40	40	40	40	40	40	40
Q. Indicate your satisfaction with it now in your office	Health	Job challenges	Income and financial security	Cleanliness of office	Furnishings at the workplace	Relationship with colleagues and superior officials	Independence at work
Dissatisfied	0	1	1	1	0	1	0
Quite dissatisfied	6	3	3	4	4	1	0
Quite satisfied	28	30	31	30	31	28	32
Very satisfied	6	6	5	5	5	10	8
Total N	40	40	40	40	40	40	40

The questionnaire asked the respondents to give their vote from a list of statements provided in the questionnaire, that they personally feel regarding their health and wellbeing. The question was intended to appraise the respondents` inherent thought about their own responsibility towards health. The responses are tabulated in Table.10d. The responses indicate that 97.5% of the respondents had a clear sense of responsibility for their own health.

Table.10d.

Question: Pick from the statements that you agree with, regarding your well-being, personally. (You can pick more than one statement)	Votes
I am directly responsible for my health	16
If I am sick, there is nothing much I can do about it	0
Good health is largely a matter of luck	1
Whenever I get some symptoms, I neglected to trace the reason for that	0
I can do a few things myself for health and well-being	6
My lifestyle, awareness and behaviour have a role in my health	26

5.6 The Objective Measurements of IAQ Parameters in the Study

The Table.11 shows the mean values and the standard deviation of the measured parameters in the 16 office rooms. The objective measurements show a high temperature in all measuring points in Building 1, two points in Building 2 and all the points in the Building 5. The carbon dioxide level exceeded 1000ppm in one of the office rooms in Building 1. In Building 2, a slightly high level of relative humidity was observed in relation to the temperature in one of the office rooms. All the remaining workplaces had the levels of variables within the recommended limits.

Table.11 Descriptive statistics- Mean values and Standard deviation of measured parameters like Temperature, Relative Humidity, Carbon dioxide, Air Velocity and Particulate Matter

Parameters		Temperature (^{0}C)		Relative Humidity (%)		CO2 (ppm)		Air Velocity (m/s)	
Office Buildings		Mean	SD	Mean	SD	Mean	S D	Mean	SD
B1	1	**27.239***	0.4857	47.088	0.8730	554.026	35.000	0.080008	0.00037
	2	**27.251***	0.1093	47.279	0.3569	**1002.409***	57.325	0.080008	0.00037
	3	**29.096***	0.3830	43.119	1.8743	598.428	106.007	0.080011	0.00041
	4	**29.360***	0.2832	41.255	1.2571	558.013	57.752	0.080008	0.00036
B2	1	**27.262***	0.2818	57.426	0.7663	658.299	9.418	0.08	0.000

	2	**29.661***	0.5065	48.037	1.3791	505.299	30.914	0.08	0.000
	3	24.467	0.4001	**62.939***	1.1697	442.110	25.708	0.080003	0.00016
B3	1	24.134	0.1589	53.052	0.1867	913.389	143.581	0.08	0.000
	2	24.528	0.1146	48.562	0.9402	670.066	84.404	0.08	0.000
	3	23.71	0.3284	53.742	0.2859	918.457	121.183	0.08	0.000
B4	1	22.197	0.9324	45.249	0.9324	567.362	24.492	0.070046	0.00067
	2	23.573	0.1079	43.710	0.3309	719.829	24.698	0.080014	0.00049
	3	22.454	0.2941	56.814	0.9161	488.789	29.737	0.080176	0.00224
B5	1	**31.174***	0.2686	42.330	1.1076	557.940	35.819	0.08	0.000
	2	**31.563***	0.3167	36.849	2.0387	496.586	47.652	0.080008	0.00028
	3	**30.698***	0.2579	41.333	0.7083	520.971	37.180	0.08	0.000

Office Buildings		Parameter-Particulate Matter (μg/m^3)			
		PM 2.5		PM 10	
		Mean	SD	Mean	SD
B1	1	5.923	1.320	5.923	1.552
	2	5.846	1.463	5.923	1.441
	3	6.230	1.012	6.203	1.012
	4	5.538	1.898	5.769	2.204
B2	1	11.538	3.406	12.846	3.782
	2	8.153	2.339	8.538	2.757
	3	4.307	1.031	4.307	1.031
B3	1	7.230	0.725	7.230	0.725
	2	5.923	1.497	5.846	1.344
	3	7.000	2.041	6.846	2.339
B4	1	4.692	1.182	4.692	1.182
	2	5.769	1.165	5.769	1.165
	3	4.769	1.013	4.769	1.013
B5	1	7.692	1.377	7.769	1.536
	2	6.000	1.354	6.000	1.291
	3	6.153	1.068	6.154	1.068

*The values exceeding the recommended levels are highlighted in bold

5.7 Assessment of Prevalence of SBS in the Offices in Hamburg

Table.12a The Percentage prevalence of all SBS symptoms

SBS Symptoms	Every Week (Often)		1-3 times a month (Yes, sometimes)		No symptoms		Yes, often due to other illnesses	
	N	%	n	%	N	%	N	%
Itching burning or irritation of the eyes	7	17.5	1	2.5	29	72.5	3	7.5
Irritating blocked or runny nose	3	7.5	9	22.5	26	65	2	5
Dryness of throat and	2	5	8	20	30	75	0	0

hoarseness of voice								
Cough (Dry/Allergic)	3	7.5	10	25	27	67.5	0	0
Irritation of skin, scalp or around the ears	2	5	6	15	31	77.5	1	2.5
Dry hands, reddening of skin of hands	4	10	5	12.5	31	77.5	0	0
Tiredness or Fatigue	10	25	27	67.5	2	5	1	2.5
Headache, heaviness of head.	6	15	22	55	11	27.5	1	2.5
Change in smell and taste sensation	0	0	2	5	38	95	0	0
Difficulty in breathing	0	0	2	5	36	90	2	5

Table.12b Prevalence of health complaints (SBS)

SBS symptoms	Symptoms occurring every week which is not due any illness		Disappearance of symptoms after leaving the premises			
			Yes, often	Yes, sometimes	Not disappeared	Not sure
	n	%	n (%)	n (%)	n (%)	n (%)
Itching, burning or irritation of eyes	7	100	3 (42.9)	3 (42.9)	0 (0)	1 (14.3)
Irritating, blocked, or runny nose	3	100	2 (66.7)	1 (33.3)	0 (0)	0 (0)
Dryness of throat or hoarseness of voice	2	100	1 (50)	1 (50)	0 (0)	0 (0)
Cough (Dry, allergic)	3	100	2 (66.7)	1 (33.3)	0 (0)	0 (0)
Irritation of skin, scalp, or around the ears	2	100	0 (0)	2 (100)	0 (0)	0 (0)
Dry hands, reddening of skin on your hands	4	100	2 (50)	1 (25)	0 (0)	1 (25)
Tiredness or fatigue	10	100	3 (30)	7 (70)	0 (0)	0 (0)
Headache or heaviness of head	6	100	2 (33.3)	3 (50)	0 (0)	1 (16.7)
Change in smell or taste sensation	0	100	0 (0)	0 (0)	0 (0)	0 (0)
Difficulty in breathing	0	100	0 (0)	0 (0)	0 (0)	0 (0)

The occupants` experience of symptoms (percentage prevalence) in the last two months is illustrated in Table 12a. The most prevalent symptom occurring often (every week) was tiredness and fatigue (25%), followed by itching, burning or irritation of the eyes (17.5%) and headache/heaviness of head (15%). 67.5% of the occupants had episodes of tiredness or fatigue, 55% had incidents of headache or heaviness of head, 25% had cough and 22.5% suffered irritating, blocked, or runny nose 1-3 times a month. The symptoms arising due to allergy or other diseases were itching, burning, irritation of eyes (7.5%), difficulty in breathing/irritating, blocked or runny nose (5%), irritation of skin, scalp, or around the ears/tiredness or fatigue/headache, heaviness of head (2.5%). The prevalence of SBS in the present study is tabulated in Table 12b.

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5.8 Descriptive statistics and One-Way Analysis of Variance (One-Way ANOVA)

Table.13 Descriptive statistics and ANOVA for Carbon dioxide in different offices

Building	N	Mean	Std. Deviation	Std. Error	95% CI for Mean		Minimum	Maximum
					Lower bound	Upper bound		
1	4	678.2192	217.05530	108.52765	332.8358	1023.6026	554.03	1002.41
2	3	535.2367	111.16020	64.17837	259.0994	811.3739	442.11	658.30
3	3	833.9709	141.96819	81.96537	481.3024	1186.6394	670.07	918.46
4	3	591.9936	117.47311	67.82313	300.1742	883.8130	488.79	719.83
5	3	525.1661	30.89135	17.83513	448.4278	601.9045	496.59	557.94
Total	16	635.7487	170.03895	42.50974	545.1413	726.3560	442.11	1002.41

ANOVA

CO_2_Mean		Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
	Between Groups	197828.146	4	49457.04	2.306	0.123	0.456
	Within Groups	235870.536	11	21442.78			
	Total	433698.682	15				

Table.14a Descriptive statistics and ANOVA for Relative Humidity in different offices

	N	Mean	Std. Deviation	Std Error	95% CI for Mean		Minimum	Maximum
					Lower bound	Upper bound		
1	4	44.6857	2.98451	1.49226	39.9367	49.4347	41.26	47.28
2	3	56.1346	7.53420	4.34987	37.4186	74.8506	48.04	62.94
3	3	51.7858	2.81277	1.62395	44.7985	58.7731	48.56	53.74
4	3	48.5915	7.16269	4.13538	30.7984	66.3846	43.71	56.81
5	3	40.1710	2.91951	1.68558	32.9185	47.4234	36.85	42.33
Total	16	48.0495	7.05253	1.76313	44.2914	51.8075	36.85	62.94

ANOVA

Relative Humidity_ Mean		Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
	Between Groups	470.343	4	117.586	4.691	0.019	0.630
	Within Groups	275.729	11	25.066			
	Total	746.072	15				

Table.14b Post Hoc Subset for Relative humidity

	Building	N	Subset for alpha = 0.05	
			1	2
Tukey HSD	5	3	40.1710	
	1	4	44.6857	44.6857
	4	3	48.5915	48.5915
	3	3	51.7858	51.7858
	2	3		56.1346
	Sig.		0 .084	0 .090

Table.15a Descriptive statistics and ANOVA for Temperature in different offices

Building	N	Mean	Std. Deviation	Std. Error	95% CI for Mean		Minimum	Maximum
					Lower bound	Upper bound		
1	4	28.2370	1.15002	.57501	26.4071	30.0670	27.24	29.36
2	3	26.1641	3.02917	1.74889	18.6392	33.6890	24.36	29.66
3	3	24.1265	0.40633	0.23460	23.1171	25.1359	23.72	24.53
4	3	22.7420	0.73155	0.42236	20.9247	24.5592	22.20	23.57
5	3	31.1456	0.43303	0.25001	30.0699	32.2213	30.70	31.56
Total	16	26.5927	3.26984	0.81746	24.8503	28.3350	22.20	31.56

ANOVA

Temperature_ Means		Sum of squares	df	Mean Square	F	Sig.	Partial η^2
	Between Groups	136.283	4	34.071	15.554	0.00	0.85
	Within Groups	24.095	11	2.190			
	Total	160.378	15				

Table.15b Post Hoc Subset for Temperature

	Building	N	Subset for alpha = 0.05		
			1	2	3
Tukey HSD	4	3	22.7420		
	3	3	24.1265		
	2	3	26.1641	26.1641	
	1	4		28.2370	28.2370
	5	3			31.1456
	Sig.		0.085	0.440	0.168

Table.16. Descriptive statistics and ANOVA of Air Velocity in different Office Buildings

Building	N	Mean	Std. Deviation	Std Error	95% CI for Mean		Minimum	Maximum
					Upper bound	Lower bound		
1	4	0.080	0.0000	0.0000	0.0800	0.0800	0.08	0.08
2	3	0.080	0.0000	0.0000	0.0800	0.0800	0.08	0.08
3	3	0.080	0.0000	0.0000	0.0800	0.0800	0.08	0.08
4	3	0.0767	0.0058	0.00335	0.0623	0.0912	0.07	0.08
5	3	0.0800	0.0000	0.0000	0.0800	0.0800	0.08	0.08
Total	16	0.0794	0.00249	0.00062	0.0781	0.0807	0.07	0.08

ANOVA

Air Velocity_ Mean		Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
	Between Groups	0.000	4	0.000	1.057	0.422	0.278
	Within Groups	0.000	11	0.000			
	Total	0.000	15				

Table.17a. Descriptive statistics and ANOVA for PM2.5 in different Office Buildings

Building	N	Mean	Std. Deviation	Std Error	95% CI for Mean		Minimum	Maximum
					Upper bound	Lower bound		
1	4	5.8847	.28437	0.14218	5.4322	6.3371	5.54	6.23
2	3	9.3590	1.89106	1.09180	4.6613	14.0566	8.15	11.54
3	3	6.7180	.69798	0.40298	4.9841	8.4518	5.92	7.23
4	3	5.0769	.60078	0.34686	3.5845	6.5693	4.69	5.77
5	3	6.6154	.93582	0.54029	4.2907	8.9401	6.00	7.69
Total	16	6.6779	1.68582	0.42146	5.7796	7.5762	4.69	11.54

ANOVA

PM2.5_Means		Sum of Squares	df	Mean Square	F	Sig.	Partial η^2

	Between Groups	31.787	4	7.947	8.062	0.003	0.746
	Within Groups	10.843	11	0.986			
	Total	42.630	15				

Table.17b. Post Hoc Subset for PM2.5

Building		N	Subset for alpha = 0.05 1	2
Tukey HSD	4	3	5.0769	
	1	4	5.8847	
	5	3	6.6154	
	3	3	6.7180	
	2	3		9.3590
	Sig.		0 .295	1.000

Table.18a. Descriptive statistics and ANOVA for PM10 in different Office Buildings

Building	N	Mean	Std. Deviation	Std Error	95% CI for Mean Upper bound	Lower bound	Minimum	Maximum	
1	4	5.9615	0.19361	0.09680	5.6535	6.2696	5.77	6.23	
2	3	10.1005	2.38538	1.37720	4.1748	16.0261	8.54	12.85	
3	3	6.6411	0.71473	0.41265	4.8656	8.4166	5.85	7.23	
4	3	5.0769	0.60078	0.34686	3.5845	6.5693	4.69	5.77	
5	3	6.6410	0.98007	0.56584	4.2064	9.0756	6.00	7.77	
Total	16	6.8265	1.99493	0.49873	5.7635	7.8896	4.69	12.85	
ANOVA									
PM10_Mean				Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
		Between Groups		44.539	4	11.135	8.081	0.003	0.746
		Within Groups		15.157	11	1.378			
		Total		59.696	15				

Table.18b. Post Hoc Subset for PM10

Building		N	Subset for alpha = 0.05	
			1	2
Tukey HSD	4	3	5.0769	
	1	4	5.9616	
	5	3	6.6410	
	3	3	6.6411	
	2	3		10.1005
	Sig.		0 .486	1.000

A One-way between-group analysis of variance (ANOVA) was performed to investigate the differences in the measured parameters between different office buildings. The results of ANOVA revealed that the mean test score of Carbon dioxide between the five building was statistically non-significant. $F = 2.306$, $p = 0.123$ and the effect size, as indexed by η^2, was 0.456. And the same was observed with the parameter Air Velocity ($F= 1.057$, $p = 0.422$, effect size $\eta^2 = 0.278$).

There was a statistically significant difference in the mean test score of Relative Humidity, Temperature and Particulate Matter (PM2.5 and PM10) between the five buildings. (Relative Humidity: $F= 4.691$, $p = 0.019$, effect size $\eta^2 = 0.630$, Temperature: $F = 15.554$, $p = 0.00$, effect size $\eta^2 =0.850$), Particulate Matter: PM2.5: $F = 8.062$, $p = 0.003$, effect size $\eta^2 = 0.746$, PM10: $F = 8.081$, $p = 0.003$, effect size $\eta^2 = 0.746$) A Tukey HSD Post Hoc multiple comparisons test was carried out to identify the specific buildings between which there is a significant difference in the mean test score of the parameters. The results are tabulated in the table 14b, 15b, 17b and 18b.

5.9 Spearman`s rho Correlation to Assess the Agreement of the Objective Measurements with the Subjective Perception of IAQ

The fourth objective was to identify the relationship between the objective IAQ and perception of IAQ by the office workers. Total score for each variable was calculated and Spearman`s rho correlation was used to get the relationship. (One-tailed test with $\alpha = 0.05$). Table 19(a-b) depicts the correlation analysis.

A negative correlation (linear relationship) was found to exist between the level of parameters (knowledge) and the perception (skills) indicating that as the scores for objective IAQ increase, the scores for perception of IAQ will decrease. ($r_s = -0.260$, $p = 0.052$)

Table.19. Descriptives and Correlations between objective measurements and subjective perception of IAQ

a. Descriptives

			Statistic	Std. Error
Sum of Objective Z scores	Mean		0.0000	0.57593
	95% Confidence Interval for Mean	Lower Bound	-1.1649	
		Upper Bound	1.1649	
	5% Trimmed Mean		0.2274	
	Median		-0.0482	
	Variance		13.268	
	Std. Deviation		3.64253	
	Minimum		-8.25	
	Maximum		4.16	
	Range		12.41	
	Interquartile Range		2.32	
	Skewness		-0.854	0.374
	Kurtosis		0.022	0.733
Sum of Objective scores	Mean		726.1408	18.64321
	95% Confidence Interval for Mean	Lower Bound	688.4313	
		Upper Bound	763.8502	
	5% Trimmed Mean		721.6486	
	Median		673.5577	
	Variance		13902.771	
	Std. Deviation		117.91001	
	Minimum		609.82	
	Maximum		923.32	
	Range		313.50	
	Interquartile Range		125.99	
	Skewness		0.840	0.374
	Kurtosis		-0.845	0.733
Sum of Perception IAQ	Mean		15.2250	.42890
	95% Confidence Interval for Mean	Lower Bound	14.3575	
		Upper Bound	16.0925	
	5% Trimmed Mean		15.3056	
	Median		15.0000	

	Variance		7.358	
	Std. Deviation		2.71262	
	Minimum		9.00	
	Maximum		20.00	
	Range		11.00	
	Interquartile Range		4.00	
	Skewness		-0.421	0.374
	Kurtosis		-0.202	0.733
Perception: Rating of Air quality in the workplace	Mean		3.8750	.21240
	95% Confidence Interval for Mean	Lower Bound	3.4454	
		Upper Bound	4.3046	
	5% Trimmed Mean		3.9444	
	Median		4.0000	
	Variance		1.804	
	Std. Deviation		1.34331	
	Minimum		1.00	
	Maximum		6.00	
	Range		5.00	
	Interquartile Range		2.00	
	Skewness		-0.696	0.374
	Kurtosis		-0.737	0.733

b. Correlations

		Sum of Objective Z scores	Sum of Objective scores	Sum of Perception IAQ	Perception: Rating of Air quality in the workplace
Spearman's rho - Sum of Objective Z scores	Correlation Coefficient	1.000	0.083	-0.260	-0.232
	Sig. (1-tailed)	.	0.304	0.052	.074
	N	40	40	40	40
Sum of Objective scores	Correlation Coefficient	0.083	1.000	-0.137	-0.050
	Sig. (1-tailed)	0.304	.	0.199	0.379
	N	40	40	40	40
Sum of Perception IAQ	Correlation Coefficient	-0.260	-0.137	1.000	0.648**

	Sig. (1-tailed)	0.052	0.199	.	<.001
	N	40	40	40	40
Perception: Rating of Air quality in the workplace	Correlation Coefficient	-0.232	-0.050	0.648**	1.000
	Sig. (1-tailed)	0.074	0.379	<.001	.
	N	40	40	40	40
**. Correlation is significant at the 0.01 level (1-tailed).					

The association between the perception of IAQ and SBS was tested using the Spearman`s rho correlation test. A negative correlation was obtained which implies that as scores for perception of IAQ increase, the scores for SBS will decrease. (r_s = -0.619, p<0.01) (Table 20b)

5.10 Spearman`s rho Correlation test- Correlation between Office Workers Perception of IAQ and SBS Complaints

Table.20. Descriptives, and Correlations between worker`s perception of IAQ in the premises and SBS Complaints

a. Descriptives

			Statistic	Std. Error
SBS (Health Complaint)	Mean		4.1500	0.55993
	95% Confidence Interval for Mean	Lower Bound	3.0174	
		Upper Bound	5.2826	
	5% Trimmed Mean		3.8333	
	Median		3.0000	
	Variance		12.541	
	Std. Deviation		3.54133	
	Minimum		0.00	
	Maximum		15.00	
	Range		15.00	
	Interquartile Range		3.75	
	Skewness		1.401	0.374
	Kurtosis		1.880	0.733
Sum of Perception IAQ	Mean		15.2250	0.42890
	95% Confidence Interval for Mean	Lower Bound	14.3575	
		Upper Bound	16.0925	
	5% Trimmed Mean		15.3056	
	Median		15.0000	
	Variance		7.358	
	Std. Deviation		2.71262	
	Minimum		9.00	
	Maximum		20.00	

	Range	11.00	
	Interquartile Range	4.00	
	Skewness	-0.421	0.374
	Kurtosis	-0.202	0.733

b. Correlations

			SBS (Health Complaint)	Sum of Perception IAQ
Spearman's rho	SBS (Health Complaint)	Correlation Coefficient	1.000	-0.619**
		Sig. (1-tailed)	.	<.001
		N	40	40
	Sum of Perception IAQ	Correlation Coefficient	-0.619**	1.000
		Sig. (1-tailed)	<.001	.
		N	40	40
***. Correlation is significant at the 0.01 level (1-tailed).*				

5.11 Independent Sample t-test to Assess the Association between Gender and SBS of the Respondents

An Independent-samples t-test was conducted to compare the SBS scores of the genders in the study. The independent t-test is an inferential test to assess the statistically significant difference between the means of two unrelated groups. The test found out that there was a statistically significant difference in the SBS score for male (Mean-3.1053, SD-2.9981) and female (Mean-5.0952, SD-3.7935); $t = -1.827$, $p = 0.038$. An inspection of the two means suggest that the female respondents have higher SBS scores compared to the male respondents. The effect size as indexed by Cohen`s d, was 0.56. (Table 21a-b)

Table.21a. Group Statistics

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
Equal variances assumed	1.015	.320	-1.827	38	.076	-1.98997	1.08909	-4.19473	.21478
Equal variances not assumed			-1.849	37.361	.072	-1.98997	1.07626	-4.16997	.19002

Table. 21b Independent Samples t-test

Gender	N	Mean	SD	Mean difference	Df	t	sig-t(1-tailed)	Cohen's d
Male	19	3.1053	2.9981	-1.9899	38	-1.827	.038	0.56
Female	21	5.0952	3.7935					

6.Discussion

6.1 Summary of Results

As detailed before, a cross sectional study was conducted among the office workers from five office buildings situated in different locations of Hamburg, Germany, during the summer season, 2019 from June to August. The study aimed at the assessment of indoor air quality and prevalence of worker complaints. The plan of study included the instrumental measurement of five relevant parameters like temperature, relative humidity, air velocity, carbon dioxide and particulate matter and followed by an online survey with the aid of a questionnaire, among the office workers to assess their subjective perceptions. The measurements were taken at 16 measuring points one in each workspace identified within the five office buildings. The objectives were to assess the IAQ using the measured parameters and determine the prevalence of sick building syndrome using the online survey responses and to assess the subjective perception of IAQ on one hand, on the other hand it also aims to assess any correlation between the measured parameter level, perception of IAQ and worker complaints of health (SBS) and any association of the gender factor and health complaints. The correlation test was included in the study due to few facts pertaining to SBS. From the literatures of the extensive studies on SBS, it was found that SBS does not have a clear aetiology and the determination was carried out solely based on the self-reports by the occupants. None of the research could identify a single risk factor to explain SBS among occupants which apparently implies that SBS is triggered by multiple factors. Besides the quantifiable variables other factors like personal, work related, or psychosocial factors were required to be considered while assessing the contributors to the continuing prevalence of SBS.

The present study measured the five parameters in the office rooms and found that the mean temperature level in the buildings B1, B2 and B5 had high values of 28.237±1.15, 26.164±3.029 and 31.145±0.433 respectively. All other parameters had mean values within the acceptable limits. No ambient temperature measurements were done which is also a limitation of the study and is a non-conformity with the air quality assessment guidelines for indoor workspaces.

One of the aims of the present study was to assess the prevalence of SBS. The most prevalent symptom was found to be tiredness and fatigue (25%) which occurred often (every week), followed by itching, burning or irritation of the eyes (17.5%) and headache/heaviness of head (15%). By definition, an occupant is said to have SBS when the symptoms occurred at least once in a week, which is not due to any pre-existing illness and the symptoms improved when the occupant moved out of the premises. This result is in concurrence with the study by Abdel Hamid et al 2013. The cross-sectional study conducted among office workers in the medical faculty to determine prevalence of SBS showed high a prevalence of SBS with highest occurrence of fatigue (76.9%) and headache (74.7%). The study also found significant association of poor ventilation, lack of sunlight, absence of air movements, temperature, ETS, inadequate cleanliness, workload and job satisfaction to the symptoms (Univariate Analysis).

The present study results for the prevalent SBS symptoms also agreed with the findings from the studies by Bluyssen et al; 2016, Norhidayah et al; 2013, Gomzi et al; 2007 and Jakkola et al; 2007 where the general symptoms like headache, tiredness & lethargy, fatigue were the most occurred SBS complaint among the indoor occupants. Besides these, the organ specific symptoms like itchy irritating eyes(Norhidayah et al., 2013), sore and dry eyes (Gomzi et al., 2007) (Bluyssen et al., 2016) were observed as the most prevalent symptoms.

The sick building syndrome among the office workers in the present study is illustrated in table 12b. The incidences of SBS among the office workers occurring often (every week) not due to any illness is compared against the incidence of relief of symptoms after leaving the workplace, which occurs often (an experience of more than three times in the previous two months) The respondents reported single or multiple symptoms in the survey. All the symptoms that occurred every week improved after leaving the office building. 70% of the respondents had experienced relief from their symptoms at least 1-3 times in the last two months. No participant disagreed to the betterment outside the office building however, 8% of the respondents who suffered symptoms not due an illness was not sure of an improvement of their SBS after leaving the office building. The study clearly shows the prevalence of SBS among the office workers.

Comparison of the measured air quality parameters in the different office buildings were done by One way between-group Analysis of Variance (ANOVA). The analysis showed statistically significant difference in the mean scores of Relative Humidity, Temperature and Particulate Matter (PM2.5 and PM10) between the office buildings. The Tukey HSD Post Hoc multiple comparisons test specifically determined the office buildings that showed the significant differences. No statistically significant differences were observed in the mean scores of CO_2 and Air Velocity between the office buildings.

The psychosocial domain in which a worker is exposed to is a determinant of perception of IAQ and SBS complaints among them. (Eriksson et al., 1996) (Lahtinen et al., 2004) In the present study Spearman's rho correlation test was run to assess the relationship between the quantitative IAQ values and the occupant perception of IAQ and to study the correlation between the perception of IAQ and the SBS reported. A negative correlation was observed in both the assessments indicating that as the parameter values increased the occupants perceived poor perception and reporting of complaints lowered when the occupants perceived a good IAQ. Lahtinen and colleagues observed that there existed multiple factors affecting the indoor health problems and the stress and strain when existed in a workplace was a vital modifying factor of symptoms reporting.

The association between the gender of the office worker and SBS complaints was compared using independent samples t-test which shows high SBS scores for female respondents compared to males. This finding is consistent with the study results from a good number of investigations. (Bullinger et al., 1999) (Brasche1 et al., 2001) (Kim et al., 2013)

6.2 Limitations of the Study

The present analytical study is a cross-sectional one, where the exposure and outcome are analysed from the data at one point of time, and here the study was conducted during summer 2019. Causality cannot be inferred from a cross-sectional study.

The study utilized a convenience sample of office workers from the agreed offices in Hamburg, Germany. The selection of participants and office buildings were non-random. Hence the representativeness of the sample is questionable and cannot be projected to a large target sample. There are higher chances of over or under representation. The disadvantages of a bias and outliers cannot be overlooked with this non-probability sampling.

The sample size of the study was small (n = 40) which was well below the required sample size for a finite sample population based on the open epi program for calculation of sample size.

The survey contained questions pertaining to indoor environment conditions experienced by the respondents and the SBS in the last two months. A recall bias cannot be excluded here. However, in the present study, the recall period was brought down to two months to minimise recall bias.

The IAQ perception will vary among the workers based on the type of work they perform. Only susceptible employee will perceive a poor IAQ and report a health problem. In the present study out of the 40 respondents 32 of them are engaged activities with minimal physical activity which, however, does not exclude them from work related stress. This may be a stimulus to poor perception of IAQ. The questionnaire did not ask ′when does the symptom start′ , hence does not throw light on the onset of symptoms (like beginning of the start of office, towards the end of the day, in weekends or indistinct).

In the present study office workers performing administrative work alone were intended to be included (for minimal physical activity). This criterion was unable to be ensured because the distribution of questionnaire was done by the contact person in each office building.

The Questionnaire was developed from MM questionnaire and the questionnaire administered in the 'Proklima Study', both are validity and reliability tested. However, a reliability and validity testing of new developed questionnaire could not be carried out due to resource limits of the study.

The outside air temperature measurement was not taken during working hours ("BAuA - ASR A3.5," n.d.) which is a limitation of the procedure for indoor assessment, in the present study. A one-hour measurement of particulate matter was done in the present study which does not satisfy the requirement of 24 hr measurement for assessment of particulate matter (PM2.5 and PM10) in the indoor environment.

6.3 Strengths of the Study

Despite the limitations, cross-sectional study is a suitable method for measuring the associations. The objective measurement (exposure) and subjective perception (outcome) can be measured simultaneously in the study and is appropriate for collecting the data of multiple variables.

6.4 Recommendations

Owing to the complex nature of the aetiology of SBS, the study could be initiated by collecting preliminary data pertaining to the office characteristics, work characteristics, demography, the health complaints (seasonal) from the employees. The knowledge of the base of the problem help to develop a more precise and grounded questionnaire for a better analysis of the problems in the indoors.

The access to control systems for both genders could reduce the dissatisfaction of indoor environment and reduce the health complaints.

The availability of a communicating channel in the organisations to report discomfort problem as it arises shall be the part of the company policy helps in correction of the same without aggravation into highly unacceptable level.

7. Conclusion

A cross-sectional study was conducted to study the prevalence of SBS among the office workers in offices in Hamburg, Germany and to assess the factors affecting the perception of indoor air quality and SBS. The tools administered in the investigation included objective measurement of the five parameters of indoor air quality using Test 480 climate indoor measuring instrument and Intelligence ai detector, followed by a survey using a self-administered questionnaire to assess the occupant perceptions.

All the objective parameter levels except temperature were within the recommended limit. The mean temperature levels in building were 28.237±1.5 (B1), 26.164±3.029 (B2), 31.145±0.433 (B5) for levels exceeding the recommended limits. The study shows the prevalence of SBS among the workers. Symptoms like tiredness and fatigue followed by itching, burning or irritation of eyes and headache, heaviness of head was experienced every week by the worker. 37.5% of the workers felt a high temperature in their workplace every week.

A one-way between-group analysis of variance showed statistically significant differences for the variables like temperature, relative humidity and particulate matter (PM2.5 and PM10) between the five office buildings. The Tukey HSD post hoc multiple comparison test for multiple comparisons test done to determine the office buildings that showed a difference in the mean score of the parameters. The study derived a negative correlation between the objective variable levels and perception of IAQ and between the perception of IAQ and SBS reporting among the office workers using Spearman's rho correlation test. The independent sample t-test is done to assess the SBS reporting scores between the two genders. Women had high SBS than men in the present study.

8. Bibliography

Abdel-Hamid, M.A., A. Hakim, S., Elokda, E.E., Mostafa, N.S., 2013. Prevalence and risk factors of sick building syndrome among office workers. The Journal Of The Egyptian Public Health Association 88, 109. https://doi.org/10.1097/01.EPX.0000431629.28378.c0

Abelmann, S., 2013. German Committee on Indoor Air Guide Values [WWW Document]. Umweltbundesamt. URL https://www.umweltbundesamt.de/en/topics/health/commissions-working-groups/german-committee-on-indoor-air-guide-values.

Adel, M., n.d. ANSIIASHRAE Standard 62.1-2007.

Al Horr, Y., Arif, M., Kaushik, A., Mazroei, A., Katafygiotou, M., Elsarrag, E., 2016. Occupant productivity and office indoor environment quality: A review of the literature. Building and Environment 105, 369–389. https://doi.org/10.1016/j.buildenv.2016.06.001

BAuA - ASR A3.5, n.d. URL https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/ASR/ASR-A3-5.html.

BAuA - ASR A3.6, n.d. URL https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/ASR/ASR-A3-6.html.

BAuA - Klima am Arbeitsplatz, n.d. URL https://www.baua.de/DE/Themen/Arbeitsgestaltung-im-Betrieb/Physikalische-Faktoren-und-Arbeitsumgebung/Klima-am-Arbeitsplatz/Faktoren.html

Becher, R., Øvrevik, J., Schwarze, P.E., Nilsen, S., Hongslo, J.K., Bakke, J.V., 2018. Do Carpets Impair Indoor Air Quality and Cause Adverse Health Outcomes: A Review.

International Journal of Environmental Research and Public Health; Basel 15, 184. http://dx.doi.org.kuleuven.ezproxy.kuleuven.be/10.3390/ijerph15020184

Bischof, W. (Ed.), 2003. Expositionen und gesundheitliche Beeinträchtigungen in Bürogebäuden: Ergebnisse des ProKlimA-Projektes. Fraunhofer-IRB-Verl, Stuttgart.

Bischof, W., Brasche, S., Kruppa, B., Bullinger, M., 2002. Do building-related complaints reflect expectations? Indoor Air 5.

Bluyssen, P.M., Fernandes, E.D.O., Groes, L., Clausen, G., Fanger, P.O., Valbjørn, O., Bernhard, C.A., Roulet, C.A., 1996. European Indoor Air Quality Audit Project in 56 Office Buildings [WWW Document]. Indoor Air. https://doi.org/10.1111/j.1600-0668.1996.00002.x

Bluyssen, P.M., Roda, C., Mandin, C., Fossati, S., Carrer, P., Kluizenaar, Y. de, Mihucz, V.G., Fernandes, E. de O., Bartzis, J., 2016. Self-reported health and comfort in 'modern' office buildings: first results from the European OFFICAIR study. Indoor Air 26, 298–317. https://doi.org/10.1111/ina.12196

Brągoszewska, E., Biedroń, I., Kozielska, B., Pastuszka, J.S., 2018. Microbiological indoor air quality in an office building in Gliwice, Poland: analysis of the case study. Air Quality, Atmosphere, & Health 11, 729–740. http://dx.doi.org.pva.uib.no/10.1007/s11869-018-0579-z

Brasche1, S., Bullinger2, M., Morfeld2, M., Gebhardt3, H.J., Bischof1, W., 2001. Why do Women Suffer from Sick Building Syndrome more often than Men? – Subjective Higher Sensitivity versus Objective Causes . Indoor Air. https://doi.org/10.1034/j.1600-0668.2001.110402.x

Bullinger, M., Morfeld, M., von Mackensen, S., Brasche, S., 1999. The Sick-Building-Syndrome —Do women suffer more?: Das Sick-Building-Syndrom — Leiden Frauen mehr? Zentralblatt für Hygiene und Umweltmedizin 202, 235–241. https://doi.org/10.1016/S0934-8859(99)80025-X

Burge, P.S., 2004. Sick building syndrome. Occupational and Environmental Medicine 61, 185–190. https://doi.org/10.1136/oem.2003.008813

Butala, V., Muhič, S., 2007. Perception of Air Quality and the Thermal Environment in Offices. Indoor and Built Environment 16, 302–310. https://doi.org/10.1177/1420326X06079886

Chen, R., Yin, P., Meng, X., Liu, C., Wang, L., Xu, X., Ross, J.A., Tse, L.A., Zhao, Z., Kan, H., Zhou, M., 2017. Fine Particulate Air Pollution and Daily Mortality. A Nationwide Analysis in 272 Chinese Cities. Am J Respir Crit Care Med 196, 73–81. https://doi.org/10.1164/rccm.201609-1862OC

Cheng, Y.-H., 2017. Measuring indoor particulate matter concentrations and size distributions at different time periods to identify potential sources in an office building in Taipei City. Building and Environment 123, 446–457. https://doi.org/10.1016/j.buildenv.2017.07.025

Deros, B.M., Ismail, S.H., Khamis, N.K., Yusof, M.Y.M., Ismail, A.R., 2012. A study of indoor air quality issues for non-industrial work place.

DGUV, D.G.U., 2013. Reports 2013. URL https://www.dguv.de/ifa/publikationen/reports-download/reports-2013/index.jsp (accessed 9.9.19).

Eriksson, N., Höög, J., Stenberg, B., Sundell, J., 1996. Psychosocial Factors and the "Sick Building-Syndrome". A case-referent study. Indoor Air 6, 101–110. https://doi.org/10.1111/j.1600-0668.1996.t01-2-00006.x

European Commission., 2013. Ethics for researchers: facilitating research excellence in FP7. Publications Office, LU.

Field, A., 2017. Discovering statistics using IBM SPSS statistics, 5th edition. ed. SAGE Publications, Thousand Oaks, CA.

Fisk, W.J., Mirer, A.G., Mendell, M.J., 2009. Quantitative relationship of sick building syndrome symptoms with ventilation rates. Indoor Air 19, 159–165. https://doi.org/10.1111/j.1600-0668.2008.00575.x

Frontczak, M., Wargocki, P., 2011. Literature survey on how different factors influence human comfort in indoor environments. Building and Environment 46, 922–937. https://doi.org/10.1016/j.buildenv.2010.10.021

Gomzi, M., Bobic, J., Radosevic-Vidacek, B., Macan, J., Varnai, V.M., Milkovic-Kraus, S., Kanceljak-Macan, B., 2007. Sick Building Syndrome: Psychological, Somatic, and Environmental Determinants. Archives of Environmental & Occupational Health 62, 147–55.

Gou, Z., Siu-Yu, L.S., 2012. Sick building syndrome in open-plan offices: Workplace design elements and perceived indoor environmental quality. Journal of Facilities Management 10, 256–265. https://doi.org/10.1108/14725961211265729

Gül, H., Işsever, H., Ayraz, Ö., Güngör, G., 2007. Occupational and Environmental Risk Factors for the Sick Building Syndrome in Modern Offices in Istanbul: A Cross Sectional Study. Indoor and Built Environment 16, 47–54. https://doi.org/10.1177/1420326X06074502

Haghighat, F., Donnini, G., 1999. Impact of psycho-social factors on perception of the indoor air environment studies in 12 office buildings. Building and Environment 34, 479–503. https://doi.org/10.1016/S0360-1323(98)00034-1

Hasegawa, A., Schleibinger, H., Nong, G., Lusztyk, E., 2009. Effects of Renovation Work on Air Quality and Occupants Health in University Buildings. CLEAN – Soil, Air, Water 37, 475–480. https://doi.org/10.1002/clen.200800215

He, C., Morawska, L., Taplin, L., 2007. Particle Emission Characteristics of Office Printers. Environ. Sci. Technol. 41, 6039–6045. https://doi.org/10.1021/es063049z

Hummelgaard, J., Juhl, P., Sæbjörnsson, K.O., Clausen, G., Toftum, J., Langkilde, G., 2007. Indoor air quality and occupant satisfaction in five mechanically and four naturally ventilated open-plan office buildings. Building and Environment, Indoor Air 2005 Conference 42, 4051–4058. https://doi.org/10.1016/j.buildenv.2006.07.042

Indoor air pollution : national burden of disease estimates, n.d. URL https://www.who.int/publications-detail-redirect/WHOSDEPHE0701rev.

Jaakkola, J.J.K., 1998. The Office Environment Model: A Conceptual Analysis of the Sick Building Syndrome*. Indoor Air 8, 7–16. https://doi.org/10.1111/j.1600-0668.1998.tb00002.x

Joshi, S.M., 2008. The sick building syndrome. Indian J Occup Environ Med 12, 61–64. https://doi.org/10.4103/0019-5278.43262

Kagi, N., Fujii, S., Horiba, Y., Namiki, N., Ohtani, Y., Emi, H., Tamura, H., Kim, Y.S., 2007. Indoor air quality for chemical and ultrafine particle contaminants from printers. Building and Environment 42, 1949–1954. https://doi.org/10.1016/j.buildenv.2006.04.008

Kim, J., de Dear, R., Cândido, C., Zhang, H., Arens, E., 2013. Gender differences in office occupant perception of indoor environmental quality (IEQ). Building and Environment 70, 245–256. https://doi.org/10.1016/j.buildenv.2013.08.022

Kim, K.-H., Kabir, E., Kabir, S., 2015. A review on the human health impact of airborne particulate matter. Environment International 74, 136–143. https://doi.org/10.1016/j.envint.2014.10.005

Kubo, T., Mizoue, T., Ide, R., Tokui, N., Fujino, Y., Minh, P.T., Shirane, K., Matsumoto, T., Yoshimura, T., 2006. Visual Display Terminal Work and Sick Building

Syndrome—The Role of Psychosocial Distress in the Relationship. Jrnl of Occup Health 48, 107–112. https://doi.org/10.1539/joh.48.107

Lahtinen, M., Sundman-Digert, C., Reijula, K., 2004. Psychosocial work environment and indoor air problems: a questionnaire as a means of problem diagnosis. Occupational and Environmental Medicine 61, 143–149. https://doi.org/10.1136/oem.2002.005835

Lan, L., Lian, Z., Pan, L., 2010. The effects of air temperature on office workers′ well-being, workload and productivity-evaluated with subjective ratings. Applied Ergonomics 42, 29–36. https://doi.org/10.1016/j.apergo.2010.04.003

Leder, S., Newsham, G.R., Veitch, J.A., Mancini, S., Charles, K.E., 2016. Effects of office environment on employee satisfaction: a new analysis. Building Research & Information 44, 34–50. https://doi.org/10.1080/09613218.2014.1003176

Lyles, W., Greve, K., Bauer, R., Ware, M., Schramke, C., Crouch, J., Hicks, A., 1991. Sick Building Syndrome. Southern Medical Journal 84, 65–71.

Moosbrugger, H., Kelava, A. (Eds.), 2012. Testtheorie und Fragebogenkonstruktion: mit ... 41 Tabellen, 2., aktualisierte und überarb. Aufl. ed, Springer-Lehrbuch. Springer, Berlin Heidelberg.

Myers, I., Maynard, R.L., 2005. Polluted air—outdoors and indoors. Occupational Medicine 55, 432–438. https://doi.org/10.1093/occmed/kqi137

Nezis, I., Biskos, G., Eleftheriadis, K., Kalantzi, O.-I., 2019. Particulate matter and health effects in offices - A review. Building and Environment 156, 62–73. https://doi.org/10.1016/j.buildenv.2019.03.042

Nordström, K., Norbäck, D., Akselsson, R., 1994. Effect of air humidification on the sick building syndrome and perceived indoor air quality in hospitals: a four month longitudinal study. Occupational and Environmental Medicine 51, 683–688. https://doi.org/10.1136/oem.51.10.683

Norhidayah, A., Chia-Kuang, L., Azhar, M.K., Nurulwahida, S., 2013. Indoor Air Quality and Sick Building Syndrome in Three Selected Buildings. Procedia Engineering, Malaysian Technical Universities Conference on Engineering & Technology 2012, MUCET 2012 53, 93–98. https://doi.org/10.1016/j.proeng.2013.02.014

Raw, G.J., 1996. A questionnaire for studies of sick building syndrome. A report to the Royal Society of Health Advisory Group on sick building syndrome. Fuel and Energy Abstracts 37, 227. https://doi.org/10.1016/0140-6701(96)89211-3

Reijula, K., Sundman-Digert, C., 2004. Assessment of indoor air problems at work with a questionnaire. Occupational and Environmental Medicine 61, 33–38.

Saraga, D., Maggos, T., Sadoun, E., Fthenou, E., Hassan, H., Tsiouri, V., Karavoltsos, S., Sakellari, A., Vasilakos, C., Kakosimos, K., 2017. Chemical Characterization of Indoor and Outdoor Particulate Matter (PM2.5, PM10) in Doha, Qatar. Aerosol Air Qual. Res. 17, 1156–1168. https://doi.org/10.4209/aaqr.2016.05.0198

Satish Usha, Mendell Mark J., Shekhar Krishnamurthy, Hotchi Toshifumi, Sullivan Douglas, Streufert Siegfried, Fisk William J., 2012. Is CO2 an Indoor Pollutant? Direct Effects of Low-to-Moderate CO2 Concentrations on Human Decision-Making Performance. Environmental Health Perspectives 120, 1671–1677. https://doi.org/10.1289/ehp.1104789

Seppänen, O.A., Fisk, W., 2006. Some Quantitative Relations between Indoor Environmental Quality and Work Performance or Health. HVAC&R Research 12, 957–973. https://doi.org/10.1080/10789669.2006.10391446

Skov, P., Valbjørn, O., Disg, 1987. The “sick” building syndrome in the office environment: The Danish town hall study. Environment International 13, 339–349. https://doi.org/10.1016/0160-4120(87)90190-5

Statistisches Bundesamt Deutschland , 2021. URL https://www-genesis.destatis.de/genesis/online?operation=abruftabelleBearbeiten&levelindex=2&levelid=1628281093738&auswahloperation=abruftabelleAuspraegungAuswaehlen&auswahlverzeichnis=ordnungsstruktur&auswahlziel=werteabruf&code=13111-0005&auswahltext=&werteabruf=Werteabruf#abreadcrumb.

Stefanovska Ceravolo, L., Mirakovski, D., Polenakovik, R., Ristova-Drewanz, E., Sovreski, Z., 2012. Indoor air quality (IAQ) as a parameter affecting workplace productivity.

Stenberg, B., Eriksson, N., Höög, J., Sundell, J., Wall, S., 1994. The Sick Building Syndrome (SBS) in office workers. A case-referent study of personal, psychosocial and building-related risk indicators. Int J Epidemiol 23, 1190–1197. https://doi.org/10.1093/ije/23.6.1190

Sullivan, K.M., Dean, A., Soe, M.M., 2009. OpenEpi: A Web-based Epidemiologic and Statistical Calculator for Public Health. Public Health Rep 124, 471–474.

Sundell, J., Lindvall, T., 1993. Indoor Air Humidity And Sensation Of Dryness As Risk Indicators Of Sbs. Indoor Air 3, 382–390. https://doi.org/10.1111/j.1600-0668.1993.00024.x

Tarrafa Silva, L., Dias Carrilho, J., Gaspar, A.R., Costa, J.J., 2016. Indoor climate assessment: A case study at a business incubation centre. Sustainable Cities and Society 26, 466–475. https://doi.org/10.1016/j.scs.2016.05.007

Testo SE & Co. KGaA [WWW Document], 2017. URL https://www.testo.com/de-DE/testo-480/p/0563-4800 (accessed 9.9.19).

Thach, T.-Q., Mahirah, D., Dunleavy, G., Nazeha, N., Zhang, Y., Tan, C.E.H., Roberts, A.C., Christopoulos, G., Soh, C.K., Car, J., 2019. Prevalence of sick building syndrome and its association with perceived indoor environmental quality in an Asian multi-ethnic working population. Building and Environment 166, 106420. https://doi.org/10.1016/j.buildenv.2019.106420

The MM Questionnaires [WWW Document], n.d. URL http://www.mmquestionnaire.se/mmq/mmq.html (accessed 7.5.19).

Torresin, S., Pernigotto, G., Cappelletti, F., Gasparella, A., 2018. Combined effects of environmental factors on human perception and objective performance: A review of experimental laboratory works. Indoor Air 28, 525–538. https://doi.org/10.1111/ina.12457

Tsai, D.-H., Lin, J.-S., Chan, C.-C., 2012. Office Workers′ Sick Building Syndrome and Indoor Carbon Dioxide Concentrations. Journal of Occupational and Environmental Hygiene 9, 345–351. https://doi.org/10.1080/15459624.2012.675291

Turiel, I., Hollowell, C.D., Miksch, R.R., Rudy, J.V., Young, R.A., Coye, M.J., 1983. The effects of reduced ventilation on indoor air quality in an office building. Atmospheric Environment (1967) 17, 51–64. https://doi.org/10.1016/0004-6981(83)90007-0

UBA, 2012. Sick Building Syndrom [WWW Document]. Umweltbundesamt. URL https://www.umweltbundesamt.de/themen/gesundheit/belastung-des-menschen-ermitteln/umweltmedizin/sick-building-syndrom.

US EPA, O., 2016. Particulate Matter (PM) Basic. URL https://www.epa.gov/pm-pollution/particulate-matter-pm-basics.

Wolkoff, P., 2018. Indoor air humidity, air quality, and health − An overview. International Journal of Hygiene and Environmental Health 221, 376–390. https://doi.org/10.1016/j.ijheh.2018.01.015

Wolkoff, P., 2013. Indoor air pollutants in office environments: Assessment of comfort, health, and performance. International Journal of Hygiene and Environmental Health 216, 371–394. https://doi.org/10.1016/j.ijheh.2012.08.001

Wolkoff, P., Kjærgaard, S.K., 2007. The dichotomy of relative humidity on indoor air quality. Environment International 33, 850–857. https://doi.org/10.1016/j.envint.2007.04.004

Young, T., 2015. Questionnaires and Surveys. pp. 163–180. https://doi.org/10.1002/9781119166283.ch11

Zainal, Z.A., Hashim, Z., Jalaludin, J., Lee, L.F., Hashim, J.H., 2019. Sick Building Syndrome among Office Workers in relation to Office Environment and Indoor Air Pollutant at an Academic Institution, Malaysia 9.

Zhai, Y., Zhang, Y., Zhang, H., Pasut, W., Arens, E., Meng, Q., 2015. Human comfort and perceived air quality in warm and humid environments with ceiling fans. Building and Environment 90, 178–185. https://doi.org/10.1016/j.buildenv.2015.04.003

Zhang, H., Arens, E., Fard, S.A., Huizenga, C., Paliaga, G., Brager, G., Zagreus, L., 2007. Air movement preferences observed in office buildings. Int J Biometeorol 51, 349–360. https://doi.org/10.1007/s00484-006-0079-y

Zweers, T., Preller, L., Brunekreef, B., Boleij, J.S.M., 1992. Health and Indoor Climate Complaints of 7043 office Workers in 61 Buildings in the Netherlands. Indoor Air 2, 127–136. https://doi.org/10.1111/j.1600-0668.1992.00001.x

9. Appendices

Appendix.1

The Questionnaire on Indoor Air Quality and Health of Employees in Offices in Hamburg

Dear participant,

As part of my master's thesis, I am conducting a survey on the topic of "Indoor air quality and Health of Employees in Offices in Hamburg".

The quality of the air we breathe is an important factor for our health. Due to poor perception and ignorance, we pay little attention to good air quality at our workplace. By understanding and improving indoor air quality, health and comfort at the workplaces can be increased to an accountable level. This study is an attempt to understand and explore those aspects with the aid of a questionnaire.

The survey takes only 10-15 minutes of your time to complete. With the help of this survey, I would like to find out how you have been perceiving and improving the air quality (temperature, humidity, air speed, carbon dioxide and dust particles) in your office. No personal data is collected, so any kind of personal assessment is impossible and only the overall result shall be analysed.

The participation is voluntary and refusal to participate does not involve any penalty or loss of benefits to which the participant would otherwise be entitled, and the participant may at any time decide to discontinue participation without penalty.

The information provided will be kept confidential in all respects and will only be used for academic purposes. I greatly appreciate your voluntary participation in this survey.

Please fill in the questionnaire as completely as possible so that I can derive information about your perception of air quality at your workplace. Thank you very much for your time and cooperation.

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[redacted]

Section.1 General information

1. In which age group do you belong to? *

- ◯ Below 30 years
- ◯ 31-35 years
- ◯ 36-40 years
- ◯ 41-45 years
- ◯ 46-50 years
- ◯ 51-55 years
- ◯ More than 55 years

2. Your gender *

- ◯ Female
- ◯ Male

3. What is the educational qualification you have obtained ? *

- ◯ Secondary School Diploma
- ◯ Bachelor Degree
- ◯ Master Degree
- ◯ Doctoral Degree

4. Do you smoke? *

- ◯ Yes
- ◯ No

5. Do you use contact lenses? *

- ◯ Yes
- ◯ No

6. Do you rear pet animals? *

- ◯ Yes
- ◯ No

Section.2 Work-place design and Work-place activities

7. Since when are you working in this workplace? *

- ◯ Less than 2 years
- ◯ 2-5 years
- ◯ 5-10 years
- ◯ 10-15 years
- ◯ More than 15 years

8. What is your professional position in the Office? *

- ◯ I perform the activities according to the instructions of my manager
- ◯ I have responsible activities assigned and with limited responsibilities for others
- ◯ I have comprehensive tasks and decision making powers
- ◯ Others

9. How many hours do you work per week? *

- ◯ Upto 20 hrs/week
- ◯ Between 20-30 hrs/week
- ◯ Between 30-40 hrs/week
- ◯ Over 40 hrs/week

10. Do you leave your workplace often as part of your professional activity? *

- ◯ Yes
- ◯ No

11. If yes then how many hours do you work in your assigned work station? For e.g appox. `x`hrs/week

Short answer text

12. How do you score your physical activity during work? *

- Sedentary
- With minimal movements (for e.g. movements within the workplace)
- Good physical activity (for e.g. climbing the stairs to go other rooms and departments or any other requiri...
- Don`t know

13. How long do you work with your monitor in the office? *

- Less than 3 hrs/day
- 3-4 hrs/day
- More than 4hrs/day

14. What type of working space are you in? *

- Single occupied work space
- Multipersonal office space
- Others (e.g. work cubicles not fully separated)

15. Do you have any kind of air flow regulating system in your workplace? *

- Yes
- No
- I don't know

16. If yes which one of these is the one your office? *

- Fan
- Airconditioning system
- Centralized air flow regulation system

17. Is your office equipped with a natural ventilation system? (e.g. manually operable windows) *

- Yes
- No

18. If so, how often do you use these ventilating facilities to naturally ventilate your office? *

- Frequently
- Sometimes
- No
- I don`t know

19. How often is the workplace cleaned and how is it done? *

	More than twic...	Once weekly	Once in two we...	Once in a month	Don`t know
Manually using ...	○	○	○	○	○
Vaccum cleaning	○	○	○	○	○

20. How do you define the space at your workplace? *

- Most spacious
- Adequately spacious
- Less spacious
- Least spacious

Section.3 Worker perception of Indoor air quality in the work-place

21. How do you rate the indoor quality in your workplace? *

- Excellant
- Good
- Neutral
- Not so good
- Poor

22. Have you experienced one or more of the following conditions during the last two months in your work-place? *

	Yes, very often (every we...	Yes, sometimes (1-3 tim...	No, never
High room temperature	◯	◯	◯
Very low room temperat...	◯	◯	◯
Dry air	◯	◯	◯
Respiratory irritability	◯	◯	◯
Unpleasant odour	◯	◯	◯

23. How often have you felt physically and mentally not in good condition in the last two months at your workplace? *

- ◯ All the time
- ◯ Very often (3-4 times/week)
- ◯ Often (3-4 times/month)
- ◯ Seldom once in a month)
- ◯ Never

24. Do you feel relieved when you are out of the working premises? *

- ◯ Yes, often (if you had more than 3 experiences)
- ◯ Yes, sometimes /1-3 time experiences)
- ◯ No, i am not relieved after moving out of the premises
- ◯ I am not sure

Section.4 Worker health perception

Description (optional)

25. How would you describe your general health status? *

- ◯ Excellant
- ◯ Very good
- ◯ Good
- ◯ Not that good
- ◯ Poor

26. Please tick the factors which you consider important for well-being *

	Not important	Slightly import...	Quite important	Very important	Extremely impo...
Ventillation	◯	◯	◯	◯	◯
Humidity	◯	◯	◯	◯	◯
Room temperat...	◯	◯	◯	◯	◯
Air movement	◯	◯	◯	◯	◯
Smelling polluti...	◯	◯	◯	◯	◯
Air conditioning	◯	◯	◯	◯	◯

27. Do you think that the room environment is detrimental to your health? *

◯ Yes

◯ No

◯ Maybe

28. How many days were you absent from the office in the past two months for health reasons? *

◯ 1-3 days

◯ 4-6 days

◯ 7-10 days

◯ Not absent

29.a. Please tick the factors which you consider important and can affect your psychosocial well-being *

	Not important	Little important	Quite important	Very important	Extremely impo...
Health	◯	◯	◯	◯	◯
Job challenges	◯	◯	◯	◯	◯
Income/financi...	◯	◯	◯	◯	◯
Cleanliness of t...	◯	◯	◯	◯	◯
Furnishings at t...	◯	◯	◯	◯	◯
Relationship wi...	◯	◯	◯	◯	◯
Independence ...	◯	◯	◯	◯	◯

29.b. Please give your satisfaction with these factors at the moment in your workplace *

	Very dissatisfied	Quite dissatisfied	Quite satisfied	Very satisfied
Health	○	○	○	○
Job challenges	○	○	○	○
Income/financial s...	○	○	○	○
Cleanliness of the ...	○	○	○	○
Furnishings at the ...	○	○	○	○
Relationship with c...	○	○	○	○
Independence at w...	○	○	○	○

30. Please tick the appropriate which is true in your case *

	Yes	No	I don`t know
I am allergic to some su...	○	○	○
I have a chronic disease ...	○	○	○

31. Have you experienced one or more of the given symptoms during last two months? *

	Yes. often (every w...	Yes, sometimes (1-...	No	Yes, often due to c...
Itching burning or ir...	○	○	○	○
Irritating, blocked o...	○	○	○	○
Dryness of throat o...	○	○	○	○
Cough (dry and alle...	○	○	○	○
Irritation of skin, sc...	○	○	○	○
Tiredness or fatigue	○	○	○	○
Headache, heavine...	○	○	○	○
Change in smell or ...	○	○	○	○
Difficulty in breathi...	○	○	○	○

32. And finally, what do you think of your health and wellbeing personally? Please pick from the given statements below. (You can pick more than one) *

- ◯ I am directly responsible for my health
- ◯ If I am sick there is nothing much I can do about it
- ◯ Good health is largely a matter of luck
- ◯ Whenever I get some symptoms , I neglected to trace the reason for that
- ◯ I can do few things myself for health and well-being
- ◯ My life style, awareness and behavior have a role in my health

Appendix.2

Declaration

DECLARATION

I hereby declare that this dissertation entitled **'Indoor Air Quality and Health: Study of Prevalence of Sick Building Syndrome and the Association of Perception of Indoor Air Quality and SBS among Workers in Offices in Hamburg'** is a bonafide work carried out independently by me under the guidance of **Prof. Dr. Walter Leal, and Prof. Dr. Andre' Klussmann.** I have explicitly cited all material which has been quoted either literally or by content from the used source.

Date: 03.09.2021 Maya Pradeep

Place: Hamburg