ASSESSMENT OF INDOOR AIR QUALITY IN AN OFFICE BUILDING IN SOUTH AFRICA

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A research report submitted to the Faculty of health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree

of

Masters in Public Health – Occupational Hygiene

Johannesburg, 2011
University of the Witwatersrand

This research report was approved by the University for this degree during June of 2011.

DECLARATION

I, Paul Jacobus Brits declare that this research report is my own work. It is being submitted for the degree Master of Public Health in the University of the Witwatersrand, Johannesburg in partial fulfilment of the requirements for the Masters Degree in Public Health Occupational Hygiene. It has not been submitted before for any degree or examination at this or any other University.

The information used in this research report has been obtained specifically for purposes of this study and has been obtained through legitimate methods as a registered student at the University of the Witwatersrand, Johannesburg.

………………………..

Paul Brits

This …………….. day of ………………….. 2011.

DEDICATION

In tribute to the unselfish support and understanding of my wife Barbara and daughter Sherine.

To my colleagues for your understanding and support during this project.

To the Almighty for giving me the physical and mental state of well being which enabled me to complete this project.

ABSTRACT

Introduction

The problems associated with poor indoor air quality and the possible subsequent effects thereof on workers, as experienced by the Department of Health in the Regional office situated in the Karel Schoeman building (KSB) in Pretoria, were investigated and are discussed. The possible association between the physical indoor environmental conditions and the sick building syndrome (SBS) like symptoms as well as the seemingly low productivity and the above average rate of absenteeism are included in these discussions.

To find a possible association between these poor physical environmental indoor conditions and the potential adverse affects on the health and motivation of workers, a cross sectional survey was conducted to assess the physical, biological and chemical quality of indoor air (Refer to as IAQ – Indoor Air Quality) as well as the chemical and biological quality of the drinking water.

Objectives

This research report documents a project to measure the environmental conditions which include CO(Carbon Monoxide), CO_2(Carbon Dioxide), relative humidity(RH), temperature, air velocity, the microbial and chemical composition of the drinking water and culturable micro organisms in specific work environments within the KSB and to compare the outcome to standards for acceptable indoor working environments.

The specific objectives of this study are:

- To describe the environmental conditions CO, $CO_{2,}$ RH, temperature and air velocity exposures in specific work environments during the period 2003-2004;
- To describe the microbial exposures to Legionellae (which is actually one of a group of similar diseases collectively known as Legionellosis.)

- To compare measured environmental exposures to the Environmental Regulations for workplaces promulgated in terms of the Occupational Health and Safety Act 1993 (Act 85 of 1993) (OHSA), the National Institute for Occupational Safety and Health (NIOSH) standards and other national and internationally recognised standards and
- To compare the microbial monitoring results including the evaluation results of the drinking water for culturable micro organisms and E.coli, to the NIOSH and other national and international recognized standards.

Methods

To control for confounding, samples of the drinking water as well as from a stagnant pool in the basement were taken and analysed for bacteriological and chemical compliance as well as identification of any microbes and chemicals that can contribute to SBS

Environmental conditions which include CO, CO_2, RH, temperature, air velocity, the microbial and chemical composition of the drinking water and culturable micro organisms including E.coli, in specific work environments were measured.

Measurements were conducted in accordance with the procedures prescribed in the ASHRAE 41.6 of 1994, ACGIH (Handbook for industrial ventilation, EPA building Air quality guidelines, US Department of Labour –OHSA Technical manual),the respective manufacturers recommendations and the SABS Code 0400 of 1990 and sampling of the water in terms of the procedures prescribed by NIOH in the case of sampling for Legionellae and the Microbiological laboratory of the Rietvlei accredited water research laboratory with reference to sampling for identification of micro organisms including E.coli and the chemical composition.

Appropriate recognized analytical methods were used to analyse and interpret the data generated from both the chemical and biological sampling results.

Results

Based on the outcome of the project results, it is clear that the air conditioning system does meet the mentioned minimum prescribed physical environmental national and international norms and standards for indoor air quality.

The findings from the study indicate compliance of the physical environmental conditions to universally accepted standards and no association between those poor physical indoor environmental conditions and the sick building syndrome (SBS) like symptoms as well as the seemingly low productivity and the above average rate of absenteeism could therefore be made. The presence of coliform organisms above the norm in the air samples is however a concern.

Discussion

The OHSA requires employees to access the health and safety risks that hazards pose to their employees in their respective working environments and to take reasonably practicable steps towards eliminating or controlling these hazards. Like any other risks in a workplace environmental conditions need to be identified and controlled based on the principles of risk management.

Conclusion

The above high rate of absenteeism, as perceived by management, could not be associated with the environmental conditions covered in this project. It could however be ascribed, directly or indirectly to the following variables and assumptions which could be categorised under environmental conditions and the management thereof as well as the management of employees/workers located within the building. Environmental conditions such as substandard quality water supply, the management processes during the decommissioning of the old HVAC system and the commissioning of the replacement system, poor general housekeeping and unacceptable management principles of good quality clean working environments location of the building in the mid city centre of Pretoria and the possible contamination of indoor air by external sources bio quality could be variables contributing to the high rate of absenteeism. The seasonal occurrences of influenza and colds as well as home and external exposures could also possibly be considered as contributing factors in this regard.

In addition poor general workers or people's management which could have resulted in low staff morale and personal motivation linked to poor supervision during a period of a very serious organizational restructuring which affected many workers could have also being considered as contributing factors to high absenteeism. Substandard ergonomics could have also played a role during this process.

ACKNOWLEGEMENTS

To the Gauteng Health Department for the partial financial support during this project.

To Mr. V Yousefi, Ms. Soogreem and Dr. Bartie from the former NCOH now NHLS and Ms. L. Coetzee from the Rietvlei Laboratories for their unselfish support and assistance during the protocol development , analysis of samples, interpretation of results and many more.

NIOH for their support in providing the sample mediums and the use of their laboratories.

Mr. Jaco Pieterse registered and certified Hygienist from the Department of Health and Social Development, Gauteng Provincial Government for your professional support in the verification of measurement methodologies, subsequent calculations, deductions made and standards verification.

Ms. Lindokuhle Ngomane, Assistant Director for research, policy and capacity building from the Department of Health and Social Development Gauteng Provincial Government for your professional assistance in verification of the data processing methodologies and calculations and the support during the interpretation of the results.

My project leader, Mr. A. Swanepoel for his patience, valuable and professional guidance and support as well as continuous motivation during this project.

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ABBREVIATIONS

ACGIH – American Conference of Governmental Industrial Hygienists

AIHA – American Industrial Hygiene Association

AIHA – American Industrial Hygiene Association

ASHRAE – American Society of Heating, Refrigeration and Air – Conditioning

BRI - building related illness

CBD – Central Business District

CCSE – Global Journal of Health Science

CFS – Cubic feet per minute

CFU – Coli form units

CO – Carbon Monoxide

CO_2 – Carbon Dioxide

EIR – Environmental Illness Resource Engineers

EPA - Environmental Protection Agency

ETS - environmental tobacco smoke

HSE UK – Health and Safety Executive of the United Kingdom

HVAC – Heat, Ventilation and Cooling system

IAQ – Indoor Air Quality

IJOEM – Indian Journal of Occupational + Environmental Medicine

KSB – Karel Schoeman Building

NIOH – National Institute for Occupational Health

NIOSH – National Institute for Occupational Safety and Health

OHSA – Occupational Health and Safety Act, 1995 (Act 85 of 1993)

ppm – part per million

RH – Relative humidity

SBS – Sick Building Syndrome

THI – Temperature Humidity Index

TPC –Total plate count

US EPA – United Sates Environmental Protection Agency

VOC’s - volatile organic compounds

CHAPTER 1 INTRODUCTION

This chapter introduces the study by briefly describing the physical environmental conditions of the working environment in which the measurements were done as well as managements concern about the effect of the seemingly adverse working environment on the health and productivity of workers as well as workers own perceptions about their working environments. It further addresses the signs and symptoms of Sick Building Syndrome (SBS) as well as the effect of exposure thereto and the recommended control procedures. It explains the health effects associated to exposure to adverse environmental conditions, it describes the relevant national and international perspectives of IAQ as well as legislation and national and international publications related to SBS measurements particularly in office working environments. The chapter concludes by explaining the importance and the purpose of the study and by listing the specific study objectives.

1.1 Background and Problem Statement

The Provincial Department of Health in Gauteng (hereafter referred to as the Department of Health) has a regional office situated in the KSB in Pretoria. The building is a nine storey high rise building with a centralised heat, ventilation and cooling (HVAC) system. The plant rooms are situated in the building and are only accessible from the roof maintenance entrances. Air is transported from the plant room in ducting to all diffusers installed in offices and inhabitable areas. Separate air conditioning (split units) are installed in all offices.
Activities and general work practises and methodologies of the workers are typical of general office workers spending 8 hours a day in their offices. Other health staff members are reporting for service in the mornings and leave the office around 08:00 each day to do field work in clinics and other health facilities in and around the Pretoria area. They will then report back in the offices around 15:30 and vacate their offices at 16:00. Most of the employees are professional health workers ranging from medical doctors, nurses to allied health professionals and of course administrative staff.

Management, comprising all sectional and programme managers, of Gauteng Health Department Pretoria Regional office, has observed SBS like symptoms amongst staff. These observations are based on medical notes on sick leave forms as well as reports from the sick bay within the building and personal observations from the medically qualified managers. High risk physical and environment conditions were also observed during qualitative assessments, which may increase the risk of SBS. In addition micro organisms such as bacteria and fungi are ubiquitous and are therefore also readily found in working environments [21.]

In addition to Managements own observation, they also received complaints about poor ventilation and poor air quality from several workers for a period of 18 months (period ending November 2004). These complaints were mostly tabled and discussed during the respective staff meetings which took place on a monthly basis in each of the unit programmes, chaired by the heads of the units. Workers complained about a lack of energy at the workplace, poor concentration especially in the late mornings and afternoons. Reports of headaches, dizziness and flu like symptoms were also recorded. These were more evident during the warmer spring and summer months. Management was also informed by the Human Resource section that there was an apparent increase in absenteeism due to flu related symptoms during that 18 months period. This information was extrapolated from the notes by Medical Practitioners on the respective sick notes. However seasonal outbreaks of influenza could have contributed to this tendency.

Based on the mentioned signs and symptoms observed amongst the office workers in the KSB which is very reminiscent of SBS, linked to the physical conditions of the working environment, management was of the opinion that there could be an association between the existing physical environmental conditions which are associated with the signs and symptoms of SBS, the seemingly low productivity and the above average rate of absenteeism.

1.1.1 Glossary of terms

Air – the mixture of invisible, odorless, tasteless gases, such as nitrogen and oxygen that surrounds the earth

Air Change – New, cleansed, or reticulated air introduced to a space

Air contaminant – a substance found (solid, liquid or gaseous) not found in the normal composition of the atmosphere

Air monitoring – the sampling for and measurement contaminants in the air

Air quality – ASHRAE defines acceptable indoor air quality as “air in which there are no known contaminants at harmful concentrations and with which a substantial majority (usually 80%) of the people exposed do not express dissatisfaction”

Air sampling – the collection and analysis of samples of air to measure the amounts of various pollutants or other substances in the air or the air’s radioactivity

American Society of Heating, Refrigeration and Air Conditioning Engineers

(ASHRAE) – A professional society committed to the establishment of standards in heating, refrigeration, and air conditioning

Analytical methods – detailed laboratory procedures that specify how to measure the amount of chemicals collected on the sampling media

Anticipation – one of the four primary responsibilities of the Industrial Hygienist. The anticipation of what health hazards problems may occur before a plant, process or product is introduced.

Area – the cross sectional area (e.g. door, duct, window or any space) through which air moves. Units used are square meters (m^2)

Attitude – manner, disposition, feeling or position toward a person or thing

Audit – a systematic check to determine the quality of operation of some function or activity and are classified in quali - and quantitative types

Behavior – the aggregate of observable responses of an organism to internal or external stimuli

Biological agent – Any of the viruses, microorganisms and toxic substances derived from living organisms and used as offensive weapons to produce death or disease in humans, animals and growing plants

Biological monitoring – the measurement of chemical markers in body media that are indicative of external exposure to chemical and physical agents

Building related illness – Infectious, allergic, or toxin- induced disease with objective clinical findings related to building occupancy (also known as “building related disease”)

Compliance – compliance with health and safety regulations

Concentration – the amount of a given substance in a stated unit of the measure

Control – one of the primary responsibilities of the Occupational Hygienist to facilitate a healthful working environment. A hierarchy of control, engineering control, work practices, administrative controls and as a last resort use of personal protective equipment is used in this process

Control measures – the overall strategy for controlling the environment as well as the specific components that make up the strategy

Employee – a worker who might be exposed to hazardous chemicals under normal operating conditions or in unforeseeable emergencies

Environmental conditions – natural or controlled conditions of air and radiation, prevailing around a person, an object, a substance, etc.

Environmental monitoring – program in which samples of air contaminants or energy measurements are taken and which establishes the level of worker exposure to such agents

Ergonomics – the application of human biological sciences with the engineering sciences to achieve optimum mutual adjustment of people and their work, the benefits measured in terms of human efficiency and well being (human factors engineering)

Evaluation – the examination and the judgment of the amount, the degree, significance, worth, or condition of something.

Exposure – as it pertains to air contaminants, it is the state of being exposed to a concentration of a contaminant

Fresh air – air taken from the outside ambient environment (“outdoor air”)

Geometric mean – mathematically is expressed in two equivalent ways or in words. The nth root of the product of all values in a set of n values, or the arithmetic mean of the logarithms of all the values of a set of values

Hazard – source of risk

Health Hazard – a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects might occur in exposed employees

Humidity – water vapor within a given space

HVAC System – is the distribution system that heats, ventilates cools, humidifies, dehumidifies, and cleanses air in a building or building zone, principally for the comfort, health and safety of the occupants.

Incident rate – the number of injuries, illnesses, or lost working days related to a common exposure base on 100 full time workers

Mean – a statistical description of the average

Measure of tendency – measures of the tendency of values in a set of data to be centered at some location. (The mean, the mode and the geometric mean)

Monitor – periodic or continuous determination of the amount of contamination presenting an occupied region used as a safety measure for purposes of health protection

Monitoring instruments – a broad range of scientific equipment used for the purposes of collecting and/or measuring chemical levels

Personal protective equipment – equipment (gloves, eye protection, and respirators) designed to protect individuals from biohazards

Range - the difference between the maximum and the minimum values of a set of values

Relative humidity – the ratio of the quantity of water vapor present in the air to the quantity that would saturate it at any specific temperature

Representative sample – a sample taken to represent a lot of population as accurately and precisely as possible

Risk – the probability and magnitude of harm

Risk Assessment – the process of determining, either quantitatively or qualitatively, the probability and magnitude of an undesired event and estimating the cost to human society or the environment in terms of morbidity, mortality, or economic impact

Risk factor – characteristic or variable associated with increased probability of a toxic effect

Sample – a subject or group of objects or things selected from a larger set called "lot" or "population"

Sick building syndrome – the term has come into common use for those problems where excessive comfort and health – related symptoms are present that are clearly related to building occupancy, but that are not associated with objective clinical signs

Significance – (importance, consequence, part of the evaluation process)

Standard – any rule, principle or measure established by authority

Temperature – that property of a body that determines the flow of heat

Velocity – the time rate of distance moved

Verification – the establishment of the reliability of a measurement method by comparison with one or more reference methods

CHAPTER 2 Literature review

In this section, publications relating to "Sick Building Syndrome" (SBS), including the health effects thereof, indicators and causes of SBS and "building related illness" (BRI), national and international perspectives, the measurement and solutions are considered.

2.1 General information

The term SBS is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified. The complaints may be localized in a particular room or zone, or may be widespread throughout the building. In contrast, the term BRI is used when symptoms of diagnosable illness are identified and can be attributed directly to airborne building contaminants [38].

A 1984 World Health Organization Committee report suggested that up to 30 percent of new and remodelled buildings worldwide may be the subject of excessive complaints related to indoor air quality. Often this condition is temporary, but some buildings have long-term problems. Frequently, problems result when a building is operated or maintained in a manner that is inconsistent with its original design or prescribed operating procedures. Sometimes indoor air problems are a result of poor building design or occupant activities [38].

2.2 Health effects of Sick Building Syndrome exposure

Unlike most specific indoor air quality (IAQ) contaminants, where building occupants experience symptoms, SBS is somewhat unique in that the symptoms usually do not fit the pattern of any particular illness and are difficult to trace to any specific source. People may complain of one or more of the following symptoms: dry or burning mucous membranes in the nose, eyes, and throat; sneezing, stuffy or runny nose, fatigue or lethargy; headache, dizziness, nausea, irritability and forgetfulness [24].

Other airborne pollutants like sulphur dioxide, volatile organic compounds, formaldehyde, aldehydes and irritants of the upper respiratory tract commonly found in indoors air may contribute to these symptoms especially burning eyes, nose and throats. Poor lighting, noise, vibration, thermal discomfort, and psychological stress may also cause, or contribute to these symptoms [58].

The most common of the building-related infections are contagious diseases, which are readily spread through indoor air, especially in crowded environments. These diseases include influenza, the common cold and tuberculosis. The only infectious disease that is commonly spread from environmental reservoirs is Legionnaires disease. All of the environmental–source infections are opportunistic, requiring some deficit in the immunity of the host before infection can occur. Obviously all infections are caused by biological pollutants [14].

There is no single manner in which these health problems appear. In some cases, problems begin as workers enter their offices and diminish as workers leave. Other times, symptoms continue until the illness is treated. Sometimes there are outbreaks of illness among many workers in a single building. In other cases, health symptoms show up only in individual workers [20].

2.3 Indicators of Sick Building Syndrome

Building occupants complain of symptoms associated with acute discomfort, e.g., headache, eye, nose, or throat irritation, dry cough, dry or itchy skin, dizziness and nausea, difficulty in concentrating, fatigue, and sensitivity to odours.

The cause of the symptoms is not known [67].

Most of the complainants report relief soon after leaving the building.

Outbreaks of SBS have been attributed to exposure to VOC’s, low relative humidity, endotoxins, some factors within the macro-molecular components of house dust and unknown exposures resulting from inadequate supplies of fresh air [14].

2.3.1 Indicators of Building Related Illness

Building occupants complain of symptoms such as cough, chest tightness, fever, chills, and muscle aches.

The symptoms can be clinically defined and have clearly identifiable causes.

Complainants may require prolonged recovery times after leaving the building.

It is important to note that complaints may result from other causes. These may include an illness contracted outside the building, acute sensitivity (e.g., allergies), job related stress or dissatisfaction, and other psychosocial factors. Nevertheless, studies show that symptoms may be caused or exacerbated by indoor air quality problems [23].

BRI factors are separated into two categories; medical conditions from identifiable causes and medical conditions from exposure to known substances. Symptoms are caused and made worse by low levels of indoor air quality and indoor air pollution from inhalation of chemical and biological contaminants. Other factors such as physical, organisational, psychological and psychosomatic also contribute to BRI [38].

The building itself plays a large part in the increased risk of developing a BRI, from the exterior to the interior. Building factors may be poor architectural design, deterioration of structure, interior surface finishes, defective operating systems and absence of building and mechanical maintenance [29]. The largest risks as mentioned earlier are from HVAC systems, especially systems which have not been regularly maintained, cleaned and repaired [15].

2.4 Causes of Sick Building Syndrome

2.4.1 Personal Factors

Various personal factors have been identified as contributors to SBS. These are gender where females have been identified as being more likely to be affected by environmental factors effecting personal health status. In addition individual history of being allergic (atopic) to certain environmental conditions such as certain chemicals and agents such as pollen, also play a role in this regard.

Then there are the psycho social elements in the working environments such as job related tensions and poor job satisfaction which are also possible contributing factors to causes of SBS or which play a significant role in workers perceptions about their physical working environments and how they perceive it [16].

2.4.2 Inadequate ventilation

In the early and mid 1900's, building ventilation standards called for approximately 15 cubic feet per minute (cfm) of outside air for each building occupant, primarily to dilute and remove body odours. As a result of the 1973 oil embargo, however, international energy conservation measures called for a reduction in the amount of outdoor air provided for ventilation to 5 cfm per occupant. In many cases these reduced outdoor air ventilation rates were found to be inadequate to maintain the health and comfort of building occupants. Inadequate ventilation, which may also occur if heating, ventilating, and air conditioning (HVAC) systems, do not effectively distribute air to people in the building, is thought to be an important factor in SBS [26]. In an effort to achieve acceptable IAQ while minimizing energy consumption, ASHRAE recently revised its ventilation standard to provide a minimum of 15 cfm of outdoor air per person (20 cfm/person in office spaces). Up to 60 cfm/person may be required in some spaces (such as smoking lounges) depending on the activities that normally occur in that space [17]. (Also see *ASHRAE Standard 62-1989*)

2.4.3 Heating, Ventilating and Air Conditioning (HVAC) Systems

HVAC systems should be designed to meet the needs of a specific building based on its design, use, and occupant activities. The HVAC system should filter the air, heat or cool as necessary, and control relative humidity during the cooling season [42]. Some systems also introduce outdoor air during this process to dilute building contaminants. After all these actions take place, the tempered air is then circulated throughout the structure. A poorly maintained HVAC system can allow water to build up in the unit, creating conditions where the system itself can become a reservoir for biological contaminants [7]. Inadequate systems can also allow high moisture levels that foster the growth of mold and mildew. For these reasons, it is very important that HVAC systems be inspected on a regular basis to ensure that the systems are clean and functioning as designed [38].

2.4.4 Chemical contaminants from indoor sources

Most indoor air pollution comes from sources inside the building. For example, adhesives, carpeting, upholstery, manufactured wood products, copy machines, pesticides, and cleaning agents may emit volatile organic compounds (VOC’s), including formaldehyde [25]. Environmental tobacco smoke contributes high levels of VOC's, other toxic compounds, and respirable particulate matter. Research shows that some VOC's can cause chronic and acute health effects at high concentrations, and some are known carcinogens. Low to moderate levels of multiple VOC's may also produce acute reactions. Combustion products such as carbon monoxide, nitrogen dioxide, as well as respirable particles, can come from unvented kerosene and gas space heaters, woodstoves, fireplaces and gas stoves [18]. It has been occasionally observed that workers in the KSB use their own private gas and kerosene heaters during the winter months in their offices.

2.4.5 Chemical contaminants from outdoor sources

The outdoor air that enters a building can be a source of indoor air pollution. For example, pollutants from motor vehicle exhausts, plumbing vents, and building exhausts (e.g. bathrooms and kitchens) can enter the building through poorly located air intake vents, windows, and other openings. In addition, combustion products can enter a building from a nearby garage [19].

2.4.6 Volatile Organic Compounds

Volatile organic compounds (VOC's) are emitted from paints, solvents, building materials, air fresheners, dry-cleaned clothing, aerosol sprays, adhesives, fabrics and many more sources. In fact, indoor air may contain several hundred different VOC's. Some of these VOC's can cause eye, nose, and throat irritation, headaches, loss of coordination, nausea, and damage to the liver, kidneys and central nervous system. Some of these chemicals can cause cancer in animals. Some are suspected or known to cause cancer in humans [22]. One of the more common VOC's found in indoor air is formaldehyde. Formaldehyde is an important chemical and can be found in many products including durable-press drapes and other textiles, particleboard products such as panelling, cabinets and furniture, tobacco smoke, and adhesives. Formaldehyde acts as an irritant to the eyes, nose and throat, and can cause tearing of the eyes, coughing and bronchial spasms. Formaldehyde is also listed as a suspected human carcinogen[12].

2.4.7 Environmental Tobacco Smoke

Second-hand smoke, or environmental tobacco smoke (ETS), is a mixture of the smoke given off by the burning end of a cigarette, pipe or cigar, and the smoke that is exhaled from the lungs of the smoker. ETS can cause significant IAQ problems in buildings. ETS contains more than 4,000 chemical compounds, approximately 40 of which are carcinogens or suspected carcinogens. Second-hand smoke has been classified by the U.S. Environmental Protection Agency (EPA) as a known cause of lung cancer in humans (Group A carcinogen). Children who breathe ETS are more likely to suffer from ear infections, pneumonia, bronchitis, and other lung diseases. ETS can increase the risk of asthma attacks in persons with asthma. For all these reasons consideration should be given to allowing smoking only in properly ventilated, dedicated smoking lounges or outside [13].

2.4.8 Biological contaminants

Bacteria, pollen, and viruses are types of biological contaminants. These contaminants may breed in stagnant water that has accumulated in ducts, humidifiers and drain pans, or where water has collected on ceiling tiles, carpeting, or insulation. Sometimes insects or bird droppings can be a source of biological contaminants. Physical symptoms related to biological contamination include cough, chest tightness, fever, chills, muscle aches, and allergic responses such as mucous membrane irritation and upper respiratory congestion. One indoor bacterium, Legionellae, has caused both Legionnaire's Disease and Pontiac Fever [28].
These elements may act in combination, and may supplement other complaints such as inadequate temperature, humidity, or lighting. Even after a building investigation, however, the specific causes of the complaints may remain unknown [42].

2.4.9 Moisture

The most important factor in the growth and spread of mold and other biological agents is moisture. Typical sources include structural leaks, roofing leaks, plumbing leaks, and malfunctioning or improperly sized heating, ventilation, building design (waterproofing) and air conditioning systems. Elimination of moisture is essential to eliminating molds, mildew and other biological agents.

Buildings often contain a large number of hidden internal cavities which are formed from skeletal construction methods. These cavities commonly exist inside walls and ceilings constructed using joists and trusses, and may also include attic, crawlspace, and drop-ceiling spaces. Such locations may have very low direct ventilation, but air does infiltrate in and out of these spaces as ambient atmospheric pressure changes occur [40].

Older building construction from before the development of insulation, moisture barriers, and composite materials tended to be drafty, cold, and wasteful of heating, but they also suffered few moisture problems. For example, before plywood was commonly used for floor construction, home and office floors were typically constructed with two layers of narrow boards laid at 90 degree angles from each other, and 45 degrees from the general lay of the floor joists. These boards had typically rough gaps between them, which allowed air to seep freely in and out of wall and ceiling joist air spaces. Some of these construction materials and construction were found inside the KSB. Modern plywood floor construction is nearly impermeable by comparison, and allows no airflow into the joist spaces [2].

Moisture can be trapped and hidden within these cavities where it builds to 70% and 95% moisture saturation by weight. Moisture buildup can occur for example inside the wall cavities surrounding a high-humidity kitchen, bathroom, or bathing area that is poorly ventilated. There are few if any, mechanisms that operate to dry out these internal wall cavities once they become saturated with moisture. Ventilation of joist spaces is typically not considered important, though it could be accomplished during construction by drilling large vent holes inside each wall cavity, through the floor and ceiling plywood sheeting.

If such airflows are of hot, humid air, this moist, warm air may reach a dew point surface, especially if indoor temperatures are maintained much below about 78 °F (26 °C). At this degree of moisture saturation, in this dark, undisturbed wall cavity space, most all molds, including starchy, thrive. Molds and bacteria rarely coexist. Molds produce generally toxic substances that create unwelcome, unhealthy environments for bacteria and insects, as well as human beings. The toxic substances generated by mould growth may become aerosolized, released and distributed to a much greater range by these unintentional airflows through the building's matrix until they may be inducted into the air conditioning and heating distribution systems and ultimately discharged into the breathing zone. These unintentional airflows create the toxicity and obscure the true source of toxicity and earthy odors as they distribute it [38].

Mechanical ventilation in a hot, humid climate may deliver water vapor into a building at the rate of approximately 0.455kg's of water per day for each 0,283 cubic meters per minute per day of unconditioned outdoor ventilation air delivered.

Radon mitigation by mechanical ventilation in hot humid climates, (Florida) is known to create gradual increases in moisture saturation that suddenly lead to mold problems when moisture saturation of a favored mold food material reaches 70% by weight. This increasing moisture saturation process may take a few months or as long as four or more years.

The uninformed or poorly informed assume that the air conditioner will successfully remove such moisture, and it may if it is operating efficiently. Many air conditioners do not, and almost all of them decline in their ability to dehumidify efficiently over time. Residual moisture remains and soaks into materials as if they were sponges, on a march toward full saturation. In hot, humid climates, the worst months for mold are October, November, December and early spring (American winter) when air conditioners rarely operate and moisture saturation increases most rapidly [35].

Identification and termination of these unintentional building matrix airflows has rarely been recognized and acted upon, hence heroic efforts to heal the sick building have been largely unsuccessful. Out of a sense of frustration with enormously expensive and ineffective healing approaches, total building destruction is sometimes selected as a way out [20].

2.4.10 Particulates

Airborne particles include combustion products, dust and pollen. Health effects from exposure to respirable-size particles in the air depend on the types and concentrations of particles present, the frequency and duration of exposure, and individual sensitivity [44]. Health effects can range from irritation of the eyes and/or respiratory tissues to more serious effects, such as cancer and decreased lung function. Biological particles such as animal and insect allergens, viruses, bacteria, and molds, can cause allergic reactions or infectious diseases [21].

2.4.11 Combustion Products, including Carbon Monoxide

Sources of combustion products include unvented fossil-fuel heaters, unvented gas stoves and ovens, and back-drafting and malfunctioning furnaces and water heaters. The health concerns caused by combustion products range from mild health effects to death. CO, a deadly gas, kills over 200 people a year in the United States. Other pollutants, such as nitrogen oxide, can cause breathing problems, particularly in sensitive individuals, and can trigger asthma attacks. To ensure that combustion pollutants do not create IAQ problems, the following steps should be taken:

- Vent all potential sources outside the building.
- Conduct regular maintenance and inspection of all systems.

Any process of combustion can produce carbon monoxide, so this gas is produced by tobacco smoking, gas cookers, and gas or oil heaters. We all exhale a small amount of carbon monoxide in our breath. A major source of CO is vehicle exhaust fumes [23].

Carbon monoxide harms the body by replacing oxygen in the haemoglobin of red blood cells and so starving the body and the brain in particular of oxygen. Less than one per cent of the haemoglobin of non-smokers is normally bound to CO rather than oxygen but this increase to 4-6 per cent in smokers [69].

Non-smokers who spend their 8-hour working day in an atmosphere containing 30 parts per million (ppm) of CO will also develop a 5 per cent concentration and possibly the early symptoms of carbon monoxide poisoning such as headache. Smokers would not be affected since their bodies have become habituated to such a high level. At levels of 50-250 ppm dizziness may accompany the headache, and above 500 ppm nausea and vomiting occur and collapse is possible. Long-term exposure to carbon monoxide is associated with heart disease.

It has been recommended that CO levels be kept below 9 ppm in offices because of the potential for health effects associated with long-term exposure to low levels of this gas [22]. In the UK the occupational exposure limit for CO is 50 ppm.

2.4.12 Radon

Radon is a naturally occurring, invisible, odourless gas that comes from natural deposits of uranium in soil, rock, and water. It is harmlessly dispersed in outdoor air, but when trapped in buildings, it can be harmful, especially at elevated levels. Radon is a radioactive decay product of radium, which is itself a decay product of uranium. Uranium and radium are both common elements in soil. In North Carolina, piedmont and mountain counties are estimated to have the greatest proportion of homes with elevated levels of radon [45].

SBS and BRI are associated with acute or immediate health problems[65]. Radon and asbestos cause long-term diseases which occur years after exposure, and are therefore not considered being among the causes of sick buildings. This is not to say that the latter are not serious health risks. Both should be included in any comprehensive evaluation of a building's IAQ [24].

2.4.13 Lead-Based Paint

Lead is a heavy metal that was used in the manufacture of paint (before 1978) and in other products such as plumbing pipes, solders and leaded gasoline. When paint containing lead deteriorates, tiny lead particles and lead dust can contaminate buildings and the environment. Regulations in most countries now limit the amount of lead used in paint and other applications. However, because lead lasts a long time, lead pollution remains a health hazard, particularly in older buildings [68].

Lead has long been recognized as a harmful environmental pollutant. In late 1991, the Secretary of the Department of Health and Human Services called lead the "number one environmental threat to the health of children in the United States." There are many ways in which humans are exposed to lead: through air, drinking water, food, contaminated soil, deteriorating paint, and dust. Airborne lead enters the body when an individual breathes or swallows lead particles or dust once it has settled. Before it was known how harmful lead could be, it was used in paint, gasoline, water pipes, and many other products.

Old lead - based paint is the most significant source of lead in the USA today. Harmful exposures to lead can be created when lead – based paint is improperly removed from surfaces by dry scraping, sanding, or open –flame burning. High concentrations of airborne lead particles in homes can also result from lead dust from outdoor sources, including contaminated soil tracked inside, and use of lead in certain indoor activities such as soldering and stained –glass making [26].

2.5 The Partnership for Clean Indoor Air

The Partnership for Clean Indoor Air was launched at the World Summit on Sustainable Development in Johannesburg to address the increased environmental health risk faced by more than 2 billion people in the developing world who burn traditional biomass fuels indoors for cooking and heating. According to the WHOn, their increased exposure results in an estimated 1.6 million premature deaths each year, largely among women and children. The mission of the partnership is to improve health, livelihood, and quality of life by reducing exposure to air pollution, primarily among women and children, from household energy use [39].

2.6 International perspective of IAQ

A study conducted by Bejan *et. Al, (1987)* found that about 20% of the American office workers are affected by SBS [27].

The WHO in their publication "Air quality guidelines, WHO, 1999" [28] confirmed that air quality in buildings in developing countries can have similar problems to those found in developed countries particularly in the large modern urban areas in developing countries.

Several cases of Legionnaires disease (Legionellosis) have also recently been linked to poor indoor air quality associated to ineffective air conditioning systems and unacceptable environmental conditions such as high temperatures [28].

The health authority of Melbourne confirmed three positive causes of Legionnaires after they spent some time indoors in the Moonce Ponds Junction. The air conditioning of this building was disinfected and no further outbreaks occurred [68].

Pontiac Fever was diagnosed in Tennessee after 100 patrons got sick after dinning at a Café in a specific shopping mall. This ailment is a mild infection caused by Legionellae bacteria found in the water of the cooling mist system [30].

The CDC in Victoria confirmed various other outbreaks of Legionnaires in May 2002 in a Nursing home in Pennsylvania (USA) during June 2002 [31].

The South Eastern Sydney/Illawarra Health Department in Australia diagnosed and investigated 7 cases of potentially deadly Legionnaires' disease. The victims all visited Wollogong CBD before getting the disease, which is contracted through breathing contaminated air from air conditioning cooling towers or bacteria in potting mix. (Latter being Legionellae longbeachae not the more usual L. pneumophila). The infectious diseases specialist at Sydney University said that there was a potential link between all cases and the contaminated air cooling units which contained the bacteria in them [32].

During February of 2005, cases of nosocomial infections of patients with Legionellosis have been reported in the Oncology unit from the Duran I Reynals Hospital in Spain. Those infected were immuno-compromised persons who had been admitted to the oncology centre. The hospital started water hyper chlorination and disinfections and the admission of new patients was also halted till after the results of water samples of the hot and cold water systems as well as the air conditioning cooling towers were negative from the causation organism. This had the desired effect and since the admission of new patients after this episode no more new cases of Legionellosis were reported [33].

There is therefore no doubt that internationally serious problem are experienced with poor indoor air quality which results in the spread of various microbial and viruses' conditions and SBS related conditions.

The phenomenon is therefore according to International research and findings not only restricted to South Africa.

During all literature surveys during which the above was identified a common agent of spread was identified as either poor indoor ventilation systems and/or environmentally related conditions such as temperature extremes, poor sanitation and hygiene.

During Tuesday 27 December 1995, a television show was televised on the NOVA show (USA) regarding SBS. The NOVA television show is based on the Wikipedia encyclopedia. Nova is a popular science television series from the USA produced by the WGHB in Boston and can be seen on the public broadcasting services (PBS). NOVA was created in 1974 and is recognized by the National Academy of television Arts and Sciences and received two Emmy awards. Funding for NOVA is provided by David H. Koch, the Howard Medical Institute, the corporation for Public Broadcasting and the HHMI educational foundation.

The NOVA SBS show started out as a factual report that there are sick buildings in the USA and elsewhere, and then went to examine several well known cases with the assistance of international experts in this field.

Various case studies were referred to during these shows. One of these shows revealed the following results applicable to this study. This was called the Birminham, Alabama Five – Ways House.

Two buildings were compared after complaints started coming in regarding the newer of the buildings in the complex. The old building had user openable windows. The new one had closed windows and air conditioning [61].

Typical problems with air conditioning are usually caused by improper system setup and balancing, incorrect damper settings, unexpected alterations, covering inlets diffusers and outlets, as well as unanticipated changes in loading factors and distribution caused by changes by space planners. These can cause uneven air velocities resulting in dead spots without adequate air turnover as well as areas with excess velocities and irritating drafts.

In this case the typical air tests were applied:

* CO_2 build-up (staleness);
* humidity;
* temperature;
* dust;
* fungi;
* other micro organisms;
* dust mites;

* fiberglass and other fibre fragments.

One typical complaint in some settings is Humidifier Fever, flu-like symptoms and breathing difficulties caused by stagnant water standing in a reservoir feeding some humidifiers. This occurs more often in printers and other manufacturing plants where the air has to be maintained at a higher humidity due to process or materials used in the factory.

The humidification equipment was replaced by a reservoir less system that drew water directly from the plumbing as needed. This, in itself, was not enough.

Fungi and insects living in ducting systems are often made worse by attempts at cutting costs by increasing return air volumes and reducing inlet air volumes – Normal criteria for system settings is 20% outdoor air / 80% return air for return air systems. In this case, the factors were shown as well within acceptable norms found in buildings without problems.

The USA Departments of Health and Public Works confirmed these facts and have since spend millions to upgrade these specific and other facilities [47].

During April – September 2008 a study was done in Kuala Lumpur City Centre to investigate the association between SBS and indoor air pollutants in two different buildings (old and new). Hundred and seventy six office workers were randomly selected in this study. One office from Tower 1, in one private building categorized as Building A (old building), while another government building, Malaysia Energy Center categorizes as Building B (new building). Modified IAQ and Work Symptoms Survey, NIOSH Indoor Environmental Quality Survey [71] was used to measure the SBS occurrence. Measurement of IAQ was performed according to IAQ Code of Practice, Department Occupational Safety and Health, (DOSH, 2005) Malaysia. Building A and B recorded 93 and 83 respondents respectively. Ventilation rates were significantly higher in Building B compared to Building A with median 21.10 cfm/person and 18.60 cfm/person respectively ($z = -11.70$, $p < 0.001$). Higher prevalence of SBS recorded in Building A, compared to Building B. Significantly higher of IAP in Building A compare to B for CO, CO_2, TVOC, PM10, PM2.5, while Building B showed higher concentration of Ultrafine Particle and Temperature Humidity Index (THI) value. There were significant association between ventilation rate and the prevalence of SBS (OR = 3.13, 95% CI = 1.62 – 6.06).

Study result showed that indoor pollutants in old building were high, while new building showed indoor pollutants high for THI value and UFP. The level of THI and CO_2 concentration was major factor contribute to SBS complain among office workers [34].

In a publication by the EPA titled, *An Office building Occupants Guide to IAQ, 1 October 1997* [70], Factors that Affect Occupant Comfort and Productivity besides the factors that *directly impact the levels of pollutants* to which people are exposed, a number of environmental and personal factors which can affect how people *perceive* air quality are described. Some of these factors affect both the levels of pollutants *and* perceptions of air quality:

- Odors;
- Temperature - too hot or cold;
- Air velocity and movement - too drafty or stuffy;
- Heat or glare from sunlight;
- Glare from ceiling lights, especially on monitor screens;
- Furniture crowding;
- Stress in the workplace or home;
- Feelings about physical aspects of the workplace: location, work environment, availability of natural light, and the aesthetics of office design, such as color and style;
- Work space ergonomics, including height and location of computer, and adjustability of keyboards and desk chairs;
- Noise and vibration levels and
- Selection, location, and use of office equipment.

2.6.1 Summary and salient findings

There is a strong correlation between IAQ in developed and developing countries especially in metropolis areas.

Strong relationships between Legionellosis and poor IAQ associated to ineffective HVAC systems and unacceptable environmental conditions such as high temperatures have been recorded following various research projects in this regard.

An outbreak of nosocomial infection between patients with Legionellosis has been associated to poor quality of hot and cold water and HVAC systems within a hospital environment.

A very strong correlation between poor IAQ and spread of various bioaerosols and SBS related conditions were identified.

During many literature surveys a common agent of spread of Legionellosis was identified as either poor indoor ventilation systems and/or environmentally related conditions such as temperature extremes, poor sanitation and hygiene.

The level of THI and CO_2 concentration was a major factor contributing to SBS complains among office workers.

Significant associations between ventilation rates and SBS have been recorded.

2.7 National perspective of IAQ

A survey was conducted in South Africa in 1994 [35] of employee attitudes regarding their workplace. The following were the key findings of the survey:

Of those interviewed, 95% worked in an air-conditioned office;

66% felt that their work rate could be improved in a cleaner, fresher office environment;

Approximately 50% have complained to management about conditions in the office. More have complained about the temperature, stuffiness, and lighting than about noise. However according to the findings there was no statistical significance between these complaints by the workers and increased incidence of absenteeism;

- 50% of those interviewed could control the temperature level in their workplace. 80% of the remainder would like to be able to do so;
- 70% stated that the office air is sometimes stuffy or stale;
- 38% considered the Natural light in their immediate work areas poor.
- About 23% said they took time off work because of ailments they blame on the office environment and more than 65% of these took multiple days off and
- Many suffered typical symptoms of Sick Building Syndrome:

    - Tiredness 42%

- Listlessness 26%
- Headaches 39%
- Watery eyes 26%
- Dry eyes 22%
- Runny noses 22%
- Dry throats 24%
- Flu – like symptoms 23%

During 2000, M.O. Bachman an J. Meyers from the health research unit, Department of Community Health, University of Cape Town Medical School, did a research study on the relationships between symptoms typical of SBS, musculoskeletal symptoms, and reported indoor environmental exposures, psychological state, work stress and interpersonal relationships at work, among 624 office workers in three buildings. Symptom prevalence's were similar in the three buildings, and were slightly lower in the two buildings characterized by its inhabitants as 'sick' than in the one building not considered to be 'sick'. The findings were statistically insignificant. Women were more likely than were men to complain of most symptoms in all three buildings. Multiple regressions showed psychological symptoms and gender to be significant independent predictors of symptoms. Reported odors, and uncomfortable humidity and temperature were also independently associated with symptoms. The study indicates that gender and psychological symptoms are important predictors of perceived building related illness [36].

2.7.1 Summary and salient findings

Very little appropriate research findings could be identified during literature surveys for the situations in South Africa to benchmark against the International perspective.
By comparison to the International literature findings, workers interviewed in SA. complained about similar environmental conditions such as poor ventilation, temperature extremes, and SBS like symptoms.

A strong correlation between poor environmental conditions within the indoor working environments and SBS related conditions were identified.

In addition, studies in SA indicated that gender is a significant independent predictor of SBS symptoms where women are more likely to complain about SBS related conditions within working environments.

2.8 Measurement of Sick Building Syndrome

The following building investigation procedures have been generally recommended as best practise when audits are done for the identification of SBS. The investigation procedures were done in accordance with US Environmental Protection Agency's Model for investigating indoor air quality complains and concerns.

Because of the nature of SBS, there is no single test that can confirm or refute problems. The best approach is to investigate the entire building. The goal of a building investigation is to identify and solve indoor air quality complaints in a way that prevents them from recurring and which avoids the creation of other problems. To achieve this goal, it is necessary for the investigator(s) to discover whether a complaint is actually related to indoor air quality, identify the cause of the complaint, and determine the most appropriate corrective actions.

An indoor air quality investigation procedure is best characterized as a cycle of information gathering, hypothesis formation, and hypothesis testing. It generally begins with a walkthrough inspection of the problem area to provide information about the four basic factors that influence indoor air quality:

- the occupants;
- the HVAC system;
- possible pollutant pathways;
- possible contaminant sources.

Preparation for a walkthrough should include documenting easily obtainable information about the history of the building and of the complaints, identifying known HVAC zones and complaint areas, notifying occupants of the upcoming investigation, and, identifying key individuals needed for information and access. The walkthrough itself entails visual inspection of critical building areas and consultation with occupants and staff [37].

The initial walkthrough should allow the investigator to develop some possible explanations for the complaint. At this point, the investigator may have sufficient information to formulate a hypothesis, test the hypothesis, and see if the problem is solved. If it is, steps should be taken to ensure that it does not recur. However, if insufficient information is obtained from the walk through to construct a hypothesis, or if initial tests fail to reveal the problem, the investigator should move on to collect additional information to allow formulation of additional hypotheses. The process of formulating hypotheses, testing them, and evaluating them continues until the problem is solved.

Although air sampling for contaminants might seem to be the logical response to occupant complaints, it seldom provides information about possible causes [6]. While certain basic measurements, e.g. temperature, RH, CO_2, and air movement, can provide a useful "snapshot" of current building conditions, sampling for specific pollutant concentrations is often not required to solve the problem and can even be misleading. Measurements in most of the cases can be useful in source determination, determining pollution pathways and in determining contributory factors related to certain SBS symptoms experienced within a building. For example formaldehyde at certain levels may result in burning eyes, nose and throat as it is an upper respiratory irritant. CO_2 only is just a good indicator in terms of sufficient ventilation. Out of experience, although CO_2 levels may not exceed standards and limits, other airborne pollutants like sulphur dioxide, VOC's, combustions pollutants and formaldehyde may exceed the certain IAQ standards but it depends on the chemical composition of the pollutants at the source[1]. Contaminant concentration levels rarely exceed existing standards and guidelines even when occupants continue to report health complaints. Variables can play a role here. Such variable may include seasonal outbreaks of disease, scientific validity of standards used, personal susceptibility, noise pollution, poor illumination, relationship issues and, overcrowding. Air sampling should not be undertaken until considerable information on the factors listed above has been collected, and any sampling strategy should be based on a comprehensive understanding of how the building operates and the nature of the complaints [38].

The American Industrial Hygiene Association (AIHA's) Practitioners approach to IAQ Investigations (1989), the ACGIH – Guidelines for the assessment of and control of

Bioaerosols (1997), the AIHA – Field guide for Bioaerosols (1996) and the EPA's Building Air Quality, A guide for Building Owners and Facility Managers (1991) are all internationally recommended for measurement of IAQ and are very useful tools in guiding actual monitoring within the working environment [45].

2.9 Solutions to Sick Building Syndrome

Solutions to sick building syndrome usually include combinations of the following:

2.9.1 Pollution source removal

Pollutant source removal or modification is an effective approach to resolving an IAQ problem when sources are known and control is feasible. Examples include routine maintenance of HVAC systems, e.g. periodic cleaning or replacement of filters, replacement of water-stained ceiling tile and carpeting, institution of smoking restrictions, venting contaminant source emissions to the outdoors, storage and use of paints, cleaning and disinfecting compounds, adhesives, solvents, and pesticides in well ventilated areas, and use of these pollutant sources during periods of non-occupancy, and allowing time for building materials in new or remodelled areas to off-gas pollutants before occupancy. Several of these options may be exercised at one time [38].

2.9.2 Ventilation rates

Increasing ventilation rates and air distribution often can be a cost effective means of reducing indoor pollutant levels. HVAC systems should be designed, at a minimum, to meet ventilation standards in local building codes. However, many systems are not operated or maintained to ensure that these design ventilation rates are provided. In many buildings, IAQ can be improved by operating the HVAC system to at least its design standard, and to ASHRAE Standard 62-1989 if possible. When there are strong pollutant sources, local exhaust ventilation may be appropriate to exhaust contaminated air directly from the building. Local exhaust ventilation is particularly recommended to remove pollutants that accumulate in specific areas such as rest rooms, copy rooms, and printing facilities [3].

Prevention of overcrowding is also a good control measure. If the design requirement in terms of number of recommended occupants are exceeded, indoor air quality problems will be problematic. A simple example: A HVAC system was installed in an area to provide 200 L of outdoor air per sec. Considering the SABS 0400 requirements where the building at the time of design allowed for 7 L/sec outdoor air/r person. Based on this the building was designed for only 29 people. If the organisation now accommodates 70 people in the same building, this will most definitely further contribute to the dilemma. With overcrowding other variables also starts to play a role and that may present typical SBS symptoms [9].

Lowering pollutant concentrations by diluting polluted (indoor) air with cleaner (outdoor) air is a natural way to ensure good quality indoor air and stay within recommended levels. Local building codes likely specify the quantity (and sometimes quality) of outdoor air that must be continuously supplied in your school or working environment. (Section 2) of this Guide for ASHRAE recommendations. Temporarily increasing ventilation as well as properly using the exhaust system while painting or applying pesticides, for example, can be useful in diluting the concentration of noxious fumes in the air [39].

2.9.3 Air cleaning

Air cleaning can be a useful adjunct to source control and ventilation but has certain limitations. Filtering particles and gaseous contaminants as air passes through ventilation equipment. This type of system should be engineered on a case-by-case basis [39] .

Particle control devices such as the typical furnace filter are inexpensive but do not effectively capture small particles. High performance air filters capture the smaller, respirable particles but are relatively expensive to install and operate. Mechanical filters do not remove gaseous pollutants. Adsorbent beds may remove some specific gaseous pollutants, but these devices can be expensive and require frequent replacement of the adsorbent material. In sum, air cleaners can be useful, but have limited application [6].

2.9.4 Education and training

Education and communication are important elements in both remedial and preventive indoor air quality management programs. When building occupants, management, and maintenance personnel fully communicate and understand the causes and consequences of IAQ problems, they can work more effectively together to prevent problems from occurring, or to solve them if they do [39].

2.9.5 Temperatures and humidity control

Temperature and humidity control are two of the most important indicators of a building's IAQ. They are also of extreme importance in the occupants' perception of IAQ. Achieving thermal comfort (temperature and humidity conditions that are acceptable to occupants) for all occupants is a difficult, if not impossible, task. ASHRAE has published recommended standards for thermal comfort parameters as illustrated in table 1. Maintaining a building within the following ranges of temperature and relative humidity will satisfy the thermal comfort requirements of most occupants [5].

Table 1: *ASHRAE STANDARD 55 – 1992 Thermal Environmental Conditions for Human Occupancy*

Relative humidity	Winter	Summer
30%	20.3 – 24.4°C	23.3 – 26.7°C
40%	20.3 – 24.15°C	23.05 – 26.4°C
50%	20.3 – 23.6°C	22.8 – 26.1°C
60%	20.0 – 23.3°C	22.8 – 25.6 °C

* Upper bound of 50% RH will also control dust mites.

2.9.6 Moisture control

The most important factor in the growth and spread of mould and other biological agents is moisture. Typical sources include structural leaks, roofing leaks, plumbing leaks, and malfunctioning or improperly sized heating, ventilation, and air conditioning systems. Elimination of excessive moisture is essential [40].

2.9.7 Humidity and Microbial growth

In addition to thermal comfort, the control of relative humidity is important to limit the growth of microorganisms such as dust mites and E.coli. To control microorganisms, it is best to keep relative humidity below 60% (to control molds) and 50% (to control dust mites) at all times, including unoccupied hours. High RH can foster proliferation of dust mites [41].

2.9.8 Environmental tobacco smoke

Second-hand smoke, or environmental tobacco smoke (ETS), is a mixture of the smoke given off by the burning end of a cigarette, pipe or cigar, and the smoke that is exhaled from the lungs of the smoker. ETS can cause significant IAQ problems in buildings. ETS contains more than 4,000 chemical compounds, approximately 40 of which are carcinogens or suspected carcinogens. Second-hand smoke has been classified by the U.S. Environmental Protection Agency (EPA) as a known cause of lung cancer in humans (Group A carcinogen). Children who breathe ETS are more likely to suffer from ear infections, pneumonia, bronchitis, and other lung diseases. ETS can increase the risk of asthma attacks in persons with asthma. For all these reasons consideration should be given to allowing smoking only in properly ventilated, dedicated smoking lounges or outside.

If smoking indoors cannot be avoided, it is recommended that ventilation in those areas where smoking takes place should be increased.

Open windows or use exhaust fans. Ventilation, a common method of reducing exposure to indoor air pollutants, also will reduce but not eliminate exposure to environmental tobacco smoke. Because smoking produces such large amounts of pollutants, natural or mechanical ventilation techniques do not remove them from the air in your home as quickly as they build up. In addition, the large increases in ventilation it takes to significantly reduce exposure to environmental tobacco smoke can also increase energy costs substantially. Consequently, the most effective way to reduce exposure to environmental tobacco smoke in the home is to eliminate smoking there [42].

In SA smoking in any public place except in a designated smoking area is prohibited in terms of the Tobacco controls Act. The regulations are also very detailed about the design of the HVAC system where smoking is allowed to avoid cross contamination of pollutes air into non smoking areas.

2.9.9 Combustion Products, including Carbon Monoxide

Sources of combustion products include unvented fossil-fuel heaters, unvented gas stoves and ovens, back-drafting and malfunctioning furnaces and water heaters. The health concerns caused by combustion products range from mild health effects to death. Carbon monoxide, a deadly gas, kills over 200 people per year in the United States. Other pollutants, such as nitrogen oxide, can cause breathing problems, particularly in sensitive individuals, and can trigger asthma attacks. To ensure that combustion pollutants do not create IAQ problems, the following steps should be taken:

- Minimize the use of these and
- ventilate all potential sources outside the building [43].

2.9.10 Volatile Organic Compounds

Volatile organic compounds (VOC's) are emitted from paints, solvents, building materials, air fresheners, dry-cleaned clothing, aerosol sprays, adhesives, fabrics and many more sources. In fact, indoor air may contain several hundred different VOC’s. Some of these VOC’s can cause eye, nose, and throat irritation, headaches, loss of coordination, nausea, and damage to the liver, kidneys and central nervous system. Some of these chemicals can cause cancer in animals. Some are suspected or known to cause cancer in humans. One of the more common VOC’s found indoor air is formaldehyde. Formaldehyde is an important chemical and can be found in many products including durable-press drapes and other textiles, particleboard products such as panelling, cabinets and furniture, tobacco smoke, and adhesives. Formaldehyde acts as an irritant to the eyes, nose and throat, and can cause tearing of the eyes, coughing and bronchial spasms. Formaldehyde is also listed as a suspected human carcinogen [43].

2.9.11 Particulates

Airborne particles include combustion products, dust and pollen. Health effects from exposure to respirable-size particles in the air depend on the types and concentrations of particles present, the frequency and duration of exposure, and individual sensitivity. Health effects can range from irritation of the eyes and/or respiratory tissues to more serious effects, such as cancer and decreased lung function. Biological particles such as animal and insect allergens, viruses and bacteria, can cause allergic reactions or infectious diseases [25]. Natural ventilation and where not possible a HVAC system with efficient manufacturers filters in compliance to the recommendations of the *EPA publication EPA 625 – R 016, June 1996* will ensure that particulates are reduced to acceptable standards [45]

2.9.12 Radon

Radon is a naturally occurring, invisible, odourless gas that comes from natural deposits of uranium in soil, rock, and water. It is harmlessly dispersed in outdoor air, but when trapped in buildings, it can be harmful, especially at elevated levels. Radon is a radioactive decay product of radium, which is itself a decay product of uranium. Uranium and radium are both common elements in soil. In North Carolina, piedmont and mountain counties are estimated to have the greatest proportion of homes with elevated levels of radon. Ensure sufficient natural ventilation and HVAC systems in compliance to the recommendations of the *EPA publication EPA 625 – R 016, June 1996* [45].

2.9.13 Heating, Ventilating & Air Conditioning (HVAC) Systems

HVAC systems should be designed to meet the needs of a specific building based on its design, use, and occupant activities. The HVAC system should filter the air, heat or cool as necessary, and control relative humidity during the cooling season. Some systems also introduce outdoor air during this process to dilute building contaminants. After all these actions take place, the tempered air is then circulated throughout the structure. A poorly maintained HVAC system can allow water to build up in the unit, creating conditions where the system itself can become a reservoir for biological contaminants. Inadequate systems can also allow high moisture levels that foster the growth of mildew. For these reasons, it is very important that HVAC systems be inspected on a regular basis to ensure that the systems are clean and functioning as designed.

Adequate supply of outdoor air, typically delivered through the HVAC system, is necessary in any office environment to dilute pollutants that are released by equipment, building materials, furnishings, products, and people. CO_2, a normal constituent of exhaled breath, is an indicator of whether sufficient quantities of outdoor air are being introduced to an occupied space for acceptable odor control. ASHRAE developed consensus standards and guidelines for HVAC systems. ASHRAE notes in an informative appendix to standard (*ANSI/ASHRAE 62.1-2007: Ventilation for Acceptable Indoor Air Quality)* that indoor CO_2 concentrations no greater than 700 ppm above outdoor CO_2 concentrations will satisfy a substantial majority (about 80%) of visitors with regard to odor from sedentary building occupants (body odor) [ANSI/ASHRAE 2007]. This would typically correspond to indoor concentrations below 1050 ppm since outdoor CO_2 concentrations usually range between 300 to 350 ppm. However, CO_2 is not an effective indicator of ventilation adequacy if the ventilated area is not occupied at its usual occupant density at the time the CO_2 is measured. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased. If CO_2 concentrations are elevated, the amount of outdoor air introduced into the ventilated space may need to be increased [1].

ASHRAE guidelines provide specific details on ventilation for acceptable IAQ. A ventilation system expert can help meet ASHRAE ventilation guidelines in the building. *ANSI/ASHRAE 62.1-2007* recommends outdoor air supply rates that take into account people-related sources as well as building-related sources. For office spaces, conference rooms, and reception areas, 0,142 cubic meters per minute of outside air per person (cmm/person) is recommended for people-related sources, and an additional 0.0,017 cmm for every square meter (cmm/m2) of occupied space is recommended to account for building-related sources. In elementary and high school classrooms, 0,283 cmm/person plus 0. 0034 cmm/m2 of outdoor air is suggested. To find rates for other indoor spaces, refer to Table 6-1 also found in *ANSI/ASHRAE 62.1-2007*.

Past research has shown that the lack of adequate outdoor air supplied into buildings contributes to occupant health symptoms. Buildings with ventilation systems designed to supply outdoor air only when indoor temperatures require adjustment may experience an increase in sick leave among employees [47].

2.9.14 Lead-Based Paint

Lead is a heavy metal that was used in the manufacture of paint (before 1978) and in other products such as plumbing pipes, solders and leaded gasoline. When paint containing lead deteriorates, tiny lead particles and lead dust can contaminate buildings and the environment. Regulations now limit the amount of lead used in paint and other applications. However, because lead lasts a long time, lead pollution remains a health hazard, particularly in older buildings.

Some solutions, such as major ventilation changes, may not be practical to implement due to lack of resources or the need for long periods of non-occupancy to ensure the safety of the students and staff. Use temporary measures to ensure good IAQ in the meantime. Other solutions, such as anti-idling programs, offer low-cost options that can be easily and quickly implemented [26].

2.10 Reasons for the study

The typical SBS symptoms observed by Management of the Department include an unusually high incidence of headaches, dry throat, lethargy, dry or itchy skin, runny noses and sore eyes. Abnormal high rates of absenteeism and dissatisfaction with working environments were also observed. The following physical and environmental conditions were observed, which may increase the risk of SBS:

- Open plan offices of more than 3 people;
- Large areas of open shelving and filing;
- Poor artificial ventilation;
- Low level of user control over ventilation and heating;
- Poor maintenance of building services and poor standards of repair;
- Excessive daily temperature fluctuations and
- Dust particles and fibres in the atmosphere.

In addition micro organisms such as bacteria and fungi are ubiquitous and are therefore readily found in our outdoor environment. Excessive proliferation or distribution of microbial growth inside buildings has been known to cause respiratory related ailments. Microbial contamination in building is often a function of moisture incursion from sources such as stagnant water in HVAC systems, air distribution systems and cooling towers and from leaking water pipes remitting in wet and damp conditions in areas such as stores, parking bays and lift shafts.

Based on the mentioned signs and symptoms observed amongst the office workers in the KSB which is very reminiscent of SBS, linked to the physical conditions of the working environment, management was of the opinion that there could be an association between the existing physical environmental conditions which are associated with the signs and symptoms of SBS, the seemingly low productivity and the above average rate of absenteeism.

The problems associated with poor indoor air quality and the subsequent effects thereof on workers, as experienced by management in Pretoria, were investigated and are discussed.

The fundamental purpose of this study is therefore to investigate and determine any possible association between the physical indoor environmental conditions and the SBS like symptoms as well as the seemingly low productivity and the above average rate of absenteeism are included in these discussions and to find a possible association between these poor physical environmental indoor conditions and the potential adverse affects on the health and motivation of workers. A cross sectional survey of all these indoor environmental conditions contributing to IAQ conditions, was conducted and compared to statutory requirements and other standards such as those contained in the SANAS codes and ANSI/ASHRAE international standards, to assess the physical, biological and chemical quality of indoor air. (Refer to as IAQ – Indoor Air Quality)

This research report therefore documents a project to measure the environmental conditions which include CO, CO_2, RH, temperature, air velocity, the microbial and chemical composition of the drinking water and culturable micro organisms in specific work environments within the KSB and to compare the outcome to standards for acceptable indoor working environments.

2.11 Aim of the study

The specific aim of this study is therefore to determine any possible relationship between microbial pathogens in the air of the working environment in the Regional Office of the Gauteng Department of Health in the KSB in Pretoria and the possible health effects thereof on the health status of exposed workers as well as environmental conditions possibly contributing to SBS.

2.12 Objectives of the study

The specific objectives of this study are:

- To describe the environmental conditions CO, CO_2, RH, temperature and air velocity exposures in specific work environments of the regional office building of the Department of Health during the period 2003-2004;
- To describe the microbial exposures, (Legionellae, the other forms, e.g. Pontiac Fever and Lochgoilhead Fever, have similar symptoms but are not as serious as Legionnaires' disease in specific work environments and drinking water of the regional office building of the Department of Health during 2003-2004;
- To compare measured environmental exposures to the Environmental Regulations for workplaces promulgated in terms of the OHSA, 1993 (Act 85 of 1993), the (NIOSH) standards as well as any appropriate national and international standards;
- To compare the microbial monitoring results of water to the NIOSH and other national and international recognized standards. (Drinking water being an environmental condition which could contribute to absenteeism if polluted and consumed as such) and
- To find possible associations between all the findings of the above and absenteeism, low productivity and associated SBS symptoms.

CHAPTER 3 METHODS AND MATERIALS

This section describes the study site and considers possible adverse environmental conditions within the working environment to which workers are exposed to and the possible association with the seemingly high rate of absenteeism and low productivity. The measurement of environmental IAQ conditions contributing to SBS are discussed as well as comparisons made between the results and the recommended and legislated requirements and recommended national and international standards. Other possible contributing factors are also identified and discussed. Data capturing and analysis techniques are also described.

3.1 STUDY DESIGN

A descriptive study was used to determine the levels of exposure to indoor air environmental conditions as well as exposure to factors contributing to SBS by a group of workers whose job description keep them office bound within specific environments in the KSB in Pretoria.

Data collection was done in the identified offices which were selected using a random sample technique. Specific environmental factors from the old HVAC and the new system will be scientifically measured using electronic equipment designed specifically for these purposes. Measurements were conducted during the morning and afternoon working sessions to generate more representative results of the IAQ environmental factors to which workers are exposed during an average 8 hour shift. A total number of 182 environmental measurements proportionally for CO, CO_2, RH, air velocity and temperature in and outside the respective study sites were taken from both the old and the new HVAC system over a period of 5 consecutive working days for each system. Measurements of the old system took place during the period 15 - 19 February 2003 and of the new during the period 6 -10 October 2003.
Concurrently a total of 4 samples from the drinking water from both the hot and cold water taps were taken for analysis of the chemical and bacteriological composition including identification of possible legionellae organisms. In addition 4 water samples from the old HVAC system were taken for analysis specifically for the Legionellae

organism. This was however not possible because Public Works removed the old system without prior notice before the sampling could be done.

Fifty six (56) air samples were taken with a biotest air sampler of the various offices which formed part of the study for the period 14 May 2003 - 14 May 2004 specifically for the identification of the Legionellae organism expressed in CFU/M3 and TPC expressed in CFU/M3.

In addition 2 water samples were taken of the stagnant water pools in the basement of the building during the 19th May 2003 for specific identification of the Legionellae organism.

The personnel office on the 4th floor, the transport section on the 3rd floor the staff room on the 9th floor as well as the switch board office on the 4th floor were selected as representative offices where sampling was done as indicated above. Workers in these offices were exposed to the indoor environmental conditions more than any other group of workers in the building. It is also in from these offices where the most absenteeism was experienced.

The results are tabulated and based on a paired comparison technique be analyzed and compared and subsequent deductions made based on the outcome of that.

3.2 STUDY SITE

The Provincial Department of Health has a regional office situated in the KSB in Pretoria. The building is a nine storey high rise building with a centralised HVAC system which transport air in ducting to all diffusers installed in offices and inhabitable areas. Separate air conditioning (split units) are installed in all offices.

Health care support staff in the Human Resource, procurement, switch board and Finance sections of the Department of Health Pretoria spent ± 90% of their time indoors of which ± 30% is at work.

Short description of the working environment which was used as the /study environment:

The Old System

The KSB in Skinner Street Pretoria was air-conditioned utilising a chilled water high – pressure induction unit system. The system was originally installed in 1975. Various attempts to obtain more detailed information from the Public works Department, who is the facilities manager for Government, were unsuccessful. It would have been ideal to have had more information to do a more practical comparison of the old and new systems specifications and effectiveness. Public Works further went on to negotiate for the upgrading /replacement of the system without giving acceptable prior notice to the management of the Department in the KSB.

The numerous complaints received from the workers and personal discomfort experienced had already been mentioned. These were the practical proof that this system was defective and not meeting the criteria of a comfortable and acceptable working environment as experienced by the very same workers exposed to the physical working conditions in the building.

The new system

The contract awarded to Messrs. CRC Engineering covered the upgrading of the existing air conditioning system and included the replacement of the following equipment:

- Chilled water generators;
- Cooling towers;
- Air handling units;
- Primary and secondary chilled water pumps;
- Condensed water pumps;
- Electrical switchgear and cabling;
- All pneumatic controls for electronic controls;
- Water treatment plant and
- Chilled and condenser water piping in the plant rooms

In addition to the above the induction units were serviced, a ducted return air system was introduced and a basement plant room ventilation system was added.

The primary chilled water pumps circulate water at 6°C. from the chilled water generators in the basement, through the cooling coils in the handling units on the tenth floor and to the mixing valves on the secondary chilled water circuits. The secondary chilled water pumps circulate a mixture of primary and secondary return chilled water, at 11°C, through the induction unit cooling coils.

The air handling units on the tenth floor handle all the latent cooling of the system and supply primary, high pressure, filtered and cooled or heated air to the induction units, on the office floors, through systems of externally insulated spiral ducting. Room air is induced through the induction unit coil by the high – pressure primary supply air, where it is cooled and supplied back to the room.

The primary chilled water is supplied at a constant temperature of 6°C and is controlled by the chilled water generator temperature controllers. The primary air supply air temperature is controlled from three averaging floor temperature controllers, which reschedule the supply air temperature. Room temperatures are controlled from room thermostats on each induction unit casing which control on/off three way valves on the cooling coils.

An intelligent direct digital control BMS system monitors and controls the operation of the whole air conditioning and ventilation system.

The system is designed for typical South African environmental conditions and has the following specifications:

- Altitude 1400m
- Summer outside conditions 35°CDB, 21°C WB
- Winter outside conditions + 2°C± 1°C
- Power supply 220 – 240 V/ 1Ph/50Hz
  380 – 420 V/

3.3. MEASUREMENT METHODOLOGY

The following measurements methodologies for the identified factors were considered for the qualification of SBS syndrome in the KSB.

A questionnaire survey on certain SBS symptoms, environmental parameters would have been a great addition. Except for all the standards in terms of measurement the ASHRAE standard states that if more than 10% of the persons in facility are not satisfied with any parameter then you can deem it a problem.
A questionnaire was not used for this study because of the fact that legislation in SA require and prescribe that quantitative samples of the environmental conditions which could contribute to SBS should be done using the prescribed measurement equipment. The prescribed statutory standards all refer to the outcome of measurement results as a means of determining compliance or not. According to International standards the same recommendations are prescribed and used for determination of IAQ compliance. A questionnaire as an alternative method for determination of any possible relationship between the IAQ conditions and absenteeism would form part of another study by Human Resource Management.

3.3.1 Environmental Measures

Measurements of both the old and the new HVAC system were done and results captured accordingly and compared to the acceptable standards such as those of NIOSH, ASHRAE Standard No: 55 of 1981 – Thermal Environmental conditions for Human Occupancy and the Environmental Regulations for workplaces promulgated in terms of the OHSA, 1993 (Act 85 of 1993). The result of each individual measurement was registered digitally and logged into the individual equipment memory. Readings were done after each measurement and manually logged into a computer data base. The mean reading of the specific measurements were calculated and the results were compared to the requirements laid down by the Environmental Regulations for workplaces published in terms of the OHSA, the National Building Regulations and Building Standards Act, 1977(act 103 of 1977) as amended, the SABS code 400 - 1990 as well as other internationally recognized standards.

For measurement of the CO, CO_2, RH, Air Velocity and temperatures the TSI – IAQ – Calc indoor air quality meter model (8762) which simultaneously measure and electronically data log, this multiple parameters for indoor air quality, was used twice per day as per manufactures recommendations captured in the TSI operations and service manual of 1996. Two ten minute measurements each of the offices which form part of the study were taken in the morning and afternoon work sessions and the results were digitally logged onto an electronic data base. Calibration certificates are attached as appendix II.

Model 8760/8762

IAQ-CALCTM
Indoor Air Quality
Meter

Figure 1: Illustrates the IAQ – Cal. meter model 8760/8762 used for measurement of Environmental IAQ conditions

Table 2 - 4 Hereunder reflects the standards of indoor air.

Table 2: *Evaluation Criteria and Standards for Physical Quality and Quantity of air*

SERIAL NO	RISK/PARAMETER	SOURCE	RECOMMENDED RANGE
1.	Recommended air temperature for comfort (Winter)	ASHRAE 55-1992: Thermal environmental conditions for human occupancy.	20.3 ^{o}C – 24.4 ^{o}C
2.	Recommended air temperature for comfort (Summer).	ASHRAE 55-1992: Thermal environmental conditions for human occupancy.	23.3 ^{o}C – 26.7 ^{o}C
3.	Recommended relative humidity levels for comfort.	ASHRAE 55-1992: Thermal environmental conditions for human occupancy.	30% - 60%

Table 3: *Evaluation Criteria and Standards for Physical Quality and Quantity of air*

SERIAL NO	STANDARD DESCRIPTION	STANDARD	SOURCE
1.	Outdoor air per person (l/sec) for Offices (non smoking).	5 l/sec	National building Regulations.
2.	Outdoor air per person (l/sec) for Offices.	9.4 l/sec	ASHRAE 62 – 1989
3.	Airflow rates for thermal comfort.	11 cub m/min	Schröder and Schoeman.
4.	Legionella (Bacteriological).	Negative	SAIMR.

Table 4: *Evaluation Criteria and Standards for Chemical and Biological Quality and Quantity of air*

SERIAL NO	RISK/PARAMETER	SOURCE	RECOMMENDED RANGE
1.	Ambient Carbon Dioxide levels.	NIOSH	350 - 400 ppm
2.	Carbon Dioxide: Indicator Level for inadequate ventilation if exhaled air is the main source of Carbon Dioxide.	NIOSH	800 ppm
3.	Carbon Dioxide: Upper limit for comfort.	NIOSH	1000 ppm
4.	Carbon Dioxide: OEL RL	Hazardous Chemical Substance Regulations – OHS Act (Act 85 of 93)	5000 ppm
5.	Carbon Monoxide: OEL RL	Hazardous Chemical Substance Regulations – OHS Act (Act 85 of 93)	50 ppm
6.	Total Colony Forming units – Bacterial.	Danish Building Research Institute – SBI Report 212.	100 Colony Forming Units/m^3. A recommended non-specific standard – Not a minimum or legal standard.

3.3.2 Sampling from the drinking water

Samples from the drinking water collected in sterile 1 litre containers at points posing the highest risk based on the experience and expertise of the Professional Technician and qualified and registered Medical Natural Scientist, Mrs. Coetzer and submitted in cool boxes maintaining the temperature at below 7 ^{o}C to the accredited water laboratory at the Rietvlei in the Pretoria region.

Analysis was done according to prescribed laboratory techniques and protocols for the identification of harmful micro organisms as well as chemical properties. The results were compared to SABS code 241: 2001 edition 5, which is the current acceptable standard in SA. Both chemical and bacteriological analysis was done.

3.3.3 Sampling from the HVAC system

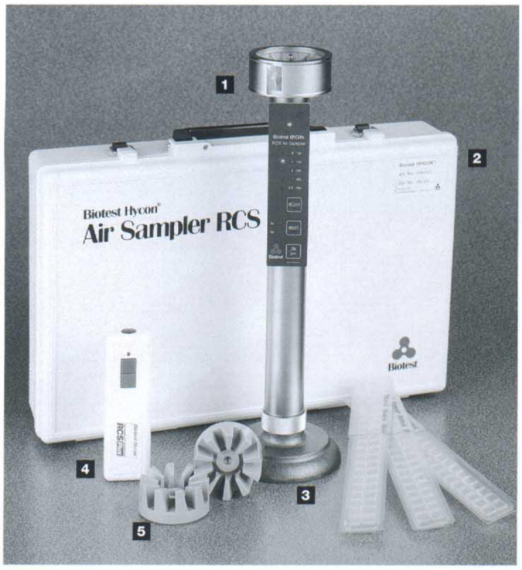
This could not be done because the system was removed prior to the sampling of the water. The new system was a closed system with no point/valve to take samples.

3.3.4 Air Samples

For measurements of the IAQ a Biotest RCS centrifugal air sampler was used. Sterile agar strips were inserted in the open-end drum of the instrument and each individual sample was taken over an 8 minute time period at various times and dates from the offices forming part of this study based on the recommendations of the manufacturer as well as the specialist technician, Dr. Soogram from NIOH. A new sterile agar strip was used for each measurement. Representative sampling was done and the worst case scenario used as the mean reading. The collected agar strips were removed and incubated at 37ºC. Microbial colonies were enumerated by visual examination directly through the strip and were reported as colony forming unit per litre (cfu/cub m) and for Legionellae the presence or absence thereof was reported upon. Representative sampling was done and the worst-case scenario used as mean reading.

An important variable that was considered is the number of occupants in the sampling environment and the impact that has Bacterial CFU’s/cub m. In most of the cases there is quite a good correlation between the CFU and number of occupants in an office room or area. The more to occupants the more the CFU per cub meter.

Figure 2: Illustrates the BIOTEST RCS Centrifugal Air Sampler



Standard RCS Centrifugal Air Sampler

SPECIFICATIONS

Collection Principle:	The Standard RCS operates on the principle of impaction whereby airborne microorganisms impact onto an agar media strip by centrifugal force.
Sampling Times:	0.5, 1, 2, 4, and 8 minutes
Separation Volume:	40 liters/min
Tolerance:	± 2%
Motor:	4,096 rpms
Power Supply:	4 alkaline "D" cell batteries or A/C adapter
Materials:	• Housing: chromium-plated brass • Keypad: polyester—resistant to common disinfection agents • Impeller blade: aluminum, autoclavable • Impeller drum: chromium-plated brass, autoclavable
Weight:	2.9 pounds (1,300 g) with batteries
Noise Level:	49 db
Miscellaneous	• Screw thread connection for floor plate • Infrared remote control sensor • Keypad with pressure keys and LED indicators • LED indicator for battery voltage • Protection cap made from POM; autoclavable • Connection for mains adapter • CE-Mark

PRODUCT AVAILABILITY

940001	**STANDARD RCS ACCESSORY KIT PACKAGE** 2 (includes 1 each: floor plate, tripod, and calibration mold)
940015	**STANDARD RCS AIR SAMPLER** 1
940020	**FLOOR PLATE** 3 for mounting Standard RCS
940030	**ADJUSTABLE TRIPOD** (not shown) for mounting Standard RCS as a free-standing unit
940041	**A/C ADAPTER** (110V) (not shown)
940050	**STERILE SLEEVES** (10/package) (not shown) for sterile wrapping of Standard RCS to protect against transmission of contaminants
940060	**CALIBRATION SET** 5 to ensure accurate angle of the impeller blade
940341	**INFRARED REMOTE CONTROL** 4 for convenient remote operation of Standard RCS, serial # ≥ 25000 (can also be used with RCS PLUS, serial # ≥ 5000)
940500	**IMPELLER BLADE ASSEMBLY** (not shown)
940510	**IMPELLER DRUM ASSEMBLY** (not shown)

Biotest

BIOTEST DIAGNOSTICS CORPORATION
66 Ford Road, Suite 131, Denville, New Jersey 07834
Phone: (973) 625-1300 • (800) 522-0090 • Fax: (973) 625-9454
www.biotest.com
STD11/9.97

Figure 3: Illustrates the BIOTEST RCS Centrifugal Air Sampler kit

3.4 DATA ANALYSIS

Registered Medical Natural Scientists verified the processed data with assistance from Professionals at the NIOH as well as the laboratories of the Metro Council of Tshwane. The measurement methodologies for environmental measurements and the processing of collected data as well as the interpretations thereof were verified by Mr. J. Pieterse a registered and certified Occupational Hygienist with support from Ms. L. Ngomane a qualified and registered Medical Natural Scientist.

3.4.1 Data collection

3.4.1.1 Environmental Measures

Measurements results were captured electronically into an excel database from Microsoft which is appended in the list of figures.

Comparisons of the measurements results of the old and new systems were done to determine the effectiveness thereof with reference to national and international standards.

3.4.1.2 Drinking water and water from the stagnant pools

The generated laboratory results were captured on a Microsoft Excel spread sheet and were compared to SABS code 241: 2001 edition 5, which is the current acceptable standard in SA.

3.4.1.3 Air Samples

Agar strips from the biotest sampler were incubated at the NHLS Immunology laboratories and microbial colonies were enumerated by visual examination directly as colony forming units per litre (cfu/l). For Legionellae analysis a similar process was followed and the presence or absence was reported upon.

The results were compared to the Apollo standards (as per annexure VI) for pathogen levels in indoor air. This is an internationally accepted standard for this particular purpose.

3.4.2 Data Analysis

Descriptive statistics were calculated using Microsoft Excel. All analysed measurements were captured electronically and the averages determined accordingly. To describe the averages and measures of central tendency for the concentrations, geometric means were used. The results were compared to the national and international standards. See appendix III.

The water sample results taken from the stagnant pools in the basement were captured on an electronic excel data base from Microsoft by the Laboratory and reflected in a result document as per section 4.3. The results were compared to the prescribed standards.

The results from the drinking water samples taken were once again captured in a report format by Rietvlei Laboratory and compared to the standards and requirements as per appendix III.

Results from the air samples were also captured in a report format by the NIOH laboratory and compared to the standards. See appendix V for the results as well as section 4.2 for a summary and discussion of the results.

3.5 ETHICAL ISSUES AND APPROVAL OF THIS STUDY

Every person in this country has the right to an environment that is not harmful to their health and well being. This right would also include the right of workers with reference to their respective working environments. This basic right is enshrined in the Constitution of the Republic of South Africa, 1996 (Act 108 of 1996) and specifically in Chapter 2, the Bill of Rights section 24(a).

In addition to the above the Occupational Health and Safety Act, 1993, (Act 85 of 1993), in the preamble, provides for the health and safety of persons at work and for matters related thereto (summarized). In particular in section 8 which provides for the general duties of CEO's to their employees as delegated by the HoD of the Department as provided for in section 16(1) to the 16(2) Managers of the various District offices and hospitals. Section 8(1) provides for the health and safety of workers in much detail. Every employer shall accordingly provide and maintain, as far as reasonably practicable, a working environment that is safe and without risk to the health of his/her employees.

In addition South Africa is a signatory to various International protocols addressing the rights of workers to a safe and health working environment such as the Seoul convention of 2009.

Within the context of the above the ethical requirements of a safe working and healthy working environment is evident and confirmed through national and international legislation and treaties.

Following official application to the HoD of Gauteng Health and the District Office of Tshwane/Metsweding District Office, authority was granted for this study to be performed in the KSB.

Partial financial supported was committed and a circular was send out under the signature of the Regional Chief Director all workers situated in the KSB requesting them to participate in all aspects of the study which included the monitoring activities in their respective working areas.

CHAPTER 4 RESULTS

This chapter deals with the presentation and interpretations of the data collected from the identified indoor air environments of the KSB following measurements of the environmental conditions CO, CO_2, RH, temperature and air velocity exposures as well as microbial exposures and the drinking water results.

For the purpose of imparting clarity, the results will be presented in the form of tables.

4.1 Results of the air measurements

4.1.1 Bio air samples

Table 5: *Summary of statistical analysis of Bio air samples*

	STANDARDS	SAMPLES
1.	< 100 CFU/cub m	29
2.	> 100 CFU/CUB M	27

The total plate counts (excluding the zero and those too numerous to count counts) vary between 31.25 – 5 250.00 CFU/M³ with a mean reading of 536.25 CFU/M³. If the zero readings are included the mean reading is 288.75 CFU/M³.

No pathogenic organisms were identified

4.1.2 Legionellae

Laboratory r*esults report of airborne microbes and Legionellae*

NATIONAL CENTRE FOR OCCUPATIONAL HEALTH
IMMUNOLOGY/MICROBIOLOGY SECTION
PO Box 4788, Johannesburg 2000
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LEGIONELLA CULTURE REPORT

DATE	LAB #	DESCRIPTION/SOURCE	TYPE	LEGIONELLA CFU/M3	TPC CFU/M3
14/05/04	IM72/03	D1 (GM) L2	Air	-	406.25
14/05/04	IM73/03	D1 (GM) L1	Air	-	31.25
14/05/04	IM74/03	D1 A L2	Air	Negative	-
14/05/04	IM75/03	D1 A L1	Air	Negative	-
14/05/04	IM76/03	D1 M (GM) 1	Air	-	387.50
14/05/04	IM77/03	D1 M (GM) 2	Air	-	118.75
14/05/04	IM78/03	D1 (M) L1	Air	Negative	-
14/05/04	IM79/03	D1 (M) L2	Air	Negative	-
15/05/03	IM81/03	D2 M (GM) L2	Air	-	543.75
15/05/03	IM82/03	D2 A (GM) L1	Air	-	231.25
15/05/03	IM84/03	D2 M (GM) L1	Air	-	575.00
15/05/03	IM86/03	D2 A (GM) L2	Air	-	350.00
15/05/03	IM87/03	D2 A (GM) 3	Air	-	143.75
15/05/03	IM90/03	D2 A (L) 1	Air	Negative	-
15/05/03	IM91/03	D2 A (L) 3	Air	Negative	-
15/05/03	IM93/03	D2 M (L) 2	Air	Negative	-
15/05/03	IM94/03	D2 M (L) 1	Air	Negative	-
15/05/03	IM95/03	D2 A (L) 2	Air	Negative	-
16/05/03	IM80/03	D3 (M) GM 1	Air	-	481.25
16/05/03	IM83/03	D3 (M) (GM) 3	Air	-	187.50
16/05/03	IM85/03	D3 (M) (GM) 2	Air	-	393.75
16/05/03	IM88/03	D3 (M) (L) 1	Air	Negative	-
16/05/03	IM89/03	D3 (M) (L) 3	Air	Negative	-
16/05/03	IM92/03	D3 (M) (L) 2	Air	Negative	-
16/05/03	IM102/03	D3 A (GM) 1	Air	-	243.75
16/05/03	IM103/03	D3 A (GM) 3	Air	-	406.25
16/05/03	IM104/03	D3 A (GM) 2	Air	-	581.25
16/05/03	IM107/03	D3 (A) (L) 2	Air	Negative	-
16/05/03	IM108/03	D3 (A) (L) 3	Air	Negative	-
16/05/03	IM109/03	D3 (A) (L) 1	Air	Negative	-
19/05/03	IM99/03	D4 M (GM) 2	Air	-	500.00
19/05/03	IM100/03	D4 M (GM) 1	Air	-	TNTC
19/05/03	IM101/03	D4 M (GM) 3	Air	-	231.25
19/05/03	IM105/03	D4 M (L) 2	Air	Negative	-
19/05/03	IM106/03	D4 M (L) 1	Air	Negative	-
19/05/03	IM110/03	D4 M (L) 3	Air	Negative	-
19/05/03	IM116/03	D4 (A) GM 4	Air	-	406.25
19/05/03	IM118/03	D4 (A) GM 1	Air	-	TNTC

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DEPARTMENT OF HEALTH

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LEGIONELLA CULTURE REPORT

19/05/03	IM119/03	D4 (A) GM 2	Air	-	TNTC
19/05/03	IM120/03	D4 (A) GM 3	Air	-	TNTC
19/05/03	IM123/03	D4 (A) L 4	Air	Negative	-
19/05/03	IM126/03	D4 (A) L2	Air	Negative	-
19/05/03	IM128/03	D4 (A) L 3	Air	Negative	-
19/05/03	IM130/03	D4 (A) L 1	Air	Negative	-
19/05/03	IM111/03	D5 (M) GM 3	Air	-	887.50
19/05/03	IM112/03	D5 (M) GM 2	Air	-	506.25
19/05/03	IM113/03	D5 (M) GM 1	Air	-	618.75
19/05/03	IM114/03	D5 (M) GM 6	Air	-	5250.00
19/05/03	IM115/03	D5 (M) GM 5	Air	-	506.25
19/05/03	IM117/03	D5 (M) GM 4	Air	-	1037.50
19/05/03	IM121/03	D5 M (L) 4	Air	Negative	-
19/05/03	IM122/03	D5 M (L) 1	Air	Negative	-
19/05/03	IM124/03	D5 M (L) 2	Air	Negative	-
19/05/03	IM125/03	D5 M (L) 5	Air	Negative	-
19/05/03	IM127/03	D5 M (L) 6	Air	Negative	-
19/05/03	IM129/03	D5 M (L) 3	Air	Negative	-

No Legionella were detected in the samples received. To interpret the results for the total bacterial counts please refer to recommended guidelines.

Yours sincerely,

Ms Tanusha Soogreem

Dr Delene Bartie

The presence of the Legionellae organism could not be detected in any of the submitted sample mediums as per laboratory result above, which confirms compliance to recommended standards for Legionellae organisms in working environments.

4.1.3 Microbial Organisms

The only microbial organisms cultured were that of the total plate counts.
See results above for detailed results of such as well as the discussions under 4.1.1 above.

4.2 Results of the environmental measurements

The combined summary is based on the mean of each category of measurement.

Tables 6(a): Summary of Environmental m*easurements results taken from the old and new HVAC system in the identified working environments during the period 15 – 19 February 2003 from the old and 6 – 10 October 2003 from the new system.(afternoons)*

	Day -1			**Day -2**			**Day -3**			**Day -4**		
	Afternoon			Afternoon			Afternoon			Afternoon		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
CO	0 (0)	0.0	0.0	0.0	0.0	0.0	0.7 (0.9)	0.0	0.0	1 (0.6)	1.0	2.0
CO -Post	1.3 (0.6)	1.0	2.0	1.3 (0.6)	1.0	2.0	0 (0.7)	1.0	2.0	0 (0)	0.0	0.0
CO_2	604.7 (4.6)	602.0	610.0	580 (51.6)	530.0	633.0	554.7 (187.6)	530.0	633.0	508.2 (79.5)	478.0	631.0
CO_2 -Post	503 (57.5)	446.0	561.0	461.7 (32.1)	425.0	485.0	455.3 (149.9)	425.0	485.0	404.7 (37.1)	367.0	442.0
RH	27.4 (0.9)	26.5	28.3	22.6 (16.7)	3.3	32.5	35.1 (12.4)	3.3	32.5	37.1 (0.5)	36.1	37.0
RH -Post	29.3 (1.2)	29.3	30.6	32.5 (0.6)	31.9	33.0	22.8 (10.0)	31.9	33.0	31.9 (4.0)	24.2	32.1
Air Vel.	0 (0)	0.0	0.0	0 (0.1)	0.0	0.1	0.1 (0.1)	0.0	0.1	0.2 (0.1)	0.0	0.1
Air Vel. -Post	0 (0)	0.0	0.1	0 (0)	0.0	0.1	0 (0.1)	0.0	0.1	0.3 (0)	0.1	0.2
Indoor Temp.	24.5 (1.2)	23.5	25.8	23.5 (0.5)	23.1	24.1	23.3 (7.5)	23.1	24.1	22.6 (0.6)	22.1	23.2
Indoor Temp. -Post	29 (1.0)	28.0	30.1	26.2 (0.8)	25.5	27.0	26.3 (8.6)	25.5	27.0	25.8 (2.1)	24.4	28.5
Workers	3 (1.0)	2.0	4.0	1.3 (0.6)	1.0	2.0	2 (0.9)	1.0	2.0	2.2 (1.5)	1.0	4.0
Workers - Post	2.7 (0.6)	2.0	3.0	2.7 (0.6)	2.0	3.0	2 (0.1)	2.0	3.0	2.2 (0.1)	1.0	3.0
Outdoor Temp.	24.8 (0)	24.8	24.8	23.2 (1.6)	21.4	24.2	23.9 (7.5)	21.4	24.2	22.1 (0.3)	23.8	24.4
Outdoor Temp. -Post	29.5 (1.9)	27.4	31.0	27.9 (0.3)	27.7	28.2	27.3 (8.7)	27.7	28.2	26.3 (0.4)	26.6	27.3

SD - Standard deviation, RH – Relative humidity

There is a significant decline in the C levels from the old to the new system of 88.3 ppm. However both the average maximum readings fall within the recommended standards. Also of significance is the reduction of the RH average reading with 3.6%. The concern is that 50% of average readings of the new system fall below the recommended limit for comfort of 30%. The increase of temperature in the new system could be ascribed to the increase in outside temperature due to the measurements being done in the summer months.

Tables 6(b): Summary of Environmental measurements results taken from the old and new HVAC system in the identified working environments during the period 15 – 19 February 2003 from the old and 6 – 10 October 2003 from the new system.(mornings)

	Day -2			**Day -3**			**Day -4**			**Day -5**		
	Morning			Morning			Morning			Morning		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
CO	0 (0)	0.0	0.0	2.3 (0.9)	2.0	3.0	0.7 (0.6)	0.6	1.0	1.3 (1.5)	0.0	3.0
CO -Post	1.3 (0.6)	1.0	2.0	0.7 (0.6)	0.0	2.0	0 (0)	0.0	0.0	0.7 (0.6)	0.0	1.0
CO_2	615.7 (129.4)	510.0	760.0	510 (194.9)	436.0	615.0	449.3 (38.1)	408.0	483.0	505.7 (73.6)	434.0	581.0
CO_2 -Post	484 (11.4)	471.0	492.0	440 (157.1)	415.0	465.0	402 (20.8)	389.0	426.0	371.5 (46.5)	460.0	547.0
RH	34.7 (2.4)	31.9	36.4	39.1 (12.9)	36.0	42.2	37.6 (3.4)	33.8	40.5	28.9 (1.9)	36.8	40.3
RH -Post	32.9 (5.5)	26.5	36.4	32.4 (10.4)	30.4	35.4	35.4 (1.0)	34.4	36.4	24.6 (1.0)	23.7	25.7
Air Vel.	0 (0.1)	0.0	0.1	0.1 (0)	0.0	0.1	0.4 (0.3)	0.1	0.8	0.1 (0.1)	0.0	0.2
Air Vel. -Post	0.1 (0)	0.0	0.1	0.3 (0.2)	0.0	0.7	0.4 (0.3)	0.1	0.7	1 (0)	0.0	0.2
Indoor Temp.	23.3 (0.1)	23.2	23.4	21.8 (7.9)	21.4	22.7	22.5 (1.8)	22.1	22.8	171.3 (0.9)	20.7	22.5
Indoor Temp. -Post	27.7 (2.0)	26.5	30.0	25.3 (9.1)	23.6	26.7	25.4 (1.8)	24.2	27.4	25.1 (1.4)	23.9	26.7
Workers	1.3 (0.6)	1.0	2.0	1.7 (0.9)	1.0	2.0	2 (1.0)	1.0	3.0	2.3 (0.6)	2.0	3.0
Workers -Post	3 (0)	3.0	3.0	3 (1.0)	3.0	3.0	2.3 (1.5)	1.0	4.0	2.8 (0.6)	2.0	3.0
Outdoor Temp.	21.3 (0.2)	21.1	21.4	19.3 (7.9)	19.1	19.5	20.1 (1.4)	19.1	21.7	149 (4.7)	14.5	23.8
Outdoor Temp. -Post	23.6 (0.7)	22.8	24.1	23.9 (9.0)	22.8	25.3	25.7 (1.4)	24.6	27.3	24.4 (2.0)	22.4	26.3

SD - Standard deviation, RH – Relative humidity

There is in general no significant difference ($p > 0.05$) between the morning and afternoon readings except for the indoor temperatures which could be ascribed to the increase in outside temperature. There is also a remarkable increase in the CO_2 levels during the afternoon measurements which could be directly associated to the exhaled air from the workers containing high levels of CO_2.

Included in the tables above are summaries of calculations of the daily means and the standard deviations for each of the measured environmental conditions.

Table 7: *Mean measurements results taken from the old and new HVAC system during the period 15 – 19 February 2003 from the old and 6 – 10 October 2003 from the new system and the NIOH Standards for IAQ.*

Factor	*Old System*	*New System*	*Standards*
Co (PPM)	0, 8	0, 6	9
CO_2 (PPM)	548, 6	460, 3	800
Rel. Humidity (%)*	34, 2	30, 6	30- 60%
Temperature (ºC) *	22, 8	25, 5	23 S - 21W
Air Velocity (L/Sec)	0, 1	0, 12	7 - 12

W = Winter season

S = Summer season

* Rel. Hum. Standards depends on temperature and season

* Temperature depends winter or summer season

Table 8: *Statistical analysis of the results of CO_2 measurements taken from the old HVAC system. during the period 15 – 19 February 2003.*

SERIAL NO	STANDARDS	ZONES
1.	< 800 ppm	4
2.	> 800pp <1000 ppm	0
3.	> 1000 ppm	0

Table 9: *Statistical analysis of the results of CO_2 measurements taken from the new HVAC system during the period 6 – 10 October 2003.*

SERIAL NO	STANDARDS	ZONES
1.	< 800 ppm	4
2.	> 800pp <1000 ppm	0
3.	> 1000 ppm	0

Table 10: *Summary of the ventilation measurement results of the new HVAC system taken during the period 6 – 10 October 2003 and a summary of the ventilation system openings into the respective offices which were selected for this study as well as the respective m^3 of each office.*

Floor	Office	No Person	Ave Flow Rate (m/sec)	Total Diffuser Size (cub m)	Total air volume (L/Sec)	Outdoor air setting (%)	Total outdoor volume	Outdoor air p/person (L/sec/pers)
3	Transport	3	0.071	3.71	263.41	20	52.682	17.56
4	HR Office	3	0.12	3.14	376.8	20	75.36	25.12
9	Management	2	0.14	1.71	163.8	20	32.76	10.92
3	Switch Board	1	0.055	1.14	62.7	20	12.54	12.54

The average flow rate indicated in meters per second are seemingly at first glance very low. However, it was considered within the context of the office space as well as occupancy as part of the calculations to determine compliance or not as reflected in figure 4 hereunder.

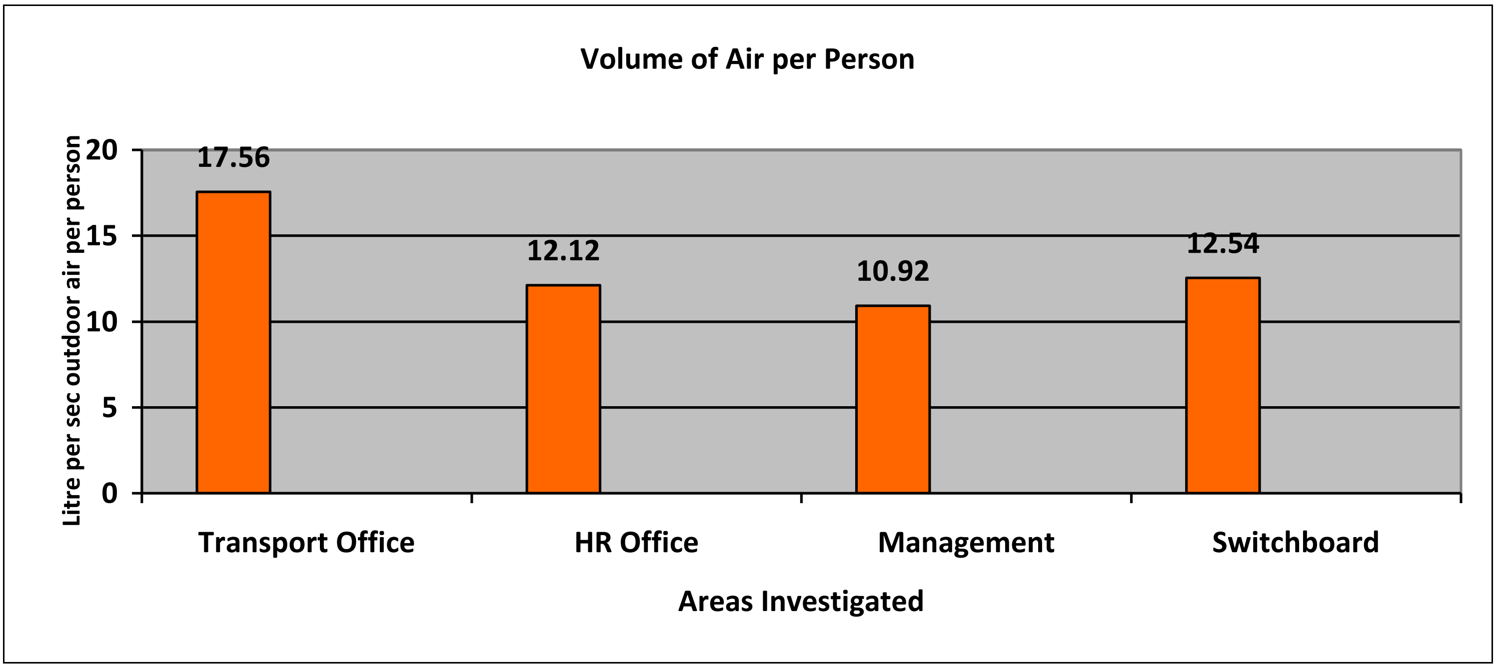


Figure 4: *A summary of air volume/person in the respective study environments taken from the new HVAC system during the period 6 – 10 October 2003.*

None of the results were below the legal limit set in SANS 0400 for ventilation in office environments. SANS 0400 requires at least 5.0 L/sec outdoor air per person in order to supply sufficient replacement air in the mentioned areas to reduce indoor air pollutants. It is therefore very likely based on the outcome of the measurement results that poor ventilation did not contribute to SBS, abseentism and low staff morale within the building.

4.3 Drinking water results

Laboratory results of the drinking water samples

Chemical Analysis	SABS 241 (2001) Class 1	Karel Schoeman
Physical and Organoleptic Requirements		
Colour (Pt/Co units)	15 - 20	0
Conductivity (mS/m) at 25°C	70 - 150	34
Dissolved Solids (mg/l) calculation	450 - 1000	228
Odour (TON)	1 - 5	NT
pH at 25 °C (pH units)	5.0 - 9.5	7.86
Taste (FTN)	1 - 5	NT[5]
Turbidity (NTU)	0.1 - 1	0.29
Chemical Requirements – macro determinatits		
Ammonia as N (mg/l)	0.2 - 1.0	0.03
Calcium as Ca (mg/l)	80 - 150	46.77
Chloride as Cl (mg/l)	100 - 200	20
Fluoride as F (mg/l)	0.7 - 1.0	0.111
Magnesium as Mg (mg/l)	30 - 70	24.09
Nitrate and Nitrite as N (mg/l)	6.0 - 10.0	0.0
Potassium as K (mg/l)	25 - 50	1.15
Sodium as Na (mg/l)	100 - 200	9.01
Sulfate as SO^{2-}_4 (mg/l)	200 - 400	9
Zinc as Zn (mg/l)	3 - 5	0.094
Total alkalinity as $CaCO_3$ (mg/l)	Not specified	203
Total hardness as $CaCO_3$ (mg/l)	Not specified	210
Calcium hardness as $CaCO_3$ (mg/l)	Not specified	110
Magnesium hardness as $MgCO_3$ (mg/l)	Not specified	100
Calcium carbonate precipitation potential (25°C)	Not specified	+16.7
Chemical Requirements – micro determinants		
Aluminium as Al (µg/l)	150 - 300	NT
Antimony as Sb (µg/l)	5 - 10	NT
Arsenic as As (µg/l)	10 - 50	NT
Cadmium as Cd (µg/l)	3 - 5	NT
Chromium as Cr (µg/l)	50 - 100	35.06
Cobalt as Co (µg/l)	250 - 500	NT
Copper as Cu (µg/l))	500 - 1000	24.79
Cyanide (free) as CN^-	30 - 50	NT
Cyanide (recoverable)as CN^-	70 - 200	NT
Iron as Fe (µg/l)	10 - 200	39.96
Lead as Pb (µg/l)	10 - 50	ND
Manganese as Mn (µg/l)	50 - 100	72.95
Mercury as Hg (µg/l)	1 - 2	NT
Nickel as Ni (µg/l)	50 - 150	16.46
Selenium as Se (µg/l)	10 - 20	NT
Vanadium as V (µg/l)	100-200	NT
Chemical Requirements – organic determinants		
Dissolved Organic Carbon as C (mg/l)	5 - 10	NT
Total Trihalomethanes (µg/l)	100 - 200	NT
Phenols (µg/l)	5 - 10	NT

[5] NT = not tested ND = not detected

1	2	3	4	5	6	7	8
Microbiological Determinants	Units	Allowable Compliance Contribution [a]			9th floor Office	Hot water tap	Cold water tap
		95% of samples, min	4% of samples, max	1% of samples, max			
		Upper Limits					
Heterotrophic plate count	count/ml	100	1 000	10 000	1	5	>
Total coliform bacteria	count/100ml	ND	10	100	>1	>1	>
Faecal coliform bacteria [b]	count/100ml	ND	1	10	>1	>1	>
E. Coli [b]	count/100ml	ND	ND	1	>1	>1	>
Somatic Coliphages	count/10ml	ND	1	10	NT	NT	NT
Enteric Viruses	count/100L	ND	1	10	NT	NT	NT
Protozoan Parasites *(Giardia / Cryptosporidium)*	count/10L	ND	ND	1	NT	NT	NT

[a] The allowable compliance contribution shall be at least 95% to the limits indicated in column 3 with a maximum of 4% and 1%, respectively, to the limits indicated in column 4 and 5. The objective of disinfection should, nevertheless, be to attain 100% compliance to the limits indicated in column 3.

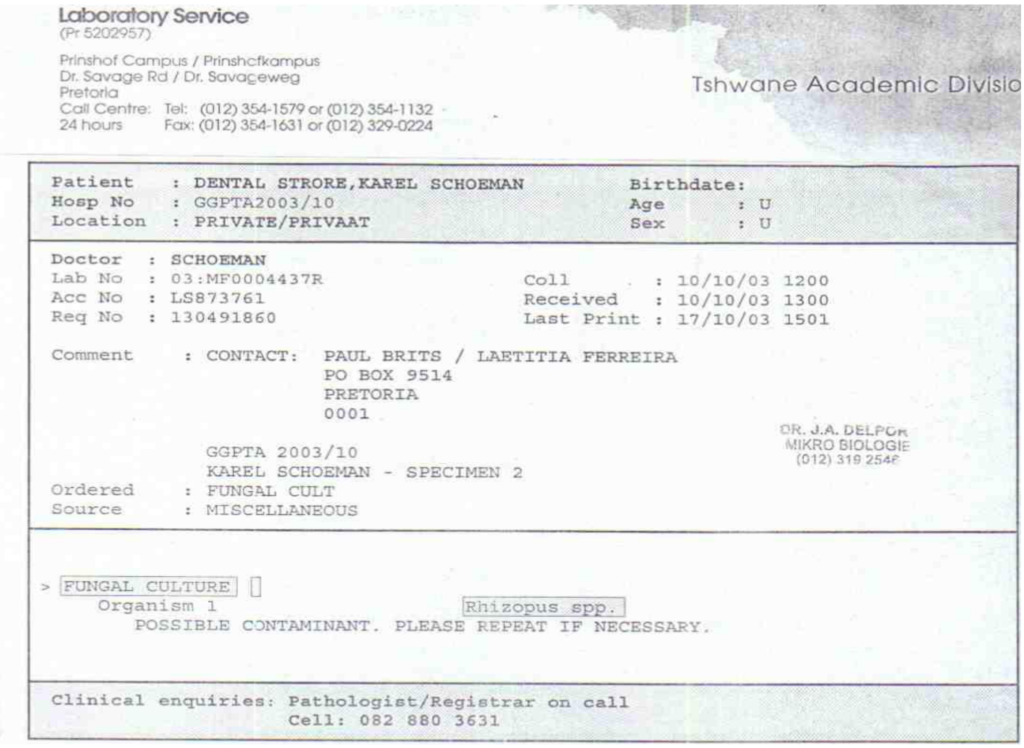
[b] In most instances it will not be necessary to conduct both these tests, one or the other will normally suffice as the required indicator

ND = Not detected; NT = Not Tested; TNTC = Too Numerous To Count

The water analysis for both bacteriological and chemical properties compared to the national standards applicable in South Africa (SABS Code 241 (2001) for class 1 water, indicate that all the parameters tested are well within the specifications for drinking water supply and use. The microbial quality of water is excellent and will have no detrimental effect on human health.

4.4 Water sample results from the stagnant pools in the basement

Laboratory results from the samples taken in the basement which were tested for pathogens which could contribute to SBS



Laboratory Service
(Pr 5202957)
Prinshof Campus / Prinshofkampus
Dr. Savage Rd / Dr. Savageweg
Pretoria
Call Centre: Tel: (012) 354-1579 or (012) 354-1132
24 hours Fax: (012) 354-1631 or (012) 329-0224

Tshwane Academic Divisio

Patient : DENTAL STRORE,KAREL SCHOEMAN Birthdate:
Hosp No : GGPTA2003/10 Age : U
Location : PRIVATE/PRIVAAT Sex : U

Doctor : SCHOEMAN
Lab No : 03:MF0004437R Coll : 10/10/03 1200
Acc No : LS873761 Received : 10/10/03 1300
Req No : 130491860 Last Print : 17/10/03 1501

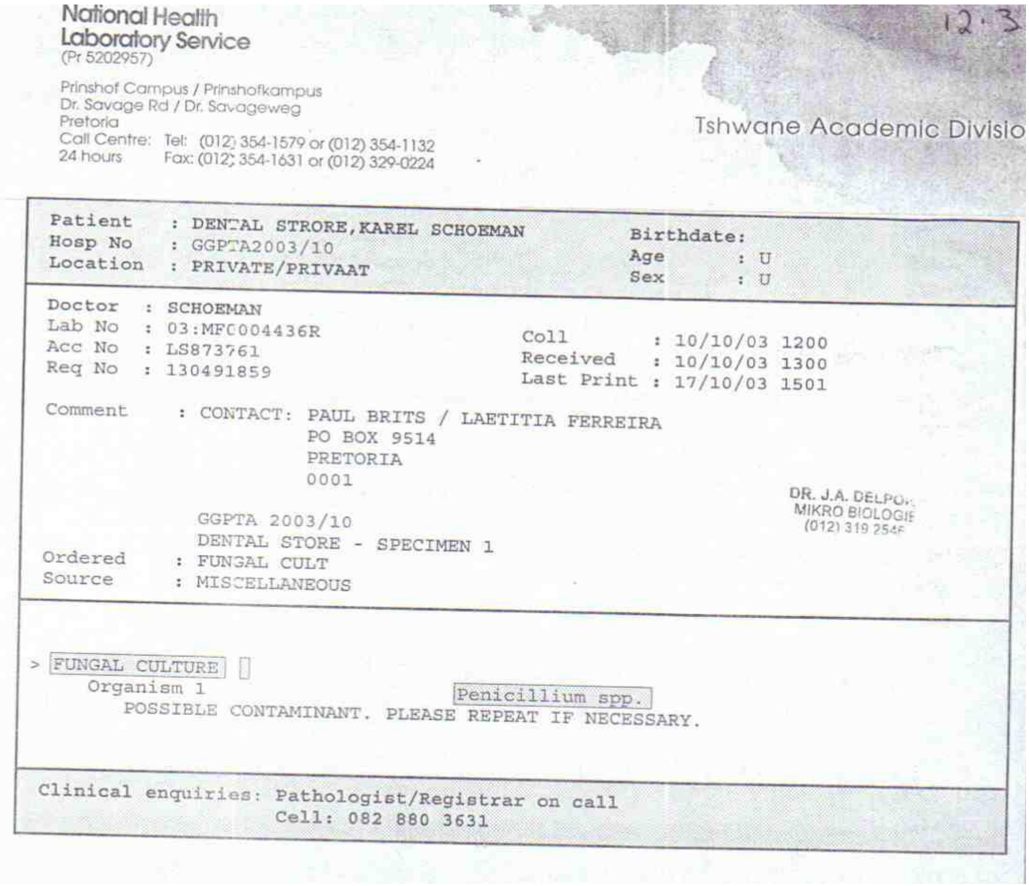
Comment : CONTACT: PAUL BRITS / LAETITIA FERREIRA
PO BOX 9514
PRETORIA
0001

DR. J.A. DELPORT
MIKRO BIOLOGIE
(012) 319 2546

GGPTA 2003/10
KAREL SCHOEMAN - SPECIMEN 2
Ordered : FUNGAL CULT
Source : MISCELLANEOUS

> FUNGAL CULTURE
Organism 1 Rhizopus spp.
POSSIBLE CONTAMINANT. PLEASE REPEAT IF NECESSARY.

Clinical enquiries: Pathologist/Registrar on call
Cell: 082 880 3631



National Health
Laboratory Service
(Pr 5202957)
Prinshof Campus / Prinshofkampus
Dr. Savage Rd / Dr. Savageweg
Pretoria
Call Centre: Tel: (012) 354-1579 or (012) 354-1132
24 hours Fax: (012) 354-1631 or (012) 329-0224

12.3

Tshwane Academic Divisio

Patient : DENTAL STRORE,KAREL SCHOEMAN Birthdate:
Hosp No : GGPTA2003/10 Age : U
Location : PRIVATE/PRIVAAT Sex : U

Doctor : SCHOEMAN
Lab No : 03:MFC004436R Coll : 10/10/03 1200
Acc No : LS873761 Received : 10/10/03 1300
Req No : 130491859 Last Print : 17/10/03 1501

Comment : CONTACT: PAUL BRITS / LAETITIA FERREIRA
PO BOX 9514
PRETORIA
0001

DR. J.A. DELPORT
MIKRO BIOLOGIE
(012) 319 2546

GGPTA 2003/10
DENTAL STORE - SPECIMEN 1
Ordered : FUNGAL CULT
Source : MISCELLANEOUS

> FUNGAL CULTURE
Organism 1 Penicillium spp.
POSSIBLE CONTAMINANT. PLEASE REPEAT IF NECESSARY.

Clinical enquiries: Pathologist/Registrar on call
Cell: 082 880 3631

The water analysis for both bacteriological and chemical properties compared to the national standards applicable in South Africa (SABS Code 241 (2001) for class 1 water, indicate that all the parameters tested are well within the specifications for drinking water supply and use. The microbial quality of water is good and will have no detrimental effect on human health when accidentally consumed directly or indirectly according to feedback from the laboratory Technician who has been involved in the initial analysis of the submitted samples. The presence of Rhizopus organisms though needs further investigation because of the recommendation by the Laboratory Technician as well as of the uncertainty about the possible role this organism can play as a contributor to SBS related conditions.

CHAPTER 5 DISCUSSIONS

5.1 Introduction

This section will include a summary of discussions regarding the outcome of all the findings, their significance and recommendations for further research will be made.

5.2 Significance of findings

5.2.1 Water samples

5.2.1.1 Samples from the old HVAC system

As mentioned under section 3.1, samples from the old system were not taken due to the fact that the system was removed by Public Works without notice prior to sampling dates and are therefore not further discussed as part of this project.

5.2.1.2 Samples from the drinking water

To control for confounding, samples of the drinking water as well as from a stagnant pool in the basement were taken and analysed for bacteriological and chemical compliance as well as identification of any microbes and chemicals that can contribute to SBS.
The water analysis for both bacteriological and chemical properties compared to the national standards applicable in South Africa (SABS Code 241 (2001) for class 1 water, indicate that all the parameters tested are well within the specifications for drinking water supply and use. The microbial quality of water is excellent and will have no detrimental effect on human health. The water might however taste slightly bitter to sensitive users due to the high calcium content. The source from which it is originally drawn is situated in the Fountains Valley in Pretoria, which is renowned for its high calcium content. (See appendix III for standards)

This section of the environmental conditions in the KSB therefore does not pose any health risk to the workers in the KSB at the time of sampling and analysis. The Department will be informed accordingly but will be advised to introduce a regular monitoring programme, which should include periodic sampling for determination or assessment of compliance. The fact that the drinking water complied with the standards set for chemical quality during these investigations does not necessarily guarantee continuous compliance at all times. However the presence of E. coli above the recommended limit could have resulted in ill health and subsequent absenteeism.

5.2.1.3 Samples from the stagnant pools

Although this water source is not for drinking purposes analysis, was done within the parameters of drinking water quality and to assist in the control of confounding.
The water analysis for both bacteriological and chemical properties compared to the national standards applicable in South Africa (SABS Code 241 (2001) for class 1 water, indicate that all the parameters tested are well within the specifications for drinking water supply and use. The microbial quality of water is good and will have no detrimental effect on human health when accidentally consumed directly or indirectly according to feedback from the laboratory Technician who has been involved in the initial analysis of the submitted samples. (See the results section for details). The presence of Rhizopus organisms though needs further investigation because of the recommendation by the Laboratory Technician and because of the uncertainty about the possible role this organism can play as a contributor to SBS related conditions.

5.2.2 Environmental conditions

Comparisons of the samples results were made between the readings of the old system and the new after it was commissioned. Reference was only made to the average readings in all cases to avoid unnecessary possible duplication. Where appropriate outliers will be singled out and analysed in the same details. Please refer to the appropriate annexures V for detailed information regarding the raw data.
The findings of various other studies have been referred to under background.

5.2.2.1 Carbon Monoxide (CO)

The average reading between the old and the newly commissioned system show a decline of 0.2 parts per million (ppm). The average reading decreased from 0.8 to 0.6 ppm in the identified areas.

No specific standard has been regulated in SA. The general internationally acceptable standard is that applied by ASHRAE, the NAAQS which stipulates the standard for CO as 9 ppm maximum for 8 – hour average exposure, or 35 ppm maximum for 1 – hour average exposure.

Monitoring at the fresh air inlet of the HVAC also indicated that the fresh air complies with the standards and could therefore also not influence the indoor air quality.

The average outcome of these measurements in the KSB are therefore well within the internationally recommended limits and therefore posed no health risk during the period of the measurements.

5.2.2.2 Carbon Dioxide (CO_2)

The average reading between the old and new system has shown a decline of 88.3 ppm. The average reading has declined from 548.6 to 460.3 ppm. The results of all samples taken in offices were below the recommended limit set by NIOSH for proper ventilation. In comparison with the NIOSH standard of 800 ppm it is indicative that enough outdoor air is introduced to reduce CO_2 levels as a result of exhalation to acceptable levels. However the new system reduced the carbon dioxide level with less than a 100 ppm's. In comparison with what CO_2 levels in outdoor air which is between 300 (rural area) and 350 ppm (urban areas), carbon dioxide level should be reduced by another 110.3 ppm to bring it in line with CO_2 levels in the natural atmosphere which is universally used as the ideal for indoor air quality bearing in mind any sources of environmental pollution.
This statement is further supported through a study done by Mendall M.J. *et al*.[23], during 2005 where they found that increased air replacements through increased air ventilation rates above the recommended standards from ACGIH and other universally acceptable norms and standards, were associated generally with reduced symptom prevalence (referring to the symptoms of SBS) and generally decrease the physical signs and symptoms of SBS.

NIOSH further prescribes that where exhaled air is the main source of CO_2, then CO_2 levels of < 800 ppm is prescribed as an indicator of good ventilation. It is a more applicable standard to determine if the ventilation is enough or not.

There is a standard regulated in the Environmental Regulations for Workplaces GN R 2281 of 16 Oct. 1987 as amended by GN R 1754 of 18 August 1989 and GN R 489 of 1994, section 5(1) (b) and (c).

The US and SA occupational exposure limit (OEL) is 5 000 ppm, as stipulated in the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) [64] and the Hazardous Chemical Substance Regulation promulgated under the Act on Occupational Health and Safety, 1993 (Act 85 of 1993). None of the sample results exceeded the legal OEL and TLV's set for CO_2.

The only South African regulated standard could be found in the National Building Regulations and Building Standards Act, 1977(Act 103 of 1977) and specifically in regulation no R.441 of 1985, section O, table 1, which deals specifically with the various ventilation standards for the different occupancies. In terms of this section the minimum air requirement for general offices is 5 litres per second outside air per person. The structural requirements in terms of the same regulation to ensure sufficient natural ventilation could not be applied to high rise buildings in cities because of possible poor quality outdoor air as a result of pollution and other surrounding buildings and the negative effect these structures will have on natural air flow phenomenon.

However in practice the ASHRAE standard 62 -1973, 1981 and 1989 which recommends airflow of between 9.4 range 7 to 12 litres/sec outside per person is used internationally as a norm.

Both the South African and the ASHRAE standards were however devised in the early seventies when a serious energy crisis was experienced. The main focus area of these standards was therefore also to conserve energy. Braun (2001) proposed improved ventilation rates for various facilities indicated in units of L/sec. per person or as a unit of L/Sec per square meter floor area [35].

The following relevant part from the SANS 0400(National Building regulations) is applicable to this project:

"The largest of 10 L/Sec per person or 2.0L/Sec. m^2" (for non smoking areas)

The most important part of a ventilation – based indoor air evaluation is how much air is actually delivered to the occupants of a building. Not only must enough outside air be drawn into a system, but this outdoor air must also be delivered to where the building occupants are. There are in general two items to be checked if investigating complaints. Firstly how much fresh air is drawn into the system and secondly where this air is delivered. In new buildings a full economy cycle should be provided, with temperature comparison at altitude and enthalpy comparison at sea level. This economizer capacity means that an 100% outdoor air can be supplied to the occupants intermittently using "free cooling" when the outdoor temperature or enthalpy is equal to or below the return air temperature or enthalpy, but within the comfort ranges of temperature, air velocity and relative humidity" according to Braun(2001) .

Another basis for the rate of ventilation is the air change method that is the number of times per hour the air content of the space should be replaced with fresh air. Braun (2001) refers to 4 – 6 air changes per hour for internal offices, which is generally used as a standard in the industry as well [35].

Mean readings of inlet air of the HVAC also fell within the range of the standard and could as such not influence the indoor air quality negatively.

The average outcome of these measurements in the KSB is therefore well within the SA and International standards and therefore also posed no health risk at the time of the investigations.

5.2.2.3 Relative Humidity (RH)

The average reading of the old and new system has shown a decline of 3.6%. The average reading has declined from 34.2% to 30.6% which is still within AHSRAE requirement. However it was found that 50% of the sampling results in the new system, RH levels were below the lower limit for comfort 30% mark with a mean reading of 25.57%. This tendency in some offices could result in the dryness of upper respiratory tract, eyes and nose as found in similar studies by the EPA according to their IAQ reference guide of 1991.

They found that it is important to control moisture and relative humidity in occupied spaces. The presence of moisture and dirt can cause molds and other biological contaminants to thrive. RH levels as referred to in *An Office Building Occupant's Guide to Indoor Air Quality"* [www.epa.gov/iaq/pubs/occupgd.html - 5](www.epa.gov/iaq/pubs/occupgd.html), that are too high can contribute to the growth and spread of unhealthy biological pollutants, as can failure to dry water-damaged materials promptly (usually within 24 hours) or to properly maintain equipment with water reservoirs or drain pans (e.g., humidifiers, refrigerators, and ventilation equipment). Humidity levels that are too low, however, may contribute to irritated mucous membranes, dry eyes, and sinus discomfort.
Findings of this project indicate RH levels well below the lower limit set for comfort and indicative of the fact that the new system does not spread reticulated and filtered cooled air equally through the system into all offices. There is no proper humidification of air by the HVAC system to maintain levels between 30 (Lower Limit) and 60% (upper limit). This of course places a question mark on the effectiveness of the new system, which costed over 4.5 million Rand to install.

It could be concluded that the RH levels are too low to promote the growth of fungi and yeasts within the HVAC system and office environments. However the opposite may be the case in summer where relative humidity levels may reach the upper limit set at 60% as recommended by the *EPA in their IAQ reference guide of 1991.*

There is once again no regulated standard in SA specifically for RH. There is however a regulated requirement in the Environmental Regulations for workplaces published as mentioned previously of the so called WBGT INDEX. This index is however mostly applied in the industry environment where extreme temperature changes are experienced. Part of the calculation includes a 0.7% of the reading of a naturally ventilated wet bulb thermometer.

The comfort zone is used as an international standard, also in SA. Acceptable temperature and humidity ranges during winter and summer, adapted from ASHRAE Standard 55 – 1981, Thermal Environmental Conditions for Human Occupancy.

The recommended relative humidity levels internationally accepted and applied accordingly varies from 30% - 60% linked to winter and summer temperatures.

The recommended ASHRAE RH standard is however applicable for conditions in the Northern hemisphere and should therefore be applied and enforced with caution in SA.

The average outcome of the measurement of RH linked to the recommended temperatures levels is subsequently just within the recommended levels. If the temperature readings are however brought into the equation for both winter and summer, the RH should be at least between 50 - 60% if the recorded temperatures are maintained.

These low levels of RH could be one of the contributors to the complaints of dry skin, lips, and dry out of the mucus membranes of the occupants as well as dry throats and nose bleeds which could lead to secondary inflammation or infection. Dryness will also permit air contaminants like VOC's to be more irritating. These findings are also supported by the *EPA in their IAQ reference guide, 1991* as well as in their publication *An introduction to IAQ, 2009* [71].

The provision of a humidifier into the air supply system, which should increase the RH to at least between 50 - 60% at current indoor temperature levels, would most definitely be a recommendation to the Department.

Special precaution should be taken to prevent ideal surface conditions within the system, which could be suitable for micro bacterial growth, including, yeasts and dust mites. The EPA in their publication, *An introduction to IAQ, 2009, in the section for Biological pollutants,* also strongly recommends maintaining the RH between 30% - 60% which will help to control mold, dust mites, and cockroaches.

The desired temperature/humidity relationship for comfort conditions is very difficult to define. People react differently to different conditions. The solution to this would be to allow occupants in different areas in a building to control the temperatures and humidity to their liking within the recommended standards of upper and lower levels.

This recommendation is supported through a report by the *EPA, published in a report Energy Cost and IAQ Performance of HVAC systems and Controls done in Jan. 2000, report 4-2-501-00* [72].

5.2.2.4 Temperatures

The average reading between the old and the newly commissioned system has shown an average increase in temperature of 2.7°C. The average reading of the old system was 22.8°C and that of the new system 25.5°C. This could however be ascribed to the higher outside temperatures due to the seasonal changes during the time of the measurements. There were no individual readings below the recommended generally acceptable levels.

The only regulated standard in SA is that of the WBGT INDEX. However the WBGT index is more relevant to the industrial and mining environments to prevent heat related disorders and not for thermal comfort in office environments. The ET of CET Index and AHSRAE comfort indexes should be used for office environments as published in ASHRAE 55-1992: Thermal environmental conditions for human occupancy. ASHRAE conducted research to establish a range of combined temperatures and humidities that provide the maximum comfort. See appendix VII which shows the standard effective temperature lines on a psychometric chart. Also shown is the ASHRAE comfort envelope.

These design recommendations according to the ASHRAE standard 55 of 1981 as amended during 1992 are defined as follows:

- Summer maximum inside temperature – 23 ± 1.5°C
- Winter minimum inside temperatures – 21 ± 1.5°C

ASHRAE has developed acceptable temperature and humidity ranges during winter and summer, adapted from the ASHRAE Standard 55 – 1981, which include RH as part of equations.

Table 11: *ASHRAE –Standards for temperatures and humidity ranges during winter and summer*

Relative humidity	Winter	Summer
30%	20.3 – 24.4°C	23.3 – 26.7°C
40%	20.3 – 24.15°C	23.05 – 26.4°C
50%	20.3 – 23.6°C	22.8 – 26.1°C
60%	20.0 – 23.3°C	22.8 – 25.6 °C

The average outcome of the measurement of temperatures linked to or not linked to the recommended RH levels are subsequently within the recommended levels.
It is therefore not an environmental risk and will not be further discussed.

5.2.2.5 Velocity

The average reading between the old and the newly commissioned system has shown an average increase in air velocity of .02 m/sec. The average readings of the old system were 0.1 m/sec and that of the new system 0.12 m/sec. measured at the working stations of staff in the identified offices.

No readings of the old and new system, which were taken at the individual workstations ± one meter from the individual and ± one and a half meter from the floor surfaces, are in compliance to the international and national acceptable requirements and or recommendations.

It must however be pointed out that the outcome of measurements taken from the old system is not a true reflection of the technical efficiency of such. The system was switched off at most of times as a result of staff complaints. It was quite clear at that stage, during the winter months, that the system was not functioning effectively. It is also reflected in the minor difference between the indoor and outdoor temperatures taken at the same time.

The average outcomes of the measurements compared to the SA standards are far above the standard of 5 L/sec outside air per person as stipulated by SANS 0400 and 9.5 l/sec outside air per person set by AHSRAE. In term of air delivery rates it seems that the new ventilation delivers according to set standards in this regard.

The air volume delivery and subsequent above standard air replacements could not be the main reason why the substantial majority of staff exposed in the KSB according to the great number of complaints (> 10%) are dissatisfied with the indoor air environment. The above high rate of absenteeism could also be ascribed, directly or indirectly to following variable and assumptions:

- Poor hygiene and housekeeping in the facility;
- Poor people's management;
- Substandard water quality supply;
- The decommissioning of the old system and commissioning of the new system for limited period;
- Poor staff morale and lack of proper supervision;
- Organisation restructuring that took place during the study period;
- Location in Pretoria mid city;
- Possible contamination of indoor air by external sources bio quality;
- Seasonal occurrences of influenza and colds;
- Home and external exposures;
- Substandard ergonomics.

The above is supported by the EPA in their publication of 1997 [70], through similar past experiences and research for the reasons about factors that affect occupant comfort and productivity besides the factors that directly impact the levels of pollutants to which people are exposed.

5.2.3 Air Measurements

5.2.3.1 Bio air samples

No pathogenic organisms were identified in any of the samples which then eliminate poor biological indoor air quality as a contributing factor for SBS.

When the 4 results depicted as " too numerous to count" (TNTC) are included in the calculations where the mean reading of 536.25 CFU/M^3 and the mentioned range of 31.25 – 5,250.00CFU/M^3 was determined, it is not 100% statistically correct.
In addition the outside air was not sampled for determination of total plate counts.
Twenty nine of the fifty six samples taken exceeded the Danish building Institutes standard of 100 CFU/M^3 set for good indoor air quality. These could be attributed to [66] :

- Over population;
- Poor facility design and housekeeping;
- Contamination of intake air and
- Supply air not being sufficient to dilute air borne biological contaminants.

5.2.3.2 Legionellae

The presence of this organism could not be identified in any of the submitted sample mediums. This possible contributor to SBS is therefore not a risk factor in the KSB.

5.2.3.3 Microbial Organisms

The results when compared to the standards as depicted in the appended annexure marked III are not within acceptable standards. The range of results varies between zero and "too numerous to count". The standard for general office as prescribed in the Danish Building Research Institute – SBI Report 212, (2001) for office environments requires a 100 CFU/m3 for total bacterial counts [66]. These standards were selected as the best standard for comparisons as it was found to be the most stringent standard of all standards investigated in comparison with NASA's indoor air quality standards as appended as annexure VI. The presence of organisms classified under the category coliform organisms per cubic meter could mostly be attributed to poor office design, poor hygiene and inappropriate and ineffective cleaning practices.

5.3 Opportunities for further research

The results of the bio air sampling which does not correlate with overcrowding and air replacements need to be further investigated.

In summary based on the outcome of the project results, it is clear that the new air conditioning system does meet the mentioned minimum prescribed physical environmental national and international norms and standards for indoor air quality.

The typical SBS symptoms experienced within the working force in the KSB will in all probability continue to exist and contribute to the seemingly above higher rate of absenteeism and lower than average productivity until the assumptions and variables are further investigated. Based on the outcome of this study, the IAQ does not contribute to SBS however.

Clearly opportunities have been identified to do personal biological monitoring following specifically designed questionnaires for all those exposed to the current indoor air in the building.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

This section will include a summary of the overall conclusions regarding the outcome of all the findings and specific recommendations will be made and briefly discussed.

6.1 Conclusions

Based on the objectives of this study as captured under 1.10 the following conclusions are summarized:

- The outcome of the air monitoring to determine any relationship between the quality thereof and the state of health of the subjects (workers) has very little association and/or relationship between that and SBS.

- However the microbial load of the total plate counts is far beyond the recommended standards for general office working environments and is in all probability one of the major contributors to the SBS experienced in the KSB. The adverse physical state of the building, poor housekeeping, poor staff morale, poor people's management, seasonal influenza outbreaks, insufficient hygiene practices, ergonomics, old carpets, lack of a well managed cleaning programme without specific operating procedures and a cleaning schedule and other external variable could be considered the causes of SBS.

- When the bacteriological results of the drinking water sampling are compared to the national and international standards, the outcome does reflect compliance to the statutory and recommended standards except for the presence of E.coli which could have contributed to absenteeism. The microbial load of the total plate counts which are far higher than the recommended standards for general office working environments could also be a contributor to SBS in the KSB.

- The fact that the Legionellae organism was not found in any of the samples is not surprising as water replacements, flushing, fluctuating chlorine levels and temperature fluctuations of below 20 degrees could have occurred as the study was performed in winter. It is anticipated that the water temperature readings will be higher in summer therefore creating a more conducive environment for bacterial and microorganism growth. As mentioned in the background of this report, all the physical conditions have been observed and identified in the KSB which is conducive for the growth and spread of the organism.

- The drinking water quality was in compliance to the standards set for chemical pollution. In addition to this the Tshwane Municipality adds water to the supply from natural protected sources at Rietvlei, which are monitored on a regular basis. They also monitor the combined supply at strategic places in the city and take the necessary corrective steps if and when necessary.

- Although air provision was found to be sufficient, the significant difference between the environmental factors of the HVAC is somewhat surprising. The reduction in the mean reading of the relative humidity from 34.2% to 30.6% (by air volume) due to defective humidifier setting or the lack of humidification is a reason for concern. The seasonal change when this result is compared to the mean outside temperature should have had an opposite effect due to the higher natural humidity in the summer months in Pretoria. The lack of sufficient humidity in the working environments will also result in the contribution of typical SBS symptoms, which in all probability contribute to the higher rate of absenteeism and apparent lack of motivation at work.

- Then there is the lack of comfort, which will be experienced by workers in the working environment especially with reference to the above, and the RH, which is just within or below the recommended standards. This is once again supported by the EPA in their guide, *An Office building Occupants Guide to IAQ, 1997* [70].

- In summary based on the outcome of the project results, it is clear that the air conditioning system does provide appropriate air replacements, which is in compliance with the mentioned national and international norms and standards for indoor air quality.
- The typical SBS symptoms experienced within the working force in the KSB will in all probability continue to exist and contribute to the above higher rate of absenteeism and seemingly lower than average productivity due to demotivated staff and the possible effect of the other variables which should be further investigated.

6.2 Recommendations

- The Landlord of the KSB (Gauteng Health) will be informed of the outcome of the study with specific reference to the possibility that environmental conditions could not be contributing towards SBS as suspected by management and allegedly experienced by employees within the building;
- Gauteng Health will be advised to seriously consider further investigating the presence of E. Coli in the drinking water as a possible contributor to SBS;
- Recommendations regarding possible poor housekeeping and cleaning methodologies of the offices found to be not very effective and possibly contributing to low staff morale, will also be included in the recommendations;
- Further investigations of seemingly low staff morale which could also contribute to SBS within the workers corpse of the KSB, will also have to be investigated through administrative and other means such as questionnaires, personal interviews and special surveys. In this regard specifically, appropriate questionnaires as part of further investigations will be recommended;
- The Department will also be advised to communicate the findings of the study to the respective health and safety representatives as well as the other workers representative bodies such as organised labor in a further attempt to improve staff morale and workers motivation.
- A psycho/social and ergonomics assessments is strongly recommended to address morale, management and workplace *issues*. This recommendation is

supported by the EPA in their guide, *An office building Occupants Guide to IAQ* [70].

6.3 Limitations

- Non testing of the water of the old HVAC system because of the removal thereof by the Department of Public Works prior to sampling without any prior notice;
- Limited funding to do more comprehensive sampling and analysis thereof;
- Long time span between original sampling period and follow up period for control sampling for purposes of quality verification of data purposes;
- Qualitative assessment of workers in the KSB attitudes towards their experience of IAQ in the KSB using a questionnaire by the Human Resource Management section. Ideally it should have been done concurrently as part of this study;

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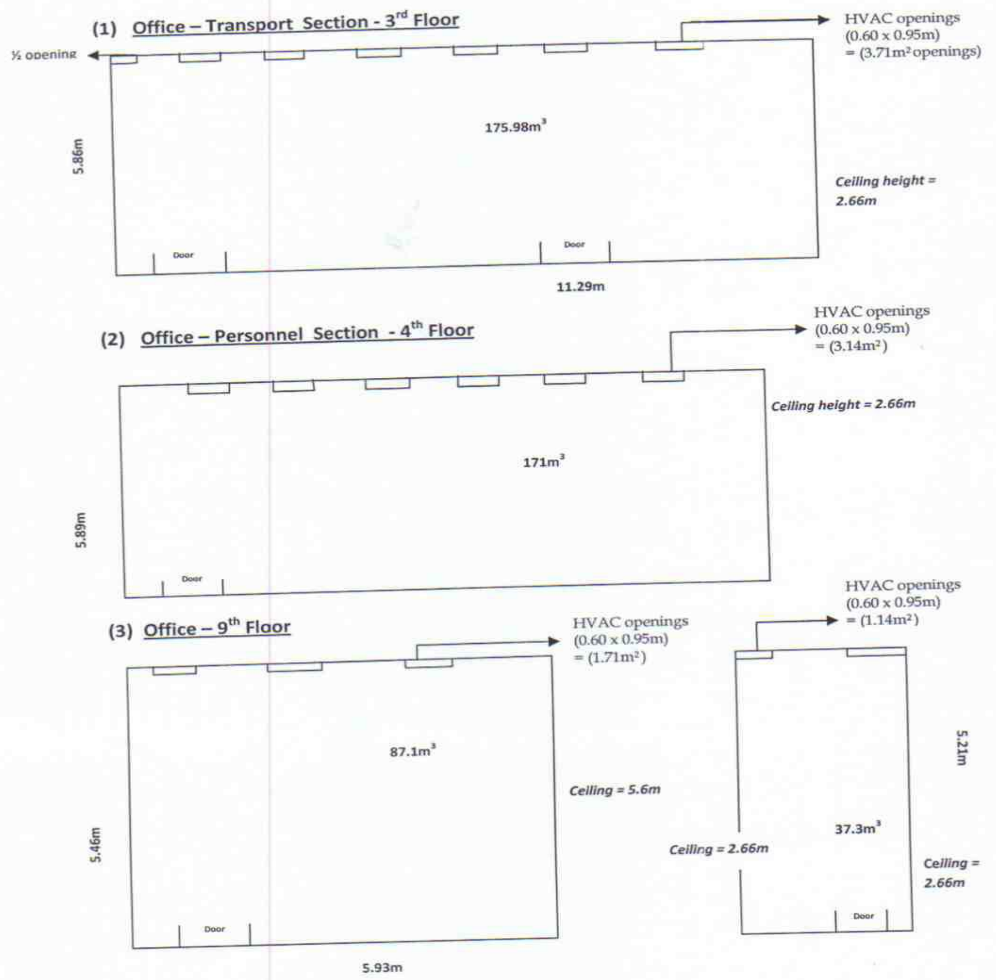
APPENDIXES

Appendix I Office floor plans



Appendix II Calibration certificates

ENVIROCON INSTRUMENTATION cc

TEL: 011 4767323   FAX: 011 4765995

sales@envirocon.co.za
www.envirocon.co.za

VERIFICATION CERTIFICATE

THE FOLLOWING INSTRUMENT HAS BEEN TESTED AGAINST A CERTIFIED CONCENTRATION OF CO_2 AT 1000ppm

TEST CERTIFICATE No: 185052-1

THE **Q TRACK** Serial No: 11414

WAS FOUND TO BE WITHIN THE REQUIRED SPECIFICATION

DATE: 6 JUNE 2002

SIGNED: B.DODDS – TECHNICIAN pp

TSI

CERTIFICATE OF CALIBRATION AND TESTING

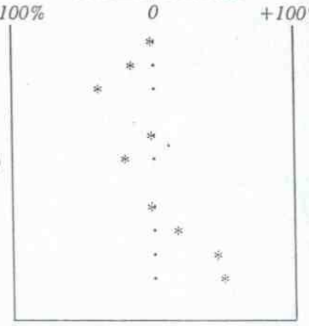
TSI Model 8550 TSI Serial No. 11415

Description *Q-Trak Indoor Air Quality Meter*

CALIBRATION VERIFICATION RESULTS

Calibration Standard	*Instrument Output*	*Difference*
500 ppm	*499 ppm*	*-0.20 %*
1200 ppm	*1188 ppm*	*-1.00 %*
3000 ppm	*2947 ppm*	*-1.77 %*
50.0°F (10.0°C)	*50.0°F (10.0°C)*	*0.0°F (0.0°C)*
104.0°F (40.0°C)	*103.8°F (39.9°C)*	*-0.2°F (-0.1°C)*
36.6 %rh	*36.6 %rh*	*0.0 %rh*
76.4 %rh	*77.0 %rh*	*0.6 %rh*
57.4 %rh	*58.9 %rh*	*1.5 %rh*
19.4 %rh	*21.0 %rh*	*1.6 %rh*

Difference as a Percent of Tolerance



Tolerance:

CO2: ±3% of reading ±50ppm
Temperature: ±1.0°F (±0.6°C)
Humidity: ±3.0% rh

Calibration Environment:

Ambient Temperature: 72.3 °F (22.4 °C)
Barometric Pressure: 761.4 mmHg

TSI AB does hereby certify that all materials, components, and workmanship used in the manufacture of this equipment are in strict accordance with the applicable specifications agreed upon by TSI and the customer and with all published specifications. All performance and acceptance tests required under this contract were successfully conducted according to required specifications. Furthermore, all test and calibration data supplied by TSI has been obtained using standards whose accuracies are traceable to the National Institute of Standards and Technology (NIST) or has been verified with respect to instrumentation whose accuracy is traceable to NIST, or is derived from accepted values of physical constants. Calibration procedures for this instrument comply with MIL-STD-45662A with an exception of the humidity calibration standard which has a calibration accuracy ratio of 2:1 with respect to the accuracy specifications of the instrument.

Applicable Test Report	Report Number	Date Last Verified
Barometric Pressure	MTmF312339-05	03-08-07
Temperature	MTvF312339	03-08-04
Dew Point	ETvF312339	03-08-13

Calibrated by [signature]   [X] Final Function Check   *JAN 29, 2004* Calibration Date

TSI AB
Address: Lindberghs gata 9 S-195 60 Arlanda Stad SWEDEN
Phone: + 46 8 595 132 30 Fax: + 46 8 595 132 49

Appendix III Standards

D.THERMAL COMFORT STANDARDS

The table underneath shows a range of temperatures and relative humidities that fall within the so-called comfort zone for most individuals dressed in typical clothing and involved in light sedentary work.

Acceptable Temperature and Humidity Ranges during Winter and Summer, adapted from ASHRAE Standard 55-1981, Thermal Environmental Conditions for Human Occupancy:

Relative humidity	Winter	Summer
30 %	20.3 - 24.4° C	23.3 – 26.7° C
40 %	20.3 - 24.15° C	23.05 – 26.4° C
50 %	20.3 - 23.6° C	22.8 – 26.1° C
60 %	20.0 - 23.3° C	22.8 – 25.6° C

Design conditions for offices are defined as follows :

Summer maximum inside temperature 23 ± 1.5 °C
Winter minimum inside temperatures 21± 1.5 °C
The recommended humidity range is 30 % to 60 %.

These conditions are developed in Europe but could not be relevant to certain groups of people in South Africa. These data should be monitored carefully.

Lower relative humidities will result in dry skin, lips and dry out the mucous membranes of the occupants as well as dry throats and nose bleeds, which will lead to secondary inflammation or infection. Dryness will also permit air contaminants, like VOC's to be more irritating.
The presence of humidification is no guarantee of good IAQ. Contaminants in the water supply or the accumulation of moisture in inappropriate places in the HVAC system can cause problems of microbiological growth within the system.
The water source for humidification should only be from **a potable quality source**, because some chemicals used in water treatment are hazardous to health.
Water accumulation in inappropriate locations causing microbiological growth inside the HVAC system should be prevented.

Therefor the following is recommended :

1. Eliminate water spray systems in air handling units unless strictly controlled.
2. Eliminate the use of cold-mist vaporizers
3. Keep indoor relative humidities below 60%.
4. Use steam humidifiers.

IAQ 17

- use steam humidifiers.

Humidity in excess of 60 % can provide surface conditions suitable for microbiological growth, including molds, yeast and dust mites.
The desired temperature/humidity relationship for comfort conditions is very difficult to define. People react differently to different conditions. Under "environmental indices" the effective temperature is defined.

Measurement method

Temperature : Thermometer, thermocouple.
Relative humidity : Capacitive detector, Sling Psychrometer

Frequency of tests

During investigation in problem area's after complaints

E. VENTILATION STANDARDS

Minimum outside air

Comparison of Outside airflow rates for Ventilation of ASHRAE standards 62-1973, -1981 and –1989

Occupancy	Outdoor Ventilation Air requirements (l/s per person)				
	ASHRAE standard 62-1973		ASHRAE standard 62-1981		ASHRAE standard 62-1989
	Minimum litres per person	Re-commended	Non-smoking	Smoking	Ventilation rate procedure
Ballrooms, disco's	7	9.5-12	3.5	16.5	12
Bars, cocktail lounges	14	16.5-19	5	24	14
Beauty shops	12	14-16.5	10	16.5	12
Classrooms	5	5-7	2.5	12	7

ASHRAE

	Min	Recommended	Non-Smoking	Smoking	Ventilation Rate Procedure
Dining rooms	5	7-10	3.5	16.5	9.5
Hospital patient rooms	5	7-10	3.5	16.5	12
Hotel conference rooms	10	12-14	3.5	16.5	9.5
Office conference rooms	12	14-19	3.5	16.5	9.5
Office space	7	7-12	2.5	9.5	9.5
Residences	2.5	3.5-5	5	5	0.35ach
Retail stores	3.5	5-7	2.5	12	0.01-0.15 l/s/m²
Smoking lounges	-	-	-	-	28
Spectator areas	9.5	12-14	3.5	16.5	7
Theater, auditoriums	2.5	2.5-5	3.5	16.5	7
Waiting rooms	7	10-12	3.5	16.5	7

liters/sec per person

As can be seen from the above data energy conservation measures instituted in the early 1970's led to decreased ventilation rates. The latest change sees an increase from 1981 mainly due to improved IAQ.

Acceptable Indoor Air Quality is defined by ASHRAE as " air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction upon survey" We propose improved ventilation rates for various facilities and they shall be as indicated below and are indicated as a unit of l/s per person or as a unit of l/s per square meter floor area.

Facility	Ventilation standard
General office	Largest of 10 l/s per person or 2.0 l/s.m²
Private office	Largest of 15 l/s per person or 2.5 l/s.m²
Control room	Largest of 10 l/s per person or 2.0 l/s.m²
Computer room	5 ac/h
Conference room	Largest of 15 l/s per person or 2.5 l/s.m²
Rest room	Largest of 10 l/s per person or 2.0 l/s.m²
Smoking room	20 l/s per person . Assume 1 person per m²
Cafeteria	Largest of 10 l/s per person or 2.0 l/s.m²
Dark room	2 ac/h

N.B. All the above standards are for non smoking areas. For smoking area's new legislation indicates a ventilation rate of 20 l /s per person and a people density of 1 person per m² if the chairs in the area are not fixed.

The most important part of a ventilation-based indoor air evaluation is how much air is actually delivered to the occupants of a building. Not only must enough outside air be drawn into a system, but this outdoor air must also be delivered to where the building occupants are. There are two items to be checked if investigating complaints. Firstly how much fresh air is drawn into the system and secondly where this air is delivered to.
In new buildings a full economy cycle should be provided, with temperature comparison at altitude and enthalpy comparison at sea level. This economizer capability means that an 100% outdoor air can be supplied to the occupants intermittently using "free cooling" when the outdoor temperature or enthalpy is equal to or below the return air temperature or enthalpy, but within the comfort ranges of temperature, air velocity and relative humidity.
Another basis for the rate of ventilation is the air change method, that is the number of times per hour the air content of the space should be replaced with fresh air. Next table give a guide to the number of air changes per hour generally accepted for ventilation.

More advantages.

Space to be ventilated	**Air changes per hour**
Banking halls	6
Bathrooms internal	6
Canteens	8-12
Cinemas	6-10
Dining halls, restaurants	10-15
Garages	6 min
Repair shops	10 min
Kitchens	20-60
Laboratories	4-6
Laundries	10-15
Lavatories and toilets	10-15
Internal offices	4-6
Theatres	6-10

Measurement method

- Direct measurement of the volume of the outside air stream.
- Measurement of the total air stream in combination with a determination of the portion of this total air which is outside air. In this second approach the percentage outside air can be determined by measuring components which vary among the three air streams involved, outside air, return air and the mixed supply air. The components which can be used are enthalpy, temperature and carbon dioxide.

to 25 °C and the relative humidity is in the range 30 to 60%. It has been shown that a velocity change of 0.135 m/s produces approximately the same effect as a temperature change of 1°C. The air distribution should be such that the temperature gradient from the ankle to the neck region shall not exceed 2°C.

The recommended room air velocities are as follows:

Recommended Standard

Room air velocity m/s	Reaction	Applications
0- 0.08 m/s	Stagnant air	None
0.125 m/s	Comfortable	All commercial applications
0.125- 0.25 m/s	Approaching maximum tolerable velocity for seated person	All commercial applications
0.325 m/s	Unfavourable – papers on desks move	None
0.375 m/s	Limit for walking person	Department stores
0.375-1.5 m/s	Acceptable for parking areas	Parking garage

The most desirable air direction for a seated person is from the front or the top, air blowing from behind or at the lower part of the body, like ankles is experienced as uncomfortable.
The induction rate of a diffuser should be in the region of 4:1, this means the air quantity induced by the diffuser is four times the actual air ejected or supplied by the diffuser. The reason for this is that due to this induction of room air into the air stream from a diffuser the actual temperature difference between the air stream coming from a diffuser and the room is smaller than 2°C.

A study of a room air distribution will show immediately he outlet characteristics of the different types of outlets that can be used. The positioning of return air grilles is also very important in the air motion in the room.
The airflow pattern that exists in a space being ventilated and the resulting ability of that air flow to dilute and remove air contaminants in that space is called " ventilation characterization". There are different categories of possible airflow pattern and they determine the ability to deliver supply air to the breathing area of the occupants. These depend on various variables:

- Temperature of the supply air and the room and the induction factor
- The type and positioning of supply and return grilles
- The shape and size of the room
- The presence of heat sources in the room
- The injection velocity of the air and throw of the supply air terminal

To account for poor or incomplete mixing of the air in an occupied space we chose a mixing factor.
This mixing factor is also called ventilation efficiency. It can be defined as:

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Vol. 237 | PRETORIA, 1 MARCH MAART 1985 | No. 9613

GOVERNMENT NOTICE

DEPARTMENT OF TRADE AND INDUSTRY

No. R. 441 | 1 March 1985

NATIONAL BUILDING REGULATIONS AND BUILDING STANDARDS ACT, 1977

Under the powers vested in him by section 17 (1) read with section 17 (3) (b) of the National Building Regulations and Building Standards Act, 1977 (Act 103 of 1977), the Minister of Trade and Industry after consultation with the Council of the South African Bureau of Standards has made the regulations set out in the Schedule. The said regulations shall come into operation on 1 September 1985.

Interested persons are invited to lodge with the Director General, South African Bureau of Standards, Private Bag X191, Pretoria 0001, any proposals that they may wish to make for the amendment or extension of the regulations. Proposals submitted within 12 months after 1 September 1985 will, if approved, be incorporated in the first revision of the regulations; subsequent proposals will be considered at regular intervals thereafter.

SCHEDULE

NATIONAL BUILDING REGULATIONS

Page

PART A—ADMINISTRATION

GOEWERMENTSKENNISGEWING

DEPARTEMENT VAN HANDEL EN NYWERHEID

No. R. 441 | 1 Maart 1985

WET OP NASIONALE BOUREGULASIES EN BOU-STANDAARDE, 1977

Kragtens die bevoegdheid hom verleen by artikel 17 (1), gelees met artikel 17 (3) (b), van die Wet op Nasionale Bouregulasies en Boustandaarde, 1977 (Wet 103 van 1977), het die Minister van Handel en Nywerheid, na oorleg met die Raad van die Suid-Afrikaanse Buro vir Standaarde, die regulasies uitgevaardig soos in die Bylae uiteengesit. Die vermelde regulasies tree op 1 September 1985 in werking.

Belanghebbendes word genooi om enige voorstelle wat hulle ten opsigte van wysiging of uitbreiding van die regulasies wil doen, by die Direkteur-Generaal, Suid-Afrikaanse Buro vir Standaarde, Privaatsak X191, Pretoria, 0001 in te dien. Voorstelle wat binne 12 maande na 1 September 1985 ontvang word sal, indien hulle goedgekeur word, in die eerste hersiening van die regulasies opgeneem word; latere voorstelle sal daarna met gereelde tussenposes oorweeg word.

BYLAE

NASIONALE BOUREGULASIES

Bladsy

DEEL A—ADMINISTRASIE

1	2	3	4
Occupancy	Minimum air requirement, ℓ/s		Remarks
	Smoking	Filtered or non-smoking	
Sports and amusement facilities			
Ballrooms and discos	7,5	—	Air supply required per person.
Bowling Alleys (seating area)	7,5	—	
Playing area (gymnasiums, etc.)	—	10,0	
Sports and amusement facilities			
Locker rooms	7,5	7,5	Air supply required per person.
Spectator areas	5,0	—	
Health Spas and Reducing salons	—	7,5	
Garages			
Parking garage	7,5	7,5	Air supply required per m² of floor area.
Ticket kiosk	5,0	5,0	Air supply required per person.
Motor car repair	10,0	10,0	Air supply required per m² of floor area.
Hotels, motels, resorts, dormitories and similar facilities			
Lobbies	7,5	5,0	Air supply required per person.
Conference room	7,5	5,0	
Assembly rooms	7,5	5,0	
Bedrooms	7,5	—	Air supply required per person.
Living rooms (suites)	7,5	—	
Central kitchens	17,5	17,5	Air supply required per person.
Private kitchens	50,0	50,0	Air supply required per room.
Libraries			
General	—	6,5	Air supply required per person.
Bookstock	—	3,5	
Offices			
General	7,5	5,0	Air supply required per person.
Meeting and waiting spaces	7,5	5,0	
Conference and Board rooms	10,0	5,0	
Cleaners rooms	—	1,0	Air supply required per m² of floor area.
Stages, TV, radio and movie studios	7,5	5,0	Air supply required per person.
Rooms containing baths, showers, WC pans or urinals			
Serving any occupancy not being a dwelling house or dwelling unit	20,0	20,0	Air supply required per bath, shower, WC pan, urinal stall or 600 mm of urinal space.
Transportation			
Waiting rooms, ticket and baggage areas, corridor and gate areas, underground platforms, concourses	7,5	5,0	Air supply required per person.
Smoking rooms	20,0	—	Air supply required per person.
Occupancies other than those listed above	As determined by the local authority.		

Notice.—The use of a dash in the above table signifies no requirement.

TABEL 1

LUGVEREISTES

1	2	3	4
Okkupasie	Minimum lugvereiste, ℓ/s		Opmerkings
	Rook	Gefiltreer of geen rook	
Openbare sale			
Vergadersale	7,5	3,5	Lugtoevoer vereis per persoon.
Kerke	7,5	3,5	
Teaters (met inbegrip van voorportale en gehoorsale)	7,5	3,5	
Bioskope	7,5	3,5	
Droogskoonmakerye en wasserye			
Kommersiële droogskoonmakerye (werkruimtes)	—	120,0	Lugtoevoer vereis per persoon.
Bewaar/versamelruimte	7,5	5,0	
Wasserye	7,5	5,0	
Opvoedkundige geboue			
Klaskamers	—	7,5	Lugtoevoer vereis per persoon.
Laboratoriums	—	7,5	
Biblioteke	—	6,5	

ANNEXURE

Standards

A. Environmental conditions

(i) CO_2 – TWA concentration not to exceed 0,5% by volume of air and CO_2 content thereof does not at any time exceed 3% by volume of air.

(ii) CO – 50 ppm or 55 mg/m³ TWA
(OEL – RL)

(iii) Relative Humidity – 40-60% (Recommended values).

(iv) Thermal Comfort standards (recommended)

RELATIVE HUMIDITY	WINTER (°C)	SUMMER (°C)
30%	20,3 – 24,4	23,3 – 26,7
40%	20,3 – 24,5	23,05 – 26,4
50%	20,3 – 23,6	22,8 – 26,1
60%	20,0 – 23,3	22,8 – 25,6

(v) (a) Air Velocity for office space (L/Sec/person)

MINIMUM	RECOMMENDED	VENTILATION RATE PROCEDURE
7	7 – 12	10 (or 2L/sec m²)

(b) Air changes/hour 4 – 6.

(*b*) the window sills are not higher and the window heads are not lower than one and a half metres above the floor level of the room; and

(*c*) such windows are glazed with transparent material.

(2) Unless an inspector otherwise directs, the provisions of subregulation (1) shall not apply under conditions where natural light will have an adverse effect on the process or material used in a room, or where the process in a room has to be conducted under critical conditions of light, temperature, humidity or air movement, or where the judgment of texture or colour in a room has to be done under conditions of constant lighting quality and intensity, or where, for reasons of safety, privacy or security, compliance with the intended provisions becomes impracticable.

(3) Where the penetration of direct sunlight into any workplace may pose a threat to the safety of persons in such workplace, the employer concerned shall ensure that such workplace is screened to avoid such penetration, but retaining, as far as is practicable, outside visual contact.

Ventilation

5. (1) An employer shall ensure that every workplace in his undertaking is ventilated either by natural or mechanical means in such a way that—

(*a*) the air breathed by employees does not endanger their safety;

(*b*) the time-weighted average concentration of carbon dioxide therein, taken over an eight-hour period, does not exceed one half per cent by volume of air;

(*c*) the carbon dioxide content thereof does not at any time exceed three per cent by volume of air.

(*d*) the prescribed exposure limits for airborne substances therein are not exceeded; and

(*e*) the concentration therein of any explosive or flammable gas, vapour or dust does not exceed the lower explosive limit of that gas, vapour or dust.

(2) Where the measures prescribed by subregulation (1) are not practicable, or where there is a danger of unsafe air in the breathing zone of an employee, the employer shall provide every such employee with, and ensure that he correctly uses, respiratory protective equipment of a type that reduces the exposure of the employee to a safe level and the employer shall, further, inform him of the dangers of and the precautionary measures against excessive exposure.

(3) The provisions of subregulation (1) (*b*) and (*c*) shall not apply in respect of workplaces where the ambient pressure differs by more than 20 per cent from atmosphere pressure at sea level.

[Sub-r. (3) amended by GN R1754 of 1989.]

Housekeeping

6. (1) A user of machinery shall provide and maintain sufficient clear and unobstructed space at every machine to enable work to be carried out without danger to persons.

Numerous gaseous contaminants are produced including carbon monoxide. Cigarette tars produce odors which last months and require up to 300 % more outdoor air compared to spaces where smoking is prohibited.
The health effects are coughing, wheezing, headaches and sinus problems.

Section 2. Various standards and evaluation criteria

A. EVALUATION CRITERIA OF OUTDOOR AIR QUALITY

Air quality standards and guidelines specify maximum concentrations and exposure times for specific contaminants in outdoor environment.
The quality of the ambient or outside air must be surveyed to see if there are sources of contaminants that may be perceived as unacceptable for indoor use with respect to odor and sensory irritation. The type of facilities concerned creating this type of contaminant are for example engaged in food preparation or dry cleaning near the building.

As no ambient air quality data are listed in South Africa we assume the standards from the National Primary Ambient-Air Quality Standards for Outdoor air as set by the U.S. Environmental Protection Agency (US EPA,1994) and as noted underneath. These standards may not be directly applicable to indoor environments because of differences in averaging times and the lack of a clearly defined enforcement mechanism.

Standard used in SA. we don't have own stand.

Contaminant	Long term Concentration			Short term Concentration		
	µg/m³	ppm	Average	µg/m³	ppm	Average
Sulfur Dioxide	80	0.03	1 year	365	0.14	24 hours
Particles (PM 10)	50	0.75	1 year	150	0.75	24 hours
Carbon Monoxide				40000	35	1 hour
Carbon Monoxide				1000	9	8 hours
Ozone				235	0.12	1 hour
Nitrogen dioxide	100	0.055	1 year			
Lead	1.5	0.75	3 months			

The above standard requires that the quality of the ambient outdoor air is assessed accordingly, but it does not require that the outside air is treated before it enters the

Drinking water standards:

Determinant		Procedure /Technique	Type of Instrument used	
pH	pH units	electrode	WTW pH meter	Measures the number of Hydrogen ions in a sample and thereby determines how acidic or basic the sample is.
Conductivity	millisiemens/meter	electrode	WTW pH meter	Measures the ability of the sample to conduct electricity.
Total Dissolved Solids	Milligrams /liter	Calculation from conductivity measurement	calculation	Current is carried by dissolved ions (chlorides, nitrates, sulphates) and cations (sodium, calcium magnesium)
Chloride	Milligrams /liter	Titration with silver nitrate solution	Burette, 0.2 N $AgCl_2$, Pottasium chromate indicator	Silver nitrate reacts with chloride to produce silver chloride – then the silver nitrate reacts with the chromate to form an orange coloured silver chromate precipitate.
Colour	Platinum /Cobalt units	Spectrophotometer Absorbance at 455nm	HACH DR 2000	Apparent colour is measured on an unfiltered sample
Turbidity	Nephelometric	Turbidity meter	HACH 2100P	Turbidity is the result of suspended clay, silt, finely

	turbidity units (NTU)			divided organic / inorganic matter etc. Turbidity measures the amount of scattering and absorbing of light by the particulate matter present
Fluoride	Milligrams /liter	Ion- specific electrode	Radiometer pH/ISE meter	Fluoride ions are selectively absorbed by the ISE membrane, which establishes a voltage (potential) that is equivalent to the concentration of the F ion.
Sulphate	Milligrams /liter	Barium chloride reaction measured at 450nm on spectrophotometer	HACH DR 2000	Sulphate ions react with barium chloride to form insoluble barium sulphate turbidity. This is proportional to the sulphate concentration
Calcium	Milligrams /liter	Atomic absorption spectrophotometer	GBC 933 AAS	Measures the number of specific ions in a atomised water vapour
Magnesium	Milligrams /liter	Atomic absorption spectrophotometer	GBC 933 AAS	Measures the number of specific ions in a atomised water vapour

Potassium	Milligrams /liter	Atomic absorption spectrophotometer	GBC 933 AAS	Measures the number of specific ions in a atomised water vapour
Sodium	Milligrams /litre	Atomic absorption spectrophotometer	GBC 933 AAS	Measures the number of specific ions in a atomised water vapour
Total Alkalinity	Milligrams / litre	Titration with 0.1M Sulphuric acid	Burette and indicator (methyl orange)	Total alkalinity is the sum of carbonate, bicarbonate and hydroxide alkalinity
Total Hardness	Milligrams/ liter	Calculation from Ca and Mg concentrations	calculation	From Ca and Mg concentrations
Ammonia	Milligrams / liter	Spectrophotometer reading at 425 nm	Absorbance	Nessler reaction – yellow colour formed with nessler reagent
Calcium hardness	Milligrams /liter	From calcium concentration	calculation	From calcium concentration
Magnesium	Milligrams/ liter	From	calculation	From Magnesium concentration

Hardness		magnesium concentration		
Aluminium as Al	Micrograms /litre=µg/l	Atomic absorption spectrophotometer	GBC 933 AAS	Measures the number of specific ions in a atomised water vapour
Cadmium as Cd	Micrograms /litre=µg/l	Atomic absorption spectrophotometer	GBC 933 AAS	Measures the number of specific ions in a atomised water vapour
Chromium as Cr	Micrograms /litre=µg/l	Atomic absorption spectrophotometer	GBC 933 AAS	Measures the number of specific ions in a atomised water vapour
Copper as Cu	Micrograms /litre=µg/l	Atomic absorption spectrophotometer	GBC 933 AAS	Measures the number of specific ions in a atomised water vapour
Iron as Fe	Micrograms /litre=µg/l	Atomic absorption spectrophotom	GBC 933 AAS	Measures the number of specific ions in a atomised water vapour

		eter		
Lead as Pb	Micrograms /litre=µg/l	Atomic absorption spectrophotometer	GBC 933 AAS	Measures the number of specific ions in a atomised water vapour
Manganese as Mn		Atomic absorption spectrophotometer	GBC 933 AAS	Measures the number of specific ions in a atomised water vapour
Nitrate as N	Milligrams / liter	Spectrophotometer Absorbency reading at 500nm	HACH DR 2000	Cadmium metal reduces nitrates present in sample to nitrite. Nitrite reacts in an acid medium with sulphuric acid to form a intermediate diazonium salt which couples to geneticist acid to form an amber coloured product
Standard Plate count	Colony forming units / 1 ml	Plate count agar and incubation of plate for 48 hours at 37ºC	Pour plate method	Not to exceed 100 cfu / ml
Coliform bacteria	Colony forming units / 100 ml	m-Endo agar , incubation for	Membrane filtration method	Count metallic green colonies – indicator of poor hygiene

		24 hours at 37ºC		
Faecal bacteria	Colony forming units / 100 ml	m- FC agar, incubation for 24 hours at 44ºC	Membrane filtration method	Blue colonies indicate faecal contamination (from a warm blooded mammal's faecal matter) and possibility of disease.

Appendix IV Ethics approval

12.5

University
of the Witwatersrand,
Johannesburg

Human Research Ethics Committee (Medical)
(formerly Committee for Research on Human Subjects (Medical)

Secretariat: Research Office, Room SH10005, 10th floor, Senate House • Telephone: +27 11 717-1234 • Fax: +27 11 339-5708
Private Bag 3, Wits 2050, South Africa

PC-J/133/dsk6/es

Postgraduate Officer
Faculty of Health Sciences

12 November 2002

TO WHOM IT MAY CONCERN:

re: Mr P J Brits - MPH11 (Occupational Health)

Indoor air quality assessment in an office building

This certifies that this project does not require clearance from the Committee for Research on Human Subjects (Medical). The research is entirely laboratory based, humans are not involved.

Yours faithfully

Professor Peter Cleaton-Jones
Chair: Committee for Research on Human Subjects (Medical)

Appendix V Environmental Measurements results

12.7

FIRST READING - OLD SYSTEM
REFERENCE:
1=Personnel section 4th Floor
2=Transport section 3rd Floor
3= Staff Room District Mx. -9th Floor
4= Switch Board 4th Floor

	Day -1 Afternoon			Day -2 Morning			Day -2 Afternoon			Day -3 Morning			Day -3 Afternoon		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Co	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	3.0	1.0	0.0	1.0
Co 2	602.0	610.0	602.0	760.0	510.0	577.0	633.0	530.0	577.0	615.0	436.0	479.0	587.0	649.0	428.0
Rel. Hum.	28.3	27.3	26.5	36.4	35.7	31.9	32.5	3.3	31.9	39.1	42.2	36.0	35.6	34.0	35.7
Air Vel.	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.0
Temp	23.5	24.2	25.8	23.4	23.2	23.4	24.1	23.1	23.4	22.7	21.4	21.4	23.9	23.1	22.8
Workers	2.0	3.0	4.0	2.0	1.0	1.0	1.0	2.0	1.0	2.0	2.0	1.0	2.0	3.0	1.0
Outside Temp.	24.8	24.8	24.8	21.1	21.4	21.4	24.2	24.1	21.4	19.5	19.4	19.1	23.3	24.6	23.7
Legionella															
Microbes															

	Day -4 Morning			Day -4 Afternoon				Day -5 Morning				AVERAGE
	1	2	3	1	2	3	4	1	2	3	4	
Co	1.0	0.0	1.0	1.0	1.0	2.0	0.0	0.0	1.0	3.0	1.0	0.8
Co 2	483.0	408.0	457.0	592.0	631.0	478.0	482.0	502.0	581.0	434.0	620.0	548.5
Rel. Hum.	40.5	38.4	33.8	36.1	36.5	37.0	38.6	36.8	40.3	37.4	38.1	34.2
Air Vel.	0.8	0.1	0.3	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.1	0.1
Temp	22.5	22.1	22.8	23.2	22.1	22.9	22.5	22.5	21.8	20.7	21.4	22.8
Workers	2.0	3.0	1.0	2.0	4.0	1.0	1.0	2.0	3.0	2.0	1.0	1.9
Outside Temp.	19.6	21.7	19.1	24.1	24.4	23.8	19.2	23.8	17.7	14.5	18.6	21.7
Legionella												
Microbes												

Rec. 01

READINGS AFTER THE COMMISIONING OF THE NEW AIR CONDITIONING UNITS

REFERENCE:
1=Personnel 4th floor
2= Transport section 3rd floor
3=Staff room District Mx.- 9th floor
4=Switch Board 4th floor

	Day -1 Afternoon 6 Oct.03			Day -2 Morning 7 OCT 03			Day -2 Afternoon 7 Oct o3			Day -3 Morning 8 OCT 03			Day -3 Afternoon 8 OCT 03		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Co	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0
Co 2	502.0	561.0	446.0	471.0	489.0	492.0	475.0	425.0	485.0	440.0	415.0	465.0	475.0	402.0	489.0
Rel. Hum.	30.6	28.9	28.3	26.5	36.4	35.7	31.9	32.5	33.0	31.5	35.4	30.4	22.7	25.2	20.5
Air Vel.	0.02	0.06	0.05	0.01	0.08	0.06	0.01	0.05	0.06	0.70	0.02	0.10	0.04	0.02	0.05
Temp	28.02	30.05	29.05	26.5	26.6	30.0	25.5	26.0	27.0	26.7	23.6	25.8	25.9	25.4	27.6
Workers	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	2.0	1.0	3.0
Outside Temp.	27.4	31.0	30.0	23.9	24.1	22.8	27.7	28.2	27.9	22.8	23.8	25.3	27.6	28.1	28.3
Legionella															
Microbes															

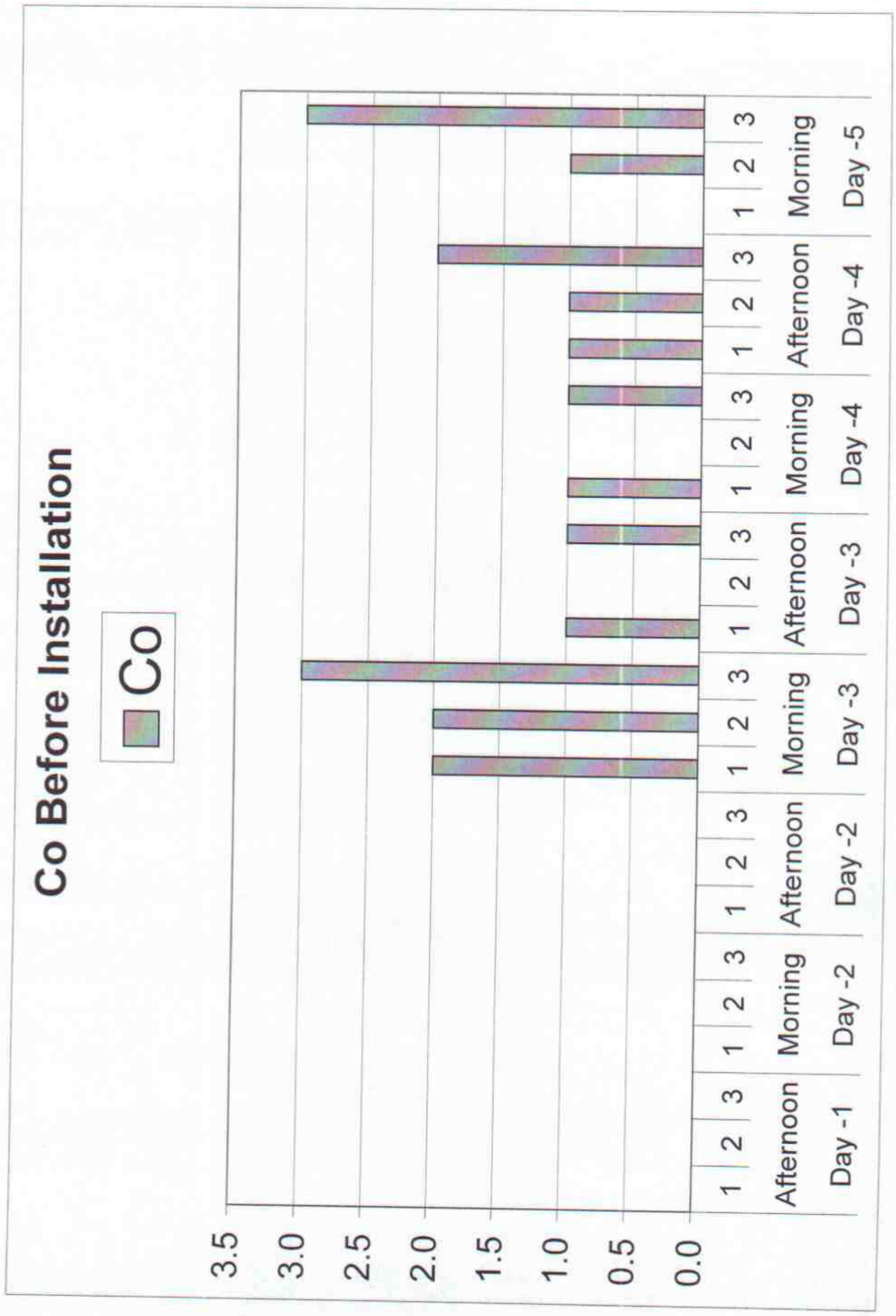
	Day -4 Morning 9 OCT 03			Day -4 Afternoon 9 OCT 03				Day -5 Morning 10 OCT 03				average
	1	2	3	1	2	3	4	1	2	3	4	
Co	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	0.8
Co 2	426.0	389.0	391.0	442.0	367.0	413.0	487.0	475.0	460.0	547.0	540.0	460.3
Rel. Hum.	35.4	36.4	34.4	32.1	24.2	29.1	28.4	24.5	25.7	23.7	24.7	30.6
Air Vel.	0.45	0.10	0.70	0.14	0.16	0.11	0.10	0.01	0.08	0.05	0.01	#DIV/0!
Temp	24.5	27.4	24.2	24.4	28.5	25.7	25.0	24.7	26.7	23.9	24.0	25.5
Workers	4.0	2.0	1.0	2.0	3.0	1.0	1.0	2.0	3.0	2.0	1.0	2.3
Outside Temp.	24.6	26.3	27.3	27.3	26.8	26.8	26.8	22.4	24.5	26.3	26.7	27.2
Legionella												
Microbes												

Rec.02

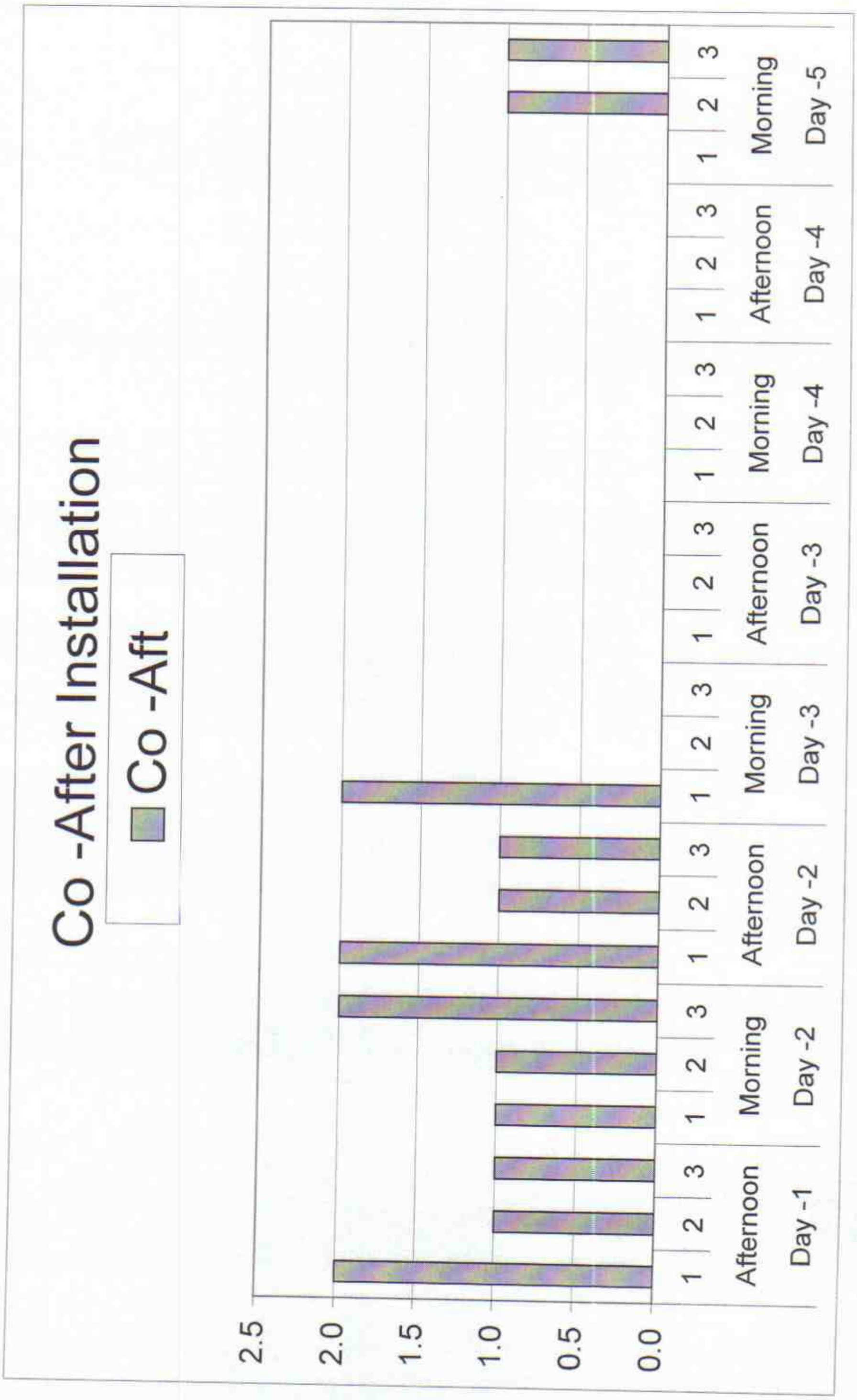
12.7

	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Co	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	3.0	1.0	0.0	1.0	1.0	0.0	1.0	1.0	1.0	2.0	0.0	1.0	3.0	0.6
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Co -Aft	2.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.7
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Co 2	602.0	610.0	602.0	760.0	510.0	577.0	633.0	530.0	577.0	615.0	436.0	479.0	587.0	649.0	428.0	483.0	408.0	457.0	592.0	631.0	478.0	502.0	581.0	434.0	548.6
	Day -1			Day -2			Day -2			Day -1			Day +1			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Co 2 -Aft	502.0	561.0	446.0	471.0	489.0	492.0	475.0	425.0	465.0	440.0	415.0	465.0	475.0	402.0	489.0	426.0	389.0	391.0	442.0	367.0	413.0	475.0	460.0	547.0	460.3
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Rel. Hum.	28.3	27.3	26.5	36.4	35.7	31.9	32.5	3.3	31.9	39.1	42.2	36.0	35.6	34.0	35.7	40.5	38.4	33.8	36.1	36.5	37.0	36.8	40.3	37.4	34.2
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Rel. Hum. -Aft	30.6	28.9	28.3	26.5	36.4	35.7	31.9	32.5	33.0	31.5	35.4	30.4	22.7	25.2	20.5	35.4	36.4	34.4	32.1	24.2	29.1	24.5	25.7	23.7	29.5
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Air Vel.	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.0	0.8	0.1	0.3	0.0	0.1	0.0	0.2	0.0	0.0	0.1
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Air Vel. -Aft	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.7	0.0	0.1	0.0	0.0	0.1	0.5	0.1	0.7	0.1	0.2	0.1	0.0	0.1	0.1	0.1
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Temp	23.5	24.2	25.8	23.4	23.2	23.4	24.1	23.1	23.4	22.7	21.4	21.4	23.9	23.1	22.8	22.5	22.1	22.8	23.2	22.1	22.9	22.5	21.8	20.7	22.8
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Temp -Aft	28.0	30.1	29.05	26.5	26.6	30.0	25.5	26.0	27.0	26.7	23.6	25.6	25.9	25.4	27.6	24.5	27.4	24.2	24.4	28.5	25.7	24.7	26.7	23.9	26.3
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Workers	2.0	3.0	4.0	2.0	1.0	1.0	1.0	2.0	1.0	2.0	2.0	1.0	2.0	3.0	1.0	2.0	3.0	1.0	2.0	4.0	1.0	2.0	3.0	2.0	1.9
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Workers -Aft	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	2.0	1.0	3.0	4.0	2.0	1.0	2.0	3.0	1.0	2.0	3.0	2.0	2.4
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Outside Temp.	24.8	24.8	24.8	21.1	21.4	21.4	24.2	24.1	21.4	19.5	19.4	19.1	23.3	24.6	23.7	19.6	21.7	19.1	24.1	24.4	23.8	23.8	17.7	14.5	21.7
	Day -1			Day -2			Day -2			Day -3			Day -3			Day -4			Day -4			Day -5			
	Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			Afternoon			Morning			AVERAGE
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Outside Temp.	27.4	31.0	30.0	23.9	24.1	22.8	27.7	28.2	27.9	22.8	23.6	25.3	27.6	26.1	28.3	24.6	25.3	27.3	27.3	26.6	26.8	22.4	24.5	26.3	26.2
Outside CO 2	382	401	358																						373.7
(Average)																									

12.7

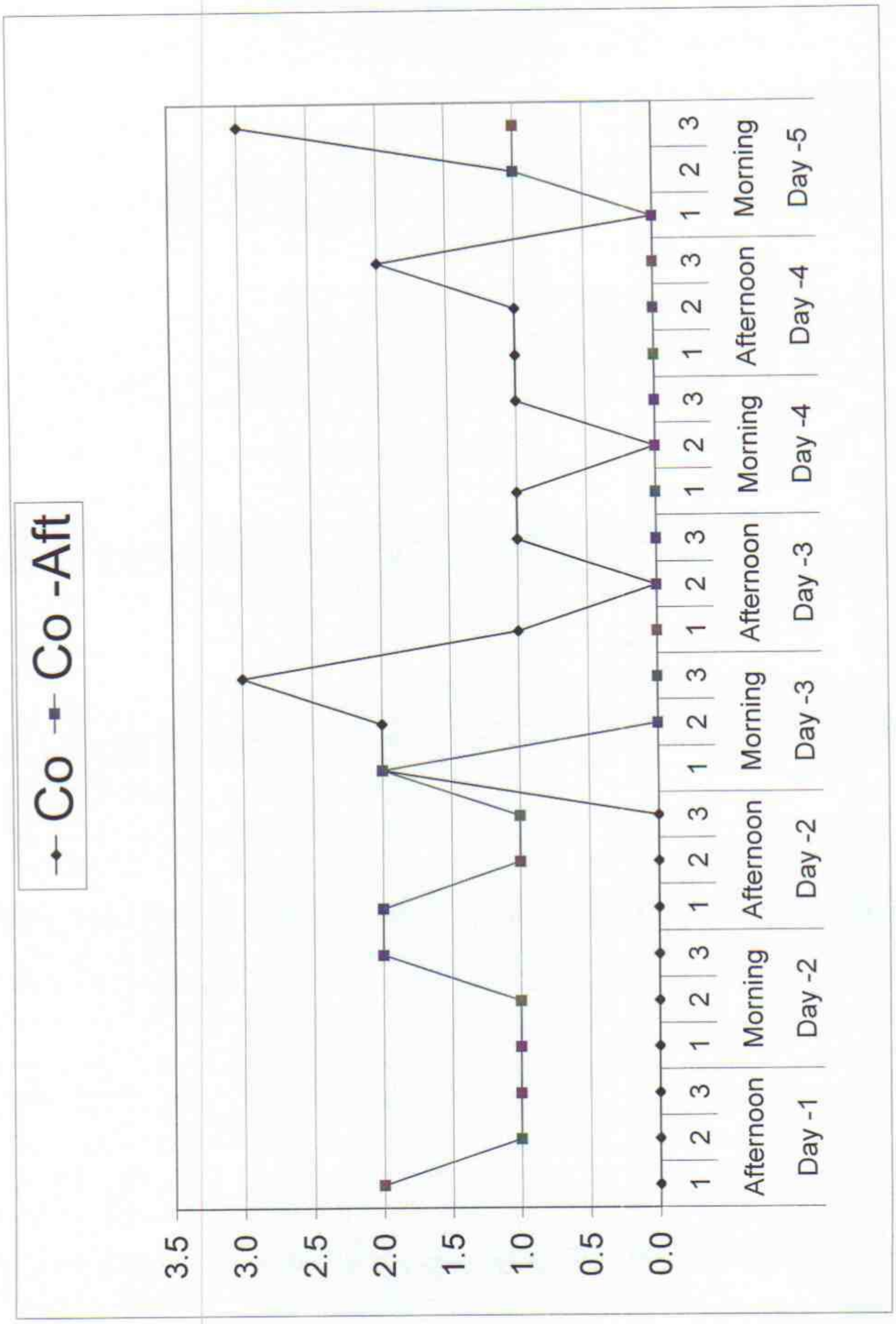

Co Before Installation
Co
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1 2 3
Afternoon
Day -1
1 2 3
Morning
Day -2
1 2 3
Afternoon
Day -2
1 2 3
Morning
Day -3
1 2 3
Afternoon
Day -3
1 2 3
Morning
Day -4
1 2 3
Afternoon
Day -4
1 2 3
Morning
Day -5

12.7



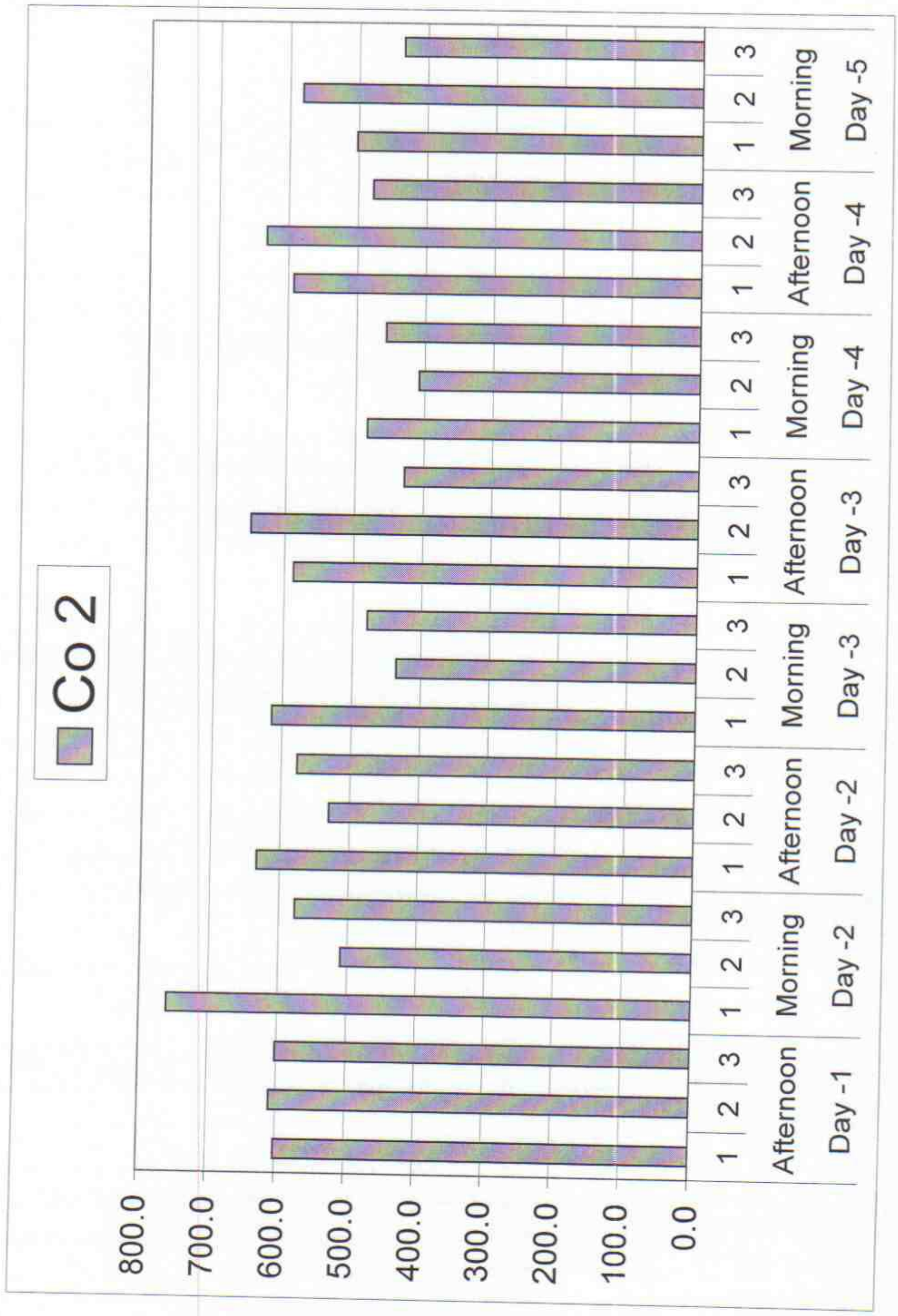
Co -After Installation
Co -Aft
2.5
2.0
1.5
1.0
0.5
0.0
1
2
3
Afternoon
Day -1
Morning
Day -2
Afternoon
Day -2
Morning
Day -3
Afternoon
Day -3
Morning
Day -4
Afternoon
Day -4
Morning
Day -5

12.7



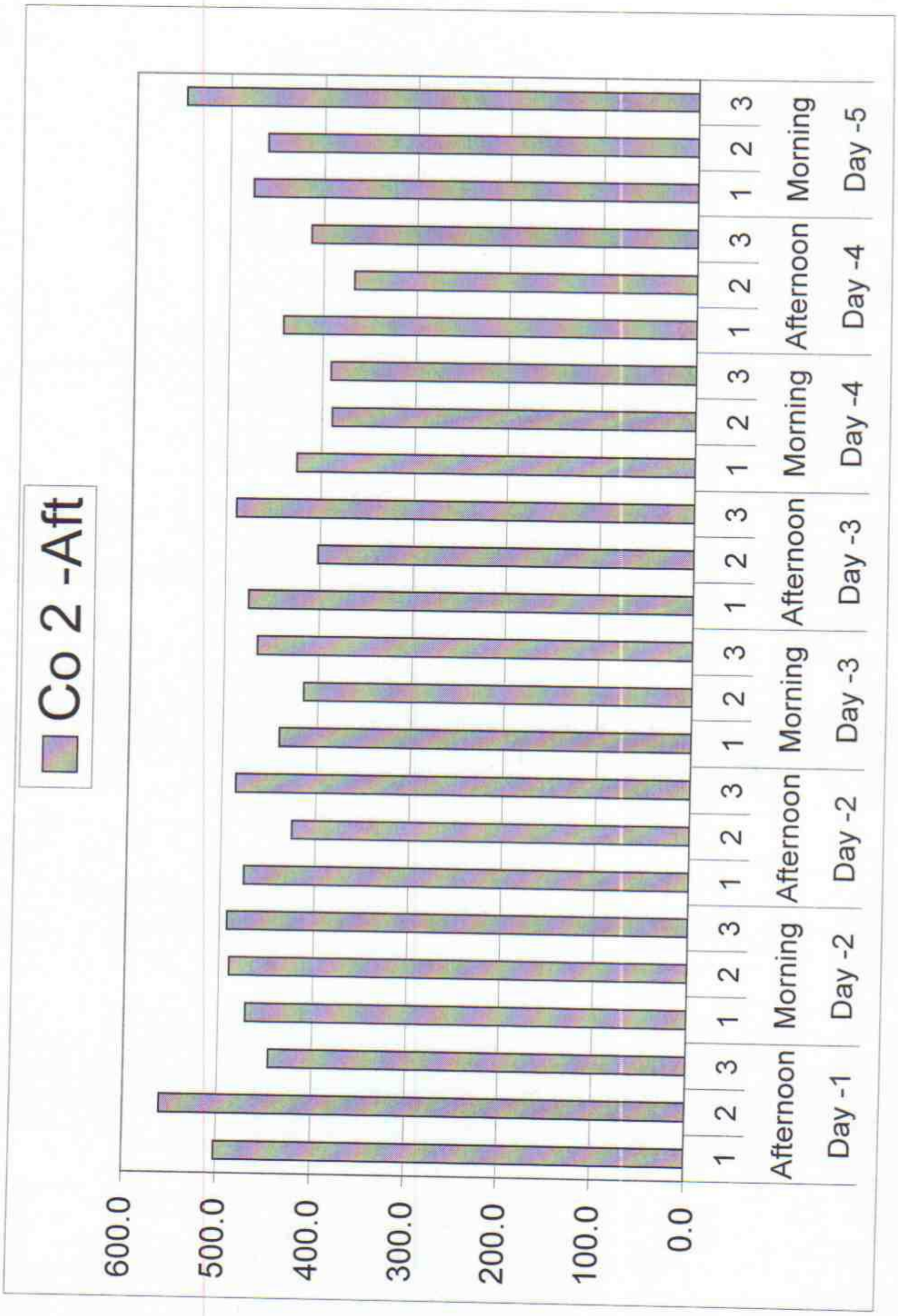
Co
Co -Aft
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1 2 3
Afternoon
Day -1
Morning
Day -2
Afternoon
Day -2
Morning
Day -3
Afternoon
Day -3
Morning
Day -4
Afternoon
Day -4
Morning
Day -5

12.7

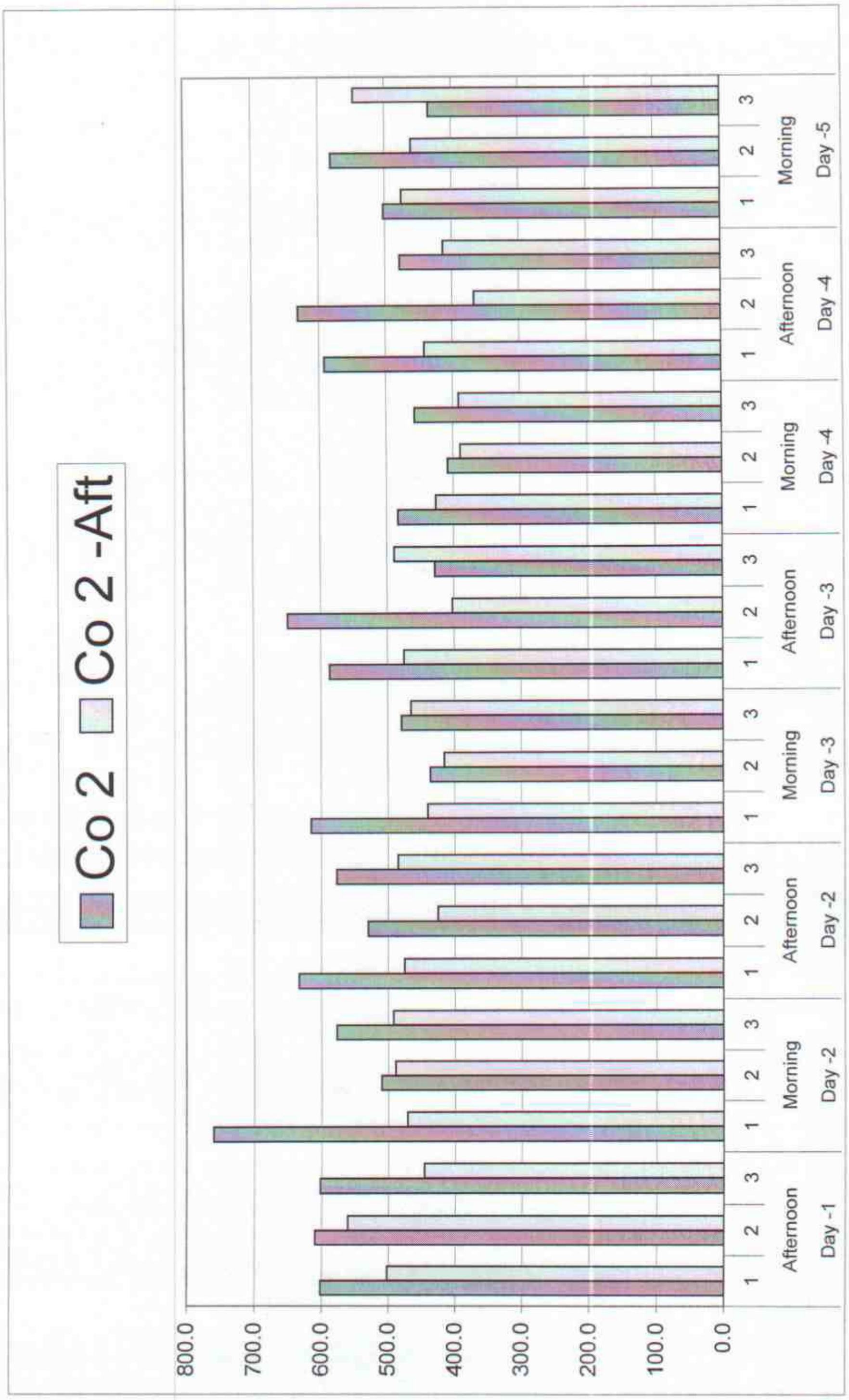


Co 2
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
1 2 3
Afternoon
Day -1
1 2 3
Morning
Day -2
1 2 3
Afternoon
Day -2
1 2 3
Morning
Day -3
1 2 3
Afternoon
Day -3
1 2 3
Morning
Day -4
1 2 3
Afternoon
Day -4
1 2 3
Morning
Day -5

12.7

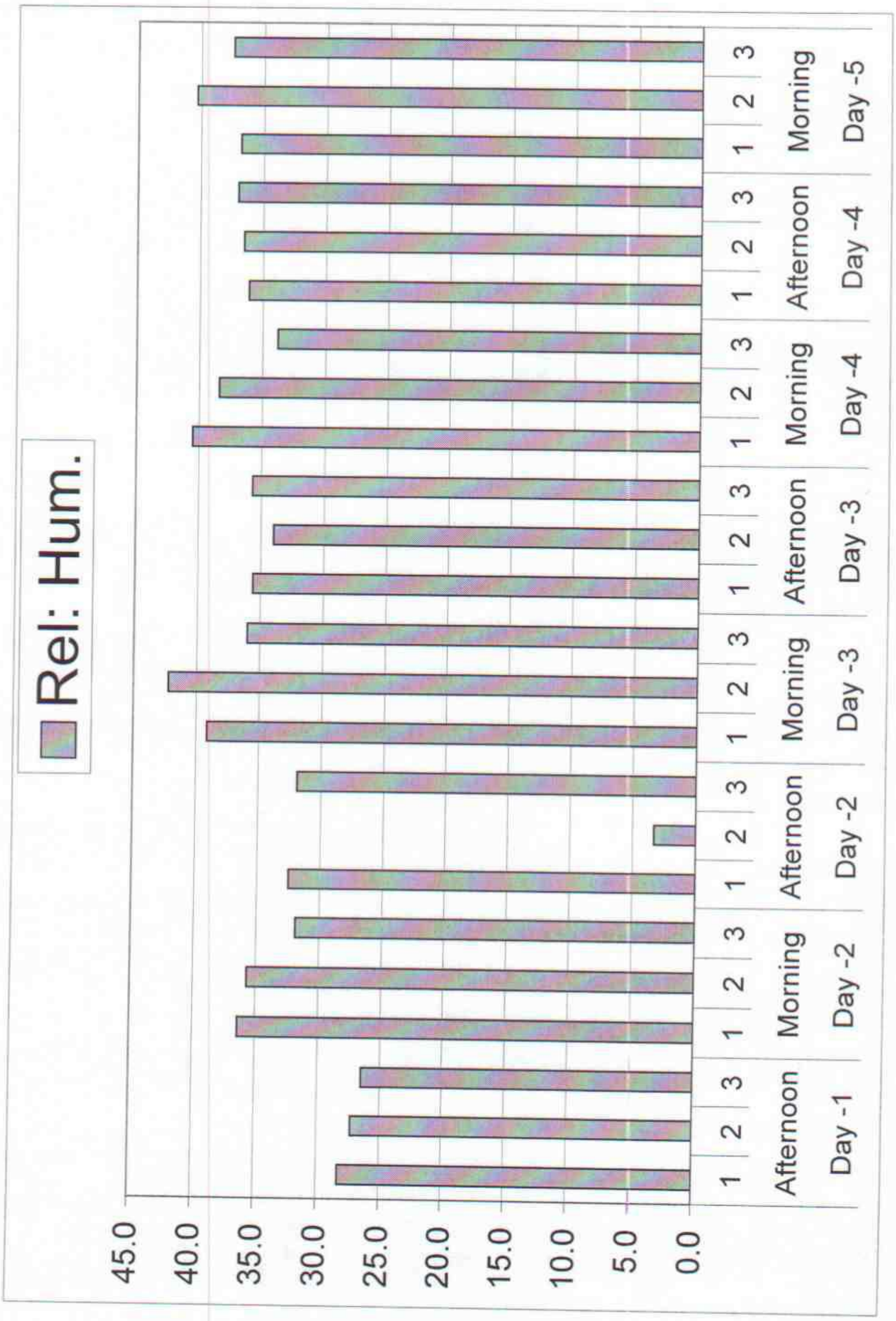

Co 2 -Aft
600.0
500.0
400.0
300.0
200.0
100.0
0.0
1 2 3
Afternoon
Day -1
1 2 3
Morning
Day -2
1 2 3
Afternoon
Day -2
1 2 3
Morning
Day -3
1 2 3
Afternoon
Day -3
1 2 3
Morning
Day -4
1 2 3
Afternoon
Day -4
1 2 3
Morning
Day -5

12.7



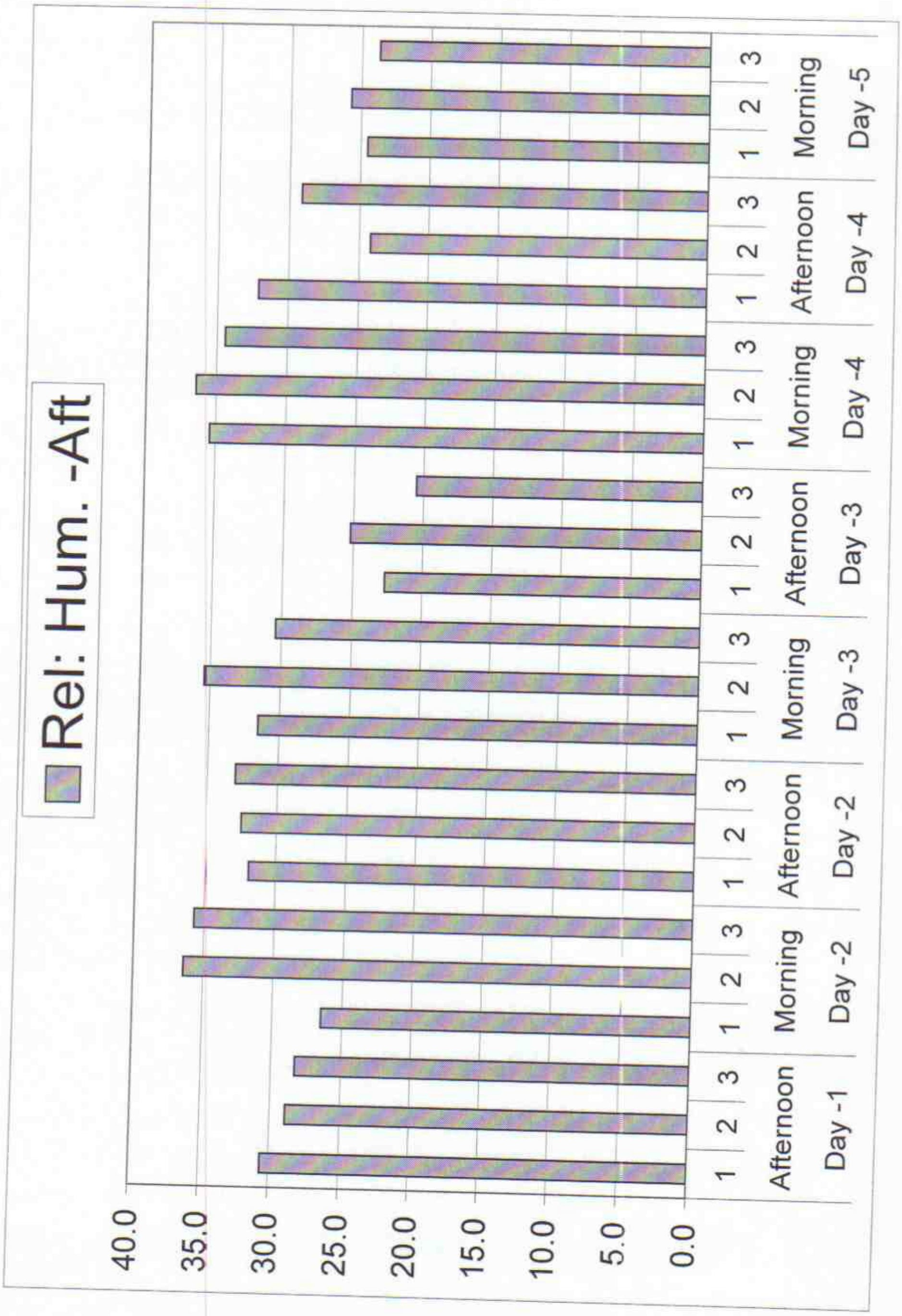
Co 2
Co 2 -Aft
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
Afternoon Day -1
Morning Day -2
Afternoon Day -2
Morning Day -3
Afternoon Day -3
Morning Day -4
Afternoon Day -4
Morning Day -5
1
2
3

12.7

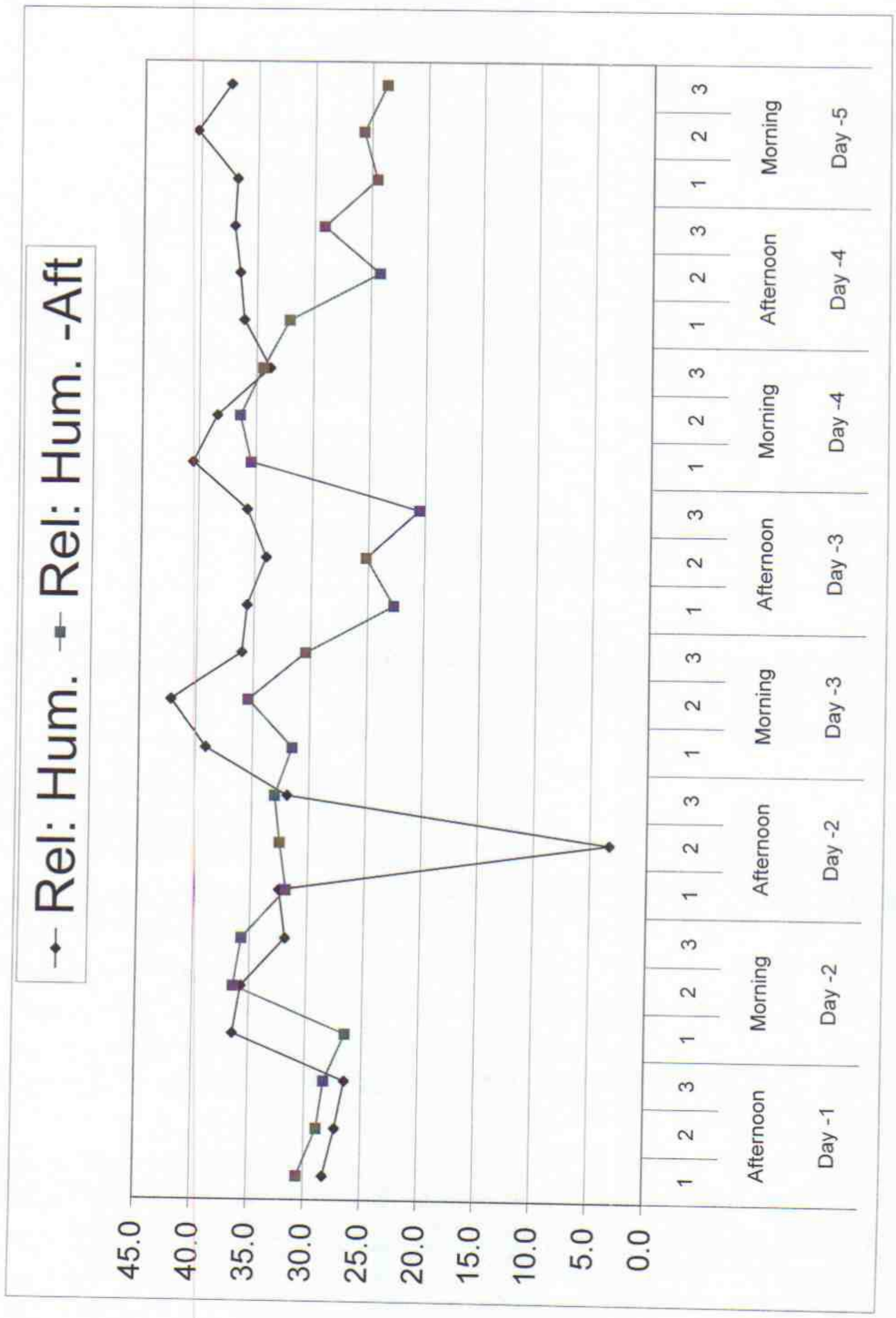


Rel: Hum.
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1 2 3 Afternoon Day -1
1 2 3 Morning Day -2
1 2 3 Afternoon Day -2
1 2 3 Morning Day -3
1 2 3 Afternoon Day -3
1 2 3 Morning Day -4
1 2 3 Afternoon Day -4
1 2 3 Morning Day -5

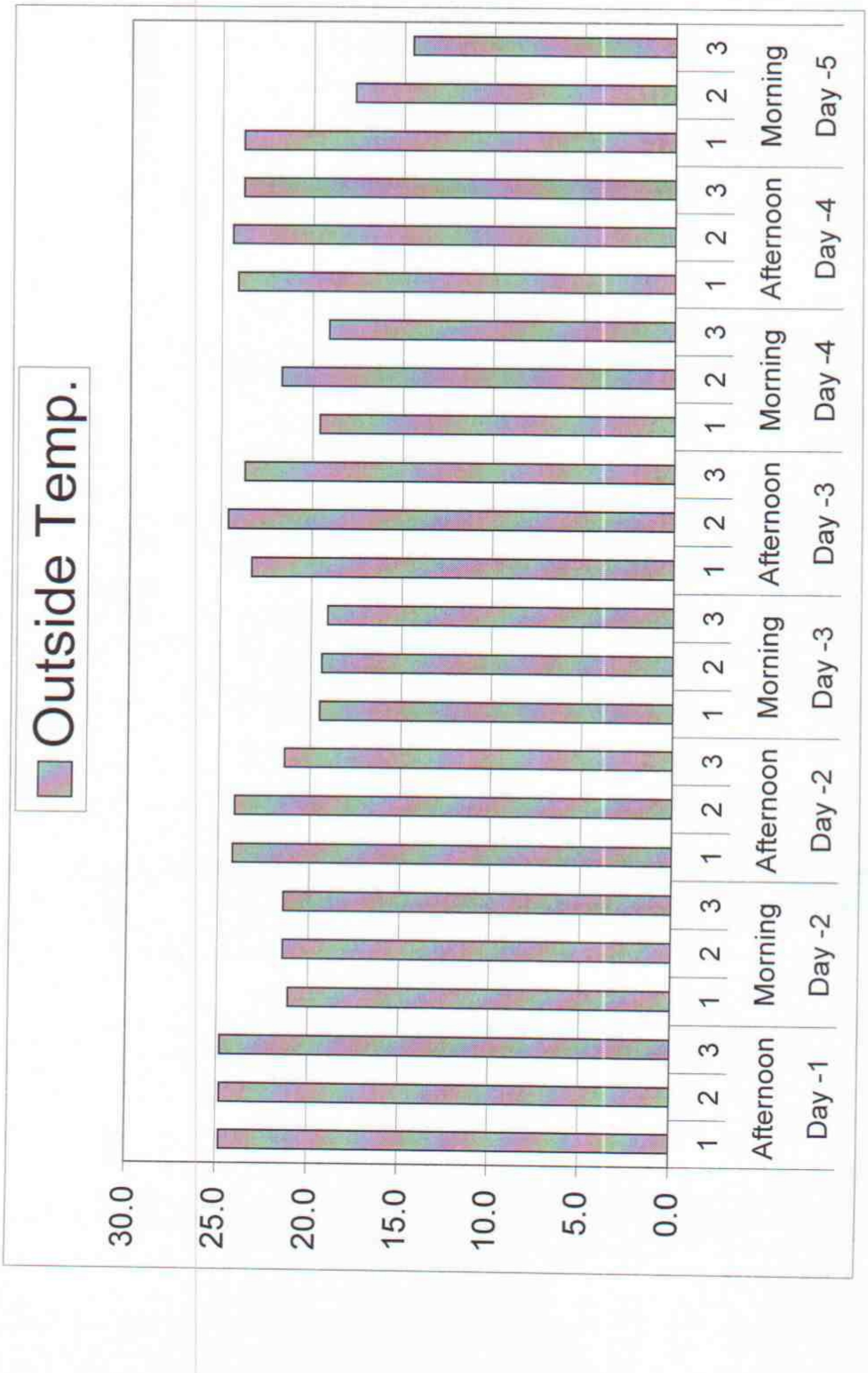
12.7


Rel: Hum. -Aft
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1 2 3
Afternoon
Day -1
1 2 3
Morning
Day -2
1 2 3
Afternoon
Day -2
1 2 3
Morning
Day -3
1 2 3
Afternoon
Day -3
1 2 3
Morning
Day -4
1 2 3
Afternoon
Day -4
1 2 3
Morning
Day -5

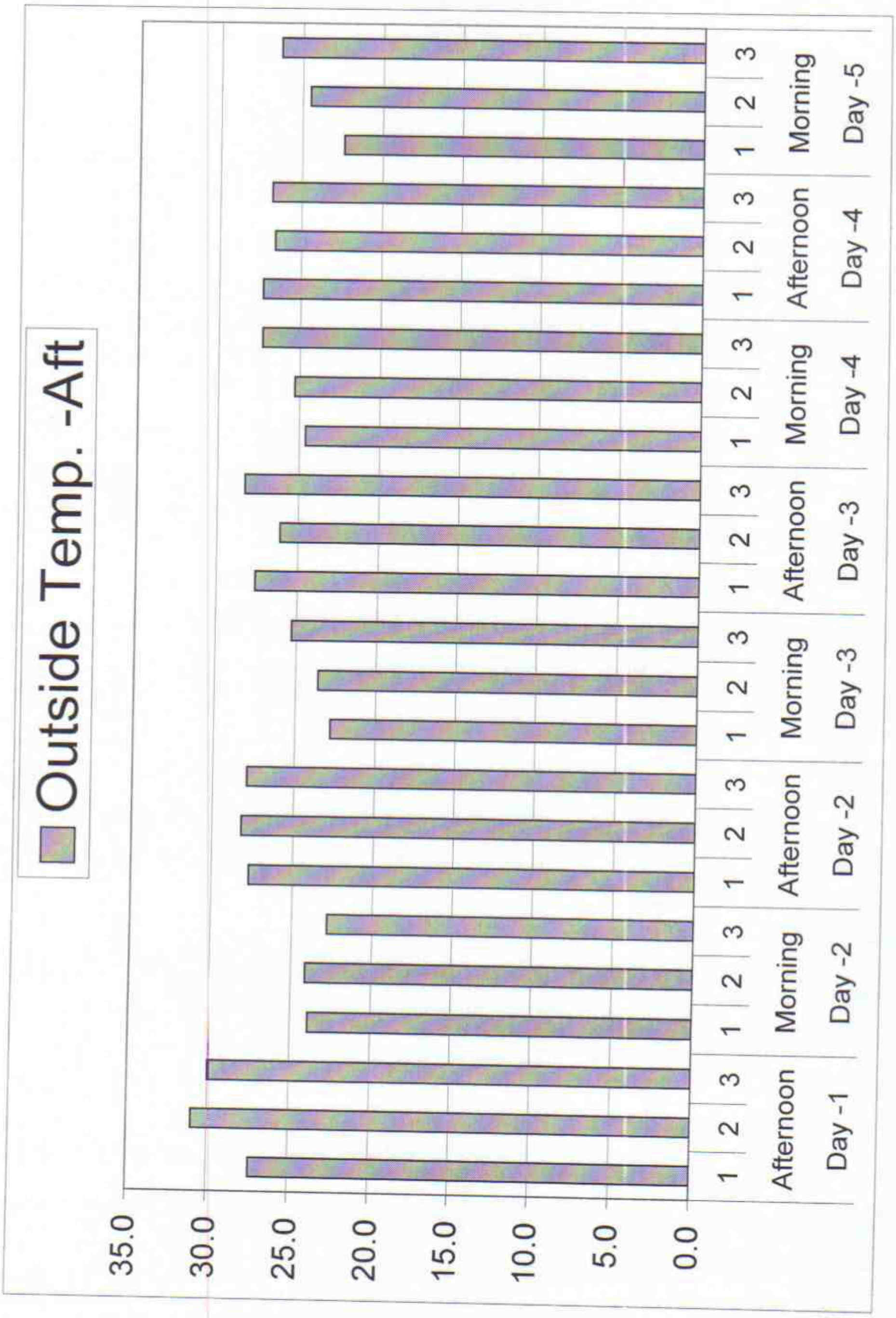
12.7


Rel: Hum.
Rel: Hum. -Aft
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1 2 3
Afternoon
Day -1
1 2 3
Morning
Day -2
1 2 3
Afternoon
Day -2
1 2 3
Morning
Day -3
1 2 3
Afternoon
Day -3
1 2 3
Morning
Day -4
1 2 3
Afternoon
Day -4
1 2 3
Morning
Day -5

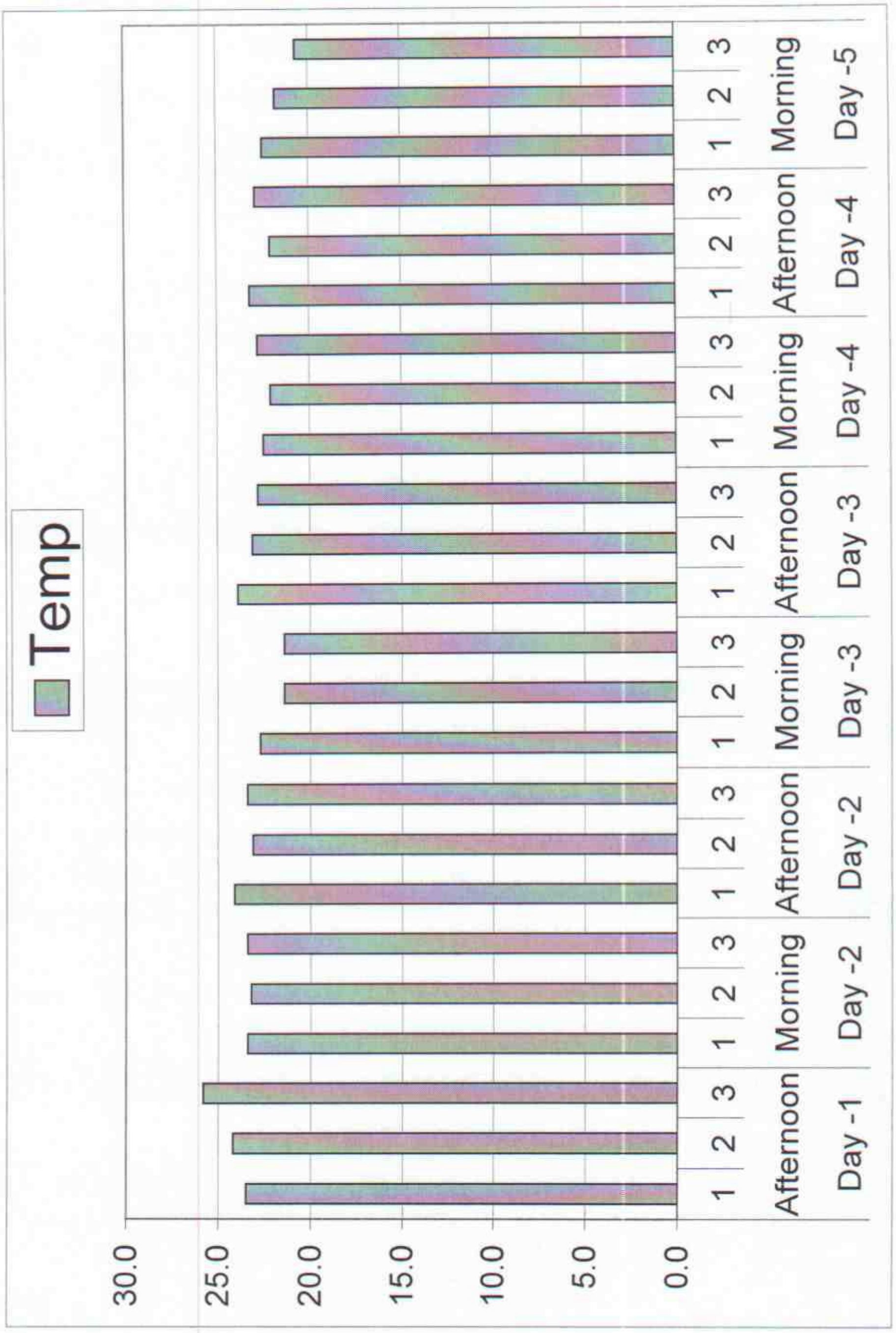
12.7


Outside Temp.
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1
2
3
Afternoon
Morning
Day -1
Day -2
Day -3
Day -4
Day -5

12.7

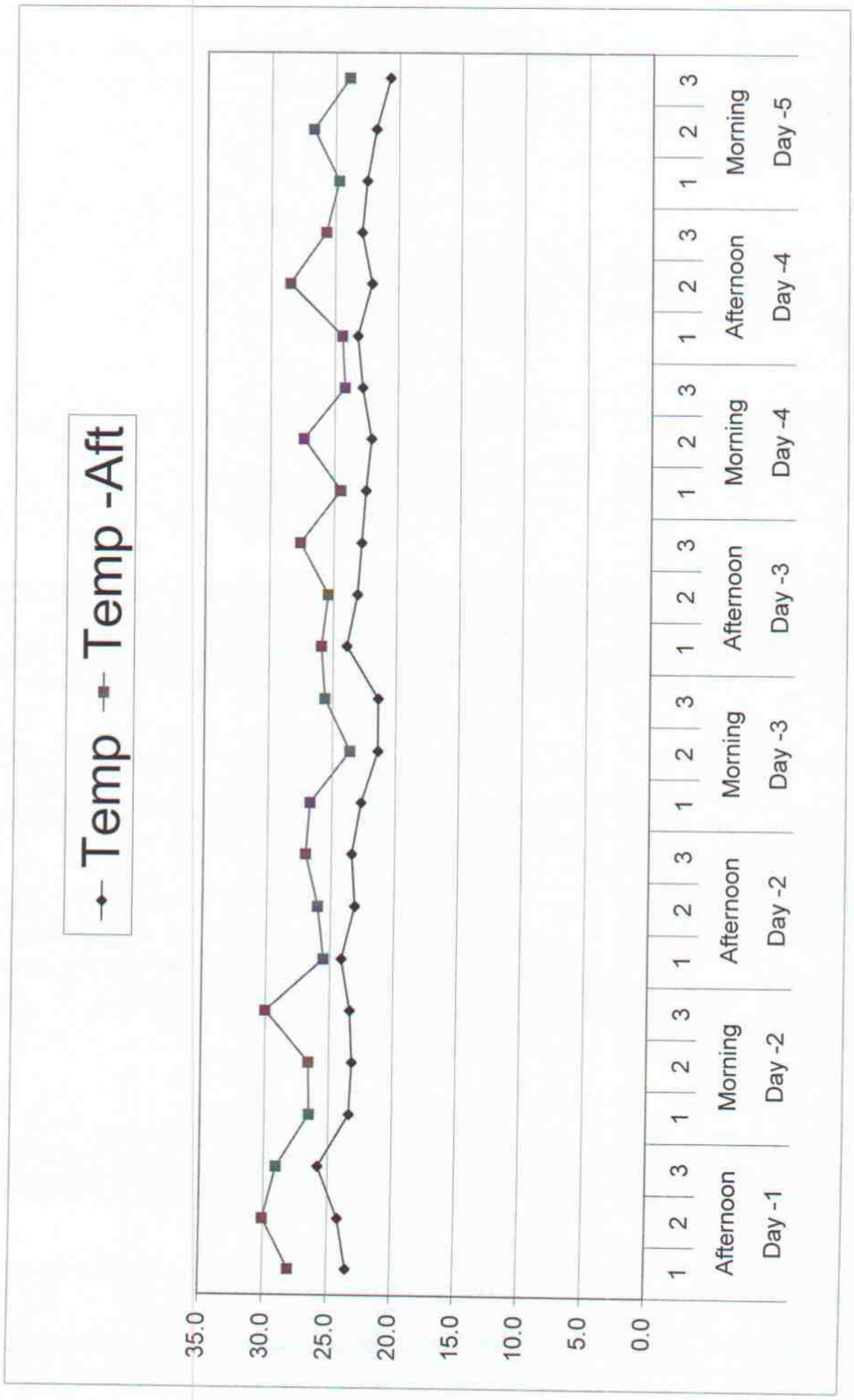

Outside Temp. -Aft
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1
2
3
Afternoon
Day -1
Morning
Day -2
Afternoon
Day -2
Morning
Day -3
Afternoon
Day -3
Morning
Day -4
Afternoon
Day -4
Morning
Day -5

12.7



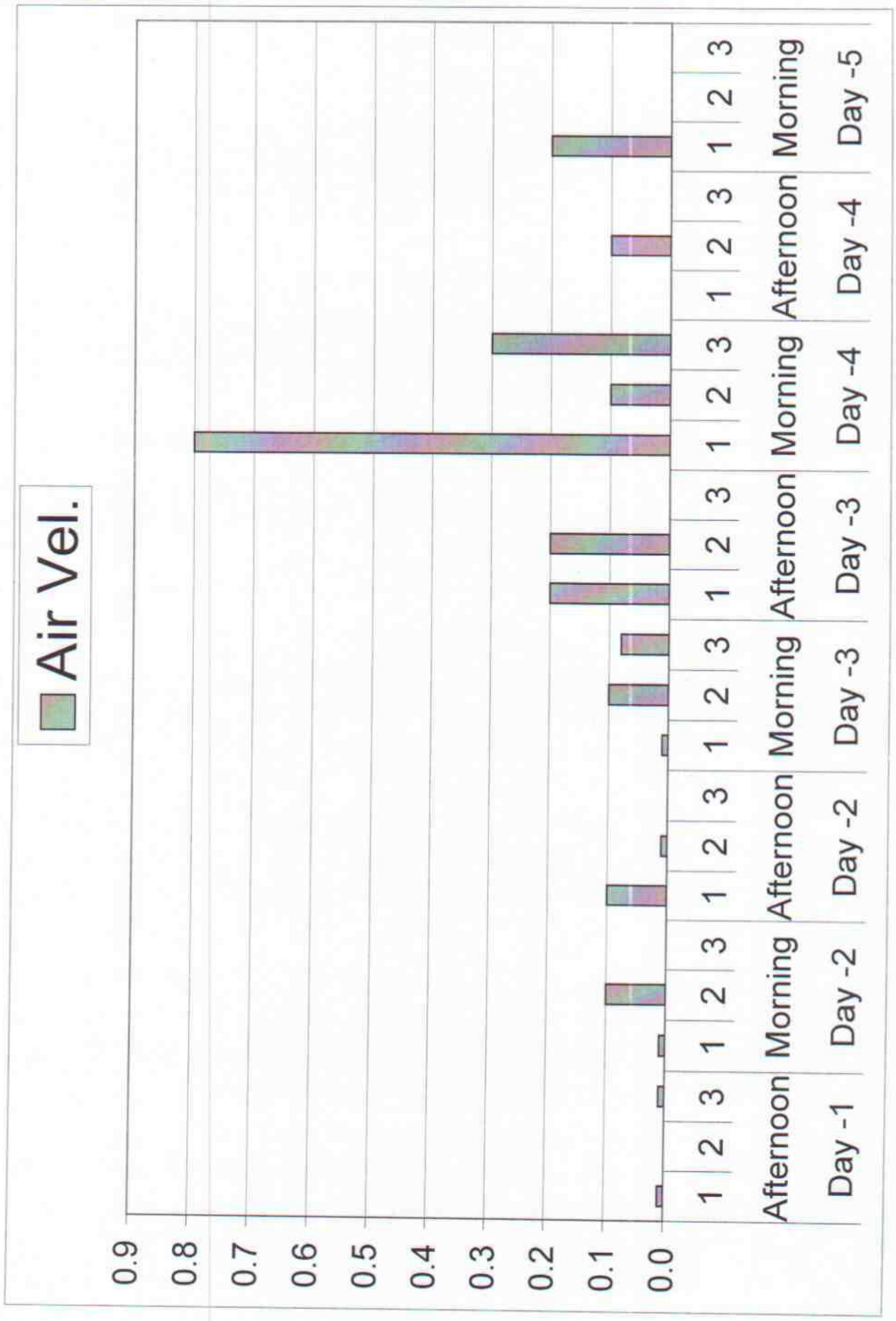
Temp
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1
2
3
Afternoon
Day -1
Morning
Day -2
Afternoon
Day -2
Morning
Day -3
Afternoon
Day -3
Morning
Day -4
Afternoon
Day -4
Morning
Day -5

12·7



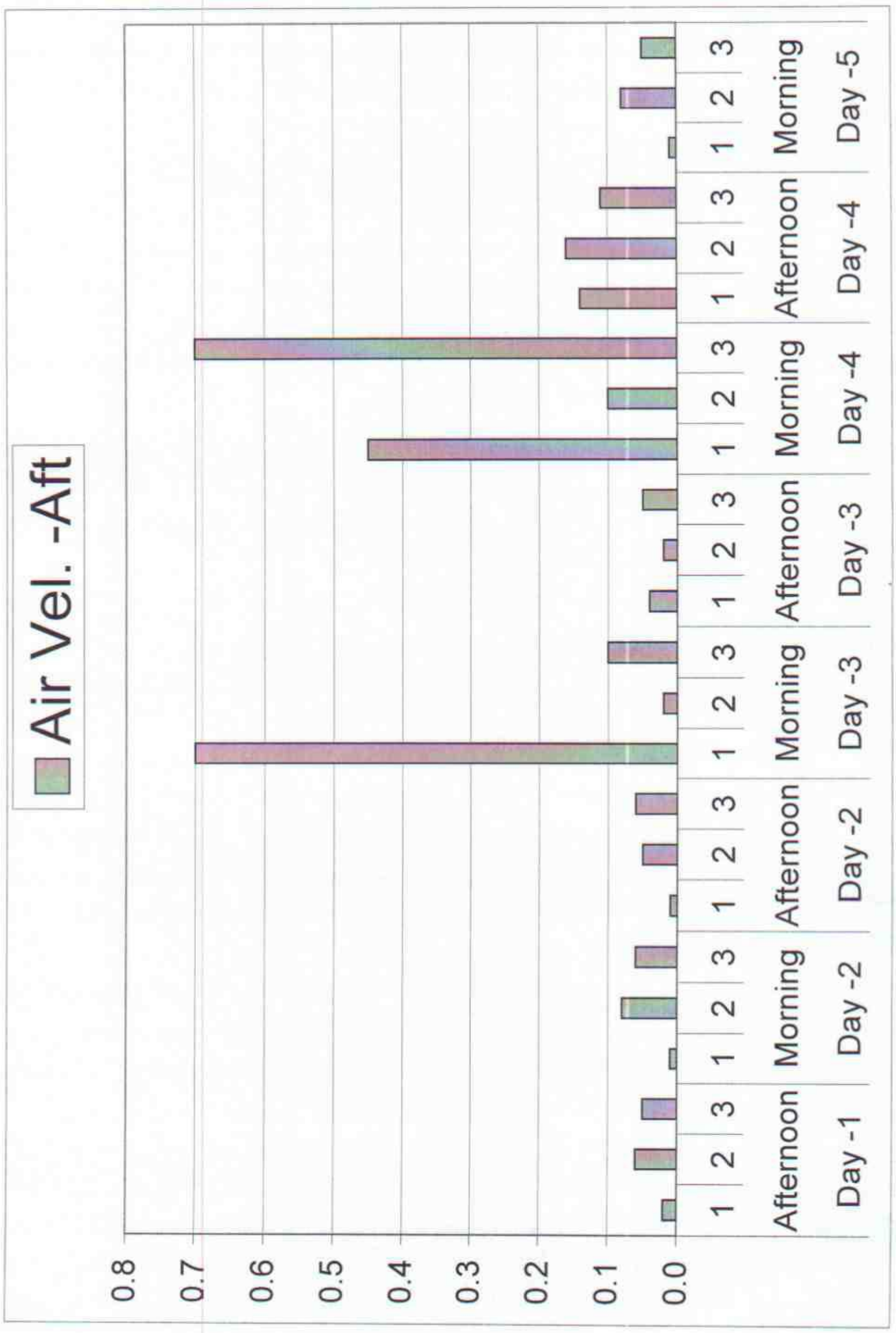
Temp
Temp -Aft
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1 2 3
Afternoon
Day -1
1 2 3
Morning
Day -2
1 2 3
Afternoon
Day -2
1 2 3
Morning
Day -3
1 2 3
Afternoon
Day -3
1 2 3
Morning
Day -4
1 2 3
Afternoon
Day -4
1 2 3
Morning
Day -5

12.7

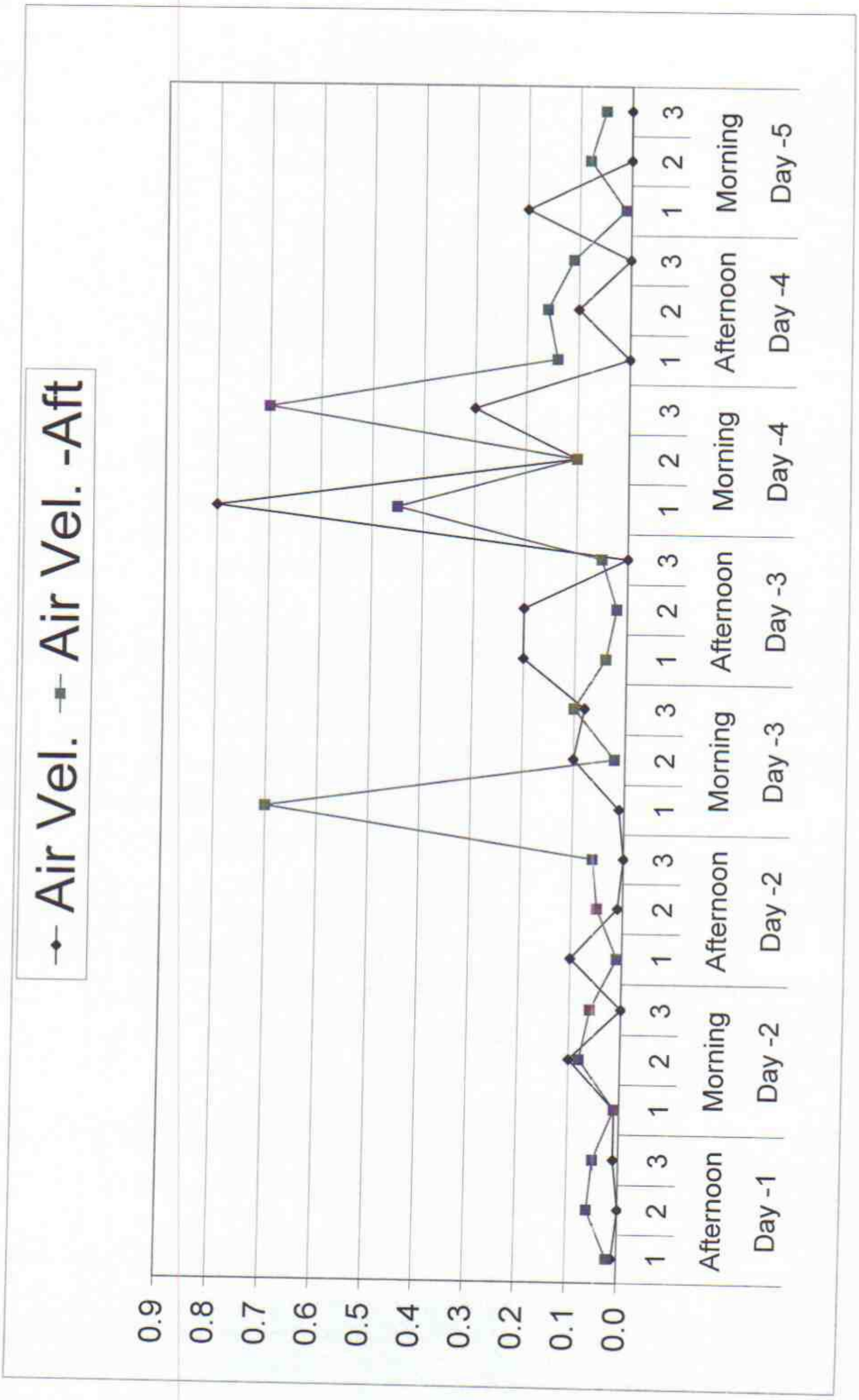


Air Vel.
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3
Afternoon
Day -1
1 2 3
Morning
Day -2
1 2 3
Afternoon
Day -2
1 2 3
Morning
Day -3
1 2 3
Afternoon
Day -3
1 2 3
Morning
Day -4
1 2 3
Afternoon
Day -4
1 2 3
Morning
Day -5

12.7


Air Vel. -Aft
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3
Afternoon
Day -1
1 2 3
Morning
Day -2
1 2 3
Afternoon
Day -2
1 2 3
Morning
Day -3
1 2 3
Afternoon
Day -3
1 2 3
Morning
Day -4
1 2 3
Afternoon
Day -4
1 2 3
Morning
Day -5

12.7


Air Vel.
Air Vel. -Aft
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3
Afternoon
Day -1
1 2 3
Morning
Day -2
1 2 3
Afternoon
Day -2
1 2 3
Morning
Day -3
1 2 3
Afternoon
Day -3
1 2 3
Morning
Day -4
1 2 3
Afternoon
Day -4
1 2 3
Morning
Day -5

Appendix VI Microbial standards

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GUIDELINES FOR PATHOGEN LEVELS IN INDOOR AIR (Other than spores, Levels considered Low, Acceptable, or Average)				
Microbe	Limit CFU/cu.m.	Qualification	I/O Ration	Reference
Bacteria (Any)	50	-	-	ACGIH
	65	mean measured	-	Holt 1990
	138	max. measured	-	Feeley et al 1988
	180	max. measured	-	Chbs 1993
	600	problem bldgs.	-	Nevalainen 1990
	380	normal bldgs.	-	Nevalainen 1990
	60	offices, mean	-	Nevalainen 1990
	50	-	0.26	Sverdrup et al 1990
	70	operating rooms	-	Bourdillion et al 1948
	154	average	0.86	Brickus 1997
	510	new houses	-	Reponen 1992
	576	mean measured	0.53	Heineman 1994
>> Outdoor Levels	190	-	-	Sverdrup et al 1990
	179	average	-	Brickus 1997
	1083	Mean measured	-	Heineman et al 1994
Dispersal of S. aureus (per person/min.)	3.5	average	-	Blowres 1973
	-	-	-	-
Pathogenic Bacteria	0	-	-	AIHA
Viruses	0	-	-	AIHA
Total Microbial	750	Non pathogenic	-	HBI
	600	-	-	Klossner et al 1996

ABBREVIATIONS USED IN TABLES

CIC	:	Cutter Information Corp.
ACGIH	:	American Conf. of Government Industrial Hygienists
CEC	:	Commission of the European Communities
AIHA	:	American Industrial Hygiene Association
HBI	:	Healthy Buildings International
CHBS	:	California Healthy Buildings Study, Fisk et al 1993

12.9

GUIDELINES FOR SPORE LEVELS IN INDOOR AIR (Levels considered Low, Acceptable, or Average)				
Spore	Limit CFU/cu.m.	Qualification	I/O Ration	Reference
Fungi	100	Hospitals	0.33	ACGIH
	100	Non Industrial	-	CEC
	200	-	<1	CIC
	100	-	-	Godish 1995
	150	-	-	Miller et al 1988
	100	-	-	Ohgke et al 1987
	200	-	-	Yang et al 1993
	50	-	-	Canadian Guidelines
	72	natural ventilation	0.72	CHBS 1993
	59	mechanical ventilation	0.5	CHBS 1993
	12	air conditioned	0.72	CHBS 1993
	108	average	0.68	Brickus 1997
	110	-	0.11	Kemp 1997
	80	new houses	-	Reponen 1992
>> Outdoor Levels	100	-	-	CHBS 1993
	200	-	-	Fouad 1997
	158	average	-	Brickus 1997
	1030	-	-	Kemp 1997
	810	-	-	Neumeister 1997
Actinomycetes	240	problem building	-	Mevalainen 1990
	12	farmhouses	-	Kalliokoski 1997
	154	problem homes	-	Mevalainen 1991
	0	Normal homes	-	Nevalainen 1991
>> Outdoor Levels	4	-	-	Heineman et al 1994

 12.9

B. **Micro Organisms**

AIRBORNE MICROORGANISMS ISOLATED IN SPACECRAFT				
BACTERIA	**APOLLO**	**SOVIET**	**SHUTTLE**	**OA**
Aclnetobacter	Y	1	Y	
Staphylococcus	Y	3	Y	
Corynebacterium		7	Y	
Streptococcus		6	Y	
Moraxella	Y	2		
Klebslella pneumoniae	Y	4		
Haemophilus influenzae	1			
Haemophilus parainfleunzae	1			
Mycoplasma	1			
Alkaligenes		1		
Neisseria spp.		5		
Pseudomonas spp.		5		
Bacillus spp.		9	Y	
FUNGI				
Aspergillus		11	Y	Y
Cladosporium		2	Y	Y
Penicillium		13	Y	Y
Mucor		1		Y
Alternarie			Y	Y

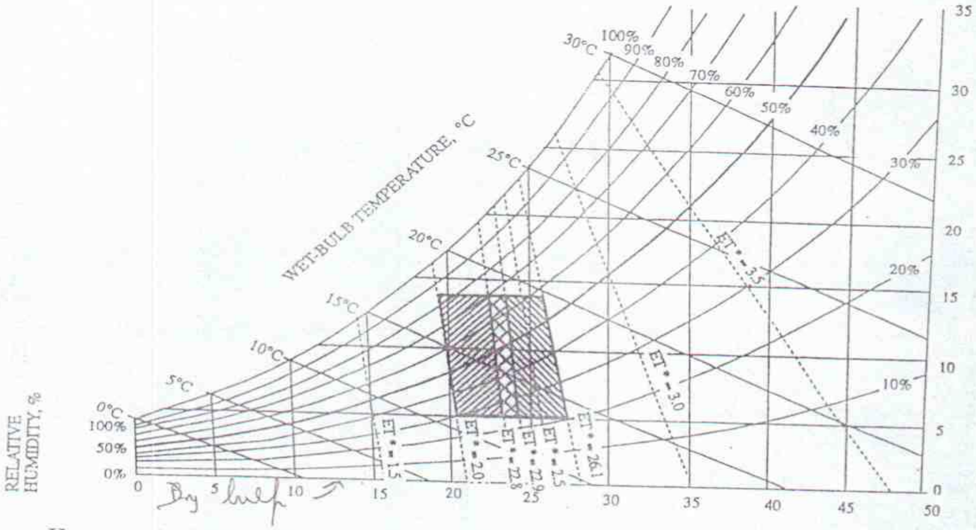
Appendix vii Effective Temperature Psychometric Chart

12·10

A number of indices simplify the description of thermal environment and stress imposed by an environment. An environmental index combines two or more parameters such as air temperature, humidity and air velocity. Only two of these indices are described, the others only mentioned.

- The effective temperature :

It is logical to ask what the temperature/humidity relationship for comfort conditions is. The answer is that there is no one specific condition. ASHRAE conducted research to establish a range of combined temperatures and humidities, that provide the maximum comfort. The effective temperature ET is probably the most common environmental index and has the widest range of application. Two environments with the same ET should evoke the same thermal response even though they have different temperatures and humidities. A standard set of conditions representative of typical indoor application is used to define a "standard effective temperature"(SET). Attached figure shows the standard effective temperature lines on a psychrometric chart. Also shown is the ASHRAE comfort envelope.



- Heat stress index
- Index of skin wettedness
- Wet-bulb Globe temperature

The WBGT is a better index of heat stress than the ET. This index is widely used for estimating the heat stress potential of industrial environments. The WBGT is an environmental heat stress index that combines dry-bulb temperature , wet-bulb

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