EVALUATION OF INDOOR AIR POLLUTANTS IN SELECTED HOSTELS OF TERTIARY INSTITUTIONS IN OWERRI-NIGERIA.

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CERTIFICATION

This is to certify that this thesis **'Evaluation of Indoor air pollutants in Selected Hostels of some Tertiary Institutions in Imo State-Nigeria** was carried out by **Nnadozie Chukwuemeka Fortunatus (20094773698)** in partial fulfillment of the award of the degree of Master of Science (M.Sc.) in Environmental Chemistry in the Department of Chemistry, Federal University of Technology, Owerri.

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DEDICATION

This project is dedicated to the Almighty God for His love and protection, and to my dear wife Chidinma, my daughter, Chimbusonma, my son Nesochukwu and to my mother, Mrs. Jessyrita Nnadozie for their support and unquantifiable care and love.

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ABSTRACT

This study was aimed at evaluating the concentration levels of indoor air pollutants in some selected hostels located in four tertiary institutions in Imo state, Nigeria. It was conducted from February 2012 to July 2012. The pollutants such as: H_2S, NO_2, CH_4, NH_3, SO_2, CO, Particulate matters and meteorological parameters; temperature, relative humidity, wind speed were measured. The gases were monitored using in-situ gas monitors while meteorological parameters were measured using multi-digital environmental meter. The observed concentration levels of indoor pollutants across the locations range as follows: H_2S, 0.02 to 0.082ppm, NO_2, 0.008 to 0.05ppm, CH_4, 0.00 to 0.01ppm, NH_3, 0.01 to 0.2ppm, SO_2, 0.004 to 0.05ppm, CO, 0.6 to 9.25 ppm and particulate matters, 7.0 to 83$\mu g/m^3$. The results revealed that the levels of pollutants were within the permissible limits of USEPA, WHO and FEPA. Multiple linear regression analysis of pollutants with meteorological parameters gave R- square (R^2) values ranging between (0.490 to 0.618), implying that the studied meteorological parameters jointly influenced (49 to 62%) levels of the pollutants in the studied locations. The monthly means of the pollutants were analyzed using two way Analysis of variance (ANOVA), and some of the results showed probability levels at ($p < 0.01$ and $p < 0.05$). These generated indoor pollutants can build up to levels of public health concerns and have also been associated with a growing burden of diseases. It is therefore recommended that periodic monitoring of indoor pollutants; use of improved stoves and fuels, as well as improving ventilation systems could reliably protect the indoor environment and reduce human exposures.

KEY WORDS: Indoor air pollutants, Meteorological Parameters.

CHAPTER ONE

INTRODUCTION

Clean air is a basic requirement of life. Human beings need a regular supply of food, water and essentially continuous supply of air. That all people should have free access to air of acceptable quality is a fundamental human right (Heavner *et al.,* 1995). However, recognizing the need of humans for clean air, in 1987, the World Health Organization (WHO) published the first Air quality guidelines for Europe containing health risk assessments of 28 chemical air contaminants. Therefore, air pollution has been identified as the major environmental challenge of the developed and developing economies of the world. In a developing country like Nigeria whose chief concern is to provide food for her populace, achieving maximum indoor air pollution monitoring and control has been a difficult task (Tawari *et al.,* 2012, Brown *et al*., 2010).

More so, the quality of air in indoor environments such as offices, inside homes, schools, day care centres, public buildings, health care facilities or other private and public buildings where people spend a large part of their life is an essential determinant of healthy life and people's well-being (Lee *et al.,* 2002). Good indoor air quality can lead to improved productivity at the workplace while poor indoor air quality will cause productivity to drop because of comfort problems, ill health and sickness-absenteeism (USEPA, 2012).

In recent time, a good number of compelling scientific evidence have proved that air within homes and buildings can be seriously polluted than the outdoor air (Ana *et al.,* 2010, Logue., 2011), therefore, the risks to public health from chronic exposure to low levels of indoor air pollutants have become detrimental since

90% of people spend their time indoors (Felicia *et al*., 2007., Anna *et al,* 2011., 2003, Weschler *et al.,* 2004, FEPA, 1991).

Hazardous substances such as gases and particulates emitted from buildings, construction materials and indoor equipment or due to human activities indoors can be detrimental to occupants (Heavner *et al*., 1995). Along with particulate matters, gases such as ozone, nitrogen dioxide, carbon monoxide, and sulfur dioxide, microbial and chemical volatile organic compounds and passive smoke are the most common types of air pollutants encountered indoors (Pandit *et al.,* 2001).

Also, lack of ventilation due to closed structured building patterns, substandard housing conditions, and the use of combustible cooking devices such as cooking with fire wood, unvented kerosene and gas stoves, use of generator sets placed close to windows etc, in residential buildings can concentrate air pollutants in indoor environments which can lead to a broad range of health problems. (Abbey *et al,* 1993., Nwaichi & Uzazobona, 2001; Herman, 1961).

Secondly, the natural and anthropogenic activities going on in the outdoor environments have also been reported to have a great influence on the concentration of pollutants recorded in the indoor environments(Wu et al, 2003, Mohammed *et al,* 2012). Born *et al*, 2007 reported that air pollutants can accumulate indoors, especially in polluted and confined areas up to twice their outdoors levels.

Biological sources of air pollutants are also found indoors such as bacteria, viruses and fungi (Mario *et al*, 2005). Again, improper air circulation allows these airborne pollutants to accumulate more than they would otherwise occur in nature (Banerajee *et al,* 2011). People produce particulates such as dust from minute skin flakes, building walls, carpeting and furniture etc. Gases such as methane and ammonia can also be emitted by indoor inhabitants, including the activities of other organisms (Okunola *et al*, 2012).

Other sources of indoor pollutants which have been reported include emissions from toilet and bathrooms, standing waters, household cleaners, human and pet metabolic process (Logue *et al*, 2011). Most of the combustion activities mentioned above especially those making use of fossil fuels can introduce oxides of sulphur and nitrogen including carbon monoxide and particulate matter. (Vineis *et al,* 2005, Slama, 2008). Ammonia and hydrogen sulphide can be introduced from nearby septic tanks. Clothings have also been reported to emit dry cleaning fluids for days after dry cleaning (Bogo *et al*, 1999).

Pollutants distribution could be affected by the indoor air conditions such as the relative humidity, wind speed and direction (ventilation), and ambient air temperature (Culhadaroglu & Demirci, 1996). Therefore, the indoor air pollutants distribution and concentration can be interpreted with the combination of various indoor meteorological factors or conditions.

Several health side effects have been linked with the concentration of indoor air pollutants (Katulski *et al*, 2006, Ambasht *et al*, 1999). Sick building syndrome has become an important social issue with the increasing desire to improve the quality. It causes throat and nasal pains, headache, nausea and vomiting. Other illnesses which have been associated with indoor air pollutants are asthma, bronchitis, and lung cancer (Mahmoud and Hani, 2011; USEPA, 2012)

Indoor air pollution can cause high blood pressure, cardiovascular problems, increased morbidity and mortality, effects on human reproductive system, low birth weight, nasal congestion (Nkwocha & Egejuru, 2008, Gurjar *et al,* 2008, Mayer, 1999., Ngele *et al.*, 2012). Most air pollutants such as carbon monoxide are known asphyxiates and can combine with haemoglobin to deprive cells with oxygen needed for cellular respiration.

However, because of the increasing awareness on the need to checkmate the levels of indoor air pollutants that have deleterious effect on humans and the ease of their accumulation in indoor environments especially in congested and poorly constructed buildings, hostels located within the Imo State University (IMSU), Alvan Ikoku Federal College of Education (AIFCE), Federal Polytechnic, Nekede and Federal University of Technology, Owerri (FUTO) which are the four major higher institutions in Imo State, Nigeria, were selected for this air quality assessment.

Therefore, it is hoped that the knowledge from this investigation will assist the authorities of the respective institutions in planning adequate pollution control measures and as well generate interests in further research on the health impact of students activities on indoor air quality in the monitored institutions in particular, and Nigeria Tertiary institutions in general.

1.1 DEFINITION AND DESCRIPTION OF AIR POLLUTION

Air pollution is defined as a scenario in which gaseous and particulate emissions generated from various sources such as industries and other anthropogenic activities are discharged into the atmosphere to the extent that air quality is impaired to a detrimentally or potentially dangerous level. (Dara, 1993). It could also be defined as any atmospheric condition in which certain substances are present in such concentrations that may produce undesirable effects on man and ecosystem. Air pollution has become an extremely serious problem for the modern industrialized world. The biochemical and physiological processes of plants can` be interfered by pollutants to an extent which could ultimately lead to yield losses (Heck *et al.,* 1988). These substances include gases (sulphur dioxide, nitrogen oxides, carbon monoxides, hydrocarbons, etc.), particulate matters (smoke, dust, fumes, aerosols, etc), radioactive materials and many others (Richa *et al.,* 2011).

1.2 TYPES OF AIR POLLUTION

1.2.1 Indoor air pollution

Indoor air pollution is the introduction of different harmful chemical, physical, and biological factors, which come from building materials, decoration materials, furniture and living discharges. These factors gathering in the room change some of the original interior elements and increase the content of certain toxic and hazardous substances then decrease indoor air quality and threat human health. It is the quality of air within and around buildings and structures especially as it relates to the health and comfort of building occupants. Indoor air pollutants can accumulate to a level of discomfort especially in air tight buildings or poorly ventilated dwellings. Some certain diseases such as cancer, asthma and other lung diseases are strong indictors of the presence of indoor air pollutants (WHO, 2007).

1.2.2 Outdoor air pollution

Outdoor air pollution is the introduction into the atmosphere of chemicals, particulates or biological materials that can cause discomfort, disease or death to humans or damage to living organisms. It occurs outside the building environment but could contribute to indoor pollutant accumulation due to dispersion (Mohammed & Abdulfatai, 2003). Outdoor air pollution is caused by small particles and ground level ozone that comes from automobile exhaust and off-road equipment. Industries and electric power plants are also the main sources of ambient air pollutants (WHO, 2013). Volcanic actions, forest fibres, and dust storm are natural sources of ambient air pollutants, but these contribute very little compared to the man-made sources.

1.3. CLASSIFICATION OF AIR POLLUTANTS

(a) Based on origin:

Primary pollutants: These are directly emitted into the atmosphere and are found as such e.g. CO, NO_2, SO_2 and hydrocarbons.

Secondary pollutants: These are derived from the primary pollutant due to chemical or photochemical reactions in the atmosphere e.g. ozone, peroxyacetly nitrate (PAN), photochemical smog etc.

(b) Based on chemical composition

Organic pollutants. Examples are hydrocarbons, aldehydes, ketones amines and alcohols.

Inorganic pollutants: These include carbon compounds, e.g. CO and carbonates, nitrogen compounds e.g. NO, NO_2 and NH_3, sulphur compounds e.g H_2S, SO_2, SO_2, SO_3, and H_2SO_4; halogen compounds, e.g. HF, HCl; and metallic fluorides; oxidizing agents e.g. ozone; inorganic particles e.g. ash, silica, asbestos and dust from transport, mining, metallurgical and other industrial activities.

(C) Based on state of matter

Gaseous pollutant: These pollutants get mixed with the air and do not normally settle out. Examples are CO, NO_2 and SO_2.

Particulate pollutant: These comprise finely divided solid or liquids and often exist in colloidal state as aerosols. Examples are fume, dust, mist, fog and sprays.

(d) Based on management of stationary sources

Natural sources: These include, wind blown dust, volcanic ash and gases, ozone from lightening and the ozone layer, esthers and terpenes from vegetation, smoke, gases and fly ash from forest fires, pollens and other aeroallergens, gases and odours from natural decomposition and natural radioactivity (Dara, 1993)

Human-made sources: These are anthropogenic or human sources of air pollutants. (Dara, 1993).These cover a wide spectrum of chemical and physical activities and are the major contributors to urban air pollution

1.4 SOURCES OF AIR POLLUTION

Sources of air pollution like factories or cars are usually categorized by regulatory agencies into one of three groups: Area, Mobile or point. Categorization of a specific source may vary depending on whether it is releasing "criteria" or "hazardous" air pollutants. Criteria pollutants refer to six chemicals which occur frequently in ambient air and can injure human health, harm the environment or cause property damage. They include carbon dioxide, lead, nitrogen dioxide, ozone particulate matter and sulphurdioxide.

Hazardous air pollutants (HAP) refer to other including substance that cause cancer neurological, respiratory and reproductive effects (Smith et al, 2002).

1.4.1 Area sources

Area sources include small pollution sources like dry cleaners, gas stations and auto body paint shops. Area sources are defined as sources that emit less than 10 tons per year of criteria or hazardous air pollutant or less than 25 tons per year of a combination of pollutants. The category also include some commercial buildings (heating and cooling units, surface coating), residential buildings (five place surface coatings), fuel combustion in non-road machinery, boats, rail roads and even the family lawn owners or barbecue grill. Waste disposal in the form of open burning, land fill and waste water treatment are significant area sources.

Though emission from individual area sources are relatively small but collectively their emissions can be of concern, particularly where large numbers of sources are located in highly populated areas. Area sources are responsible for over 50% of particulate matter emissions and more than point or mobile sources for volatile organic compounds (VOC) emission which contribute significantly to the formation of ground level ozone.

1.4.2 Mobile Sources

Driving a car is probably a person's single polluting daily activity nationwide. Mobile source are responsible for about 75% of carbon monoxide pollution, and more oxides of nitrogen emissions than area or point source. The sources include on road vehicles such as, cars, trucks and buses and off road equipment such as, ships, airplanes, agricultural and construction equipment. Mobile sources contribute significantly to air pollution especially in urban areas where motor vehicles can contribute more than 90% of CO emission. In a typical urban area at least half of the hydrocarbon and nitrogen dioxide pollutant come from mobile sources. Motor vehicles are also substantial sources of hazardous air pollutant such as the recognized carcinogenic benzene formaldehyde, acetaldehyde, 1,3 butadiene and diesel particulate matter. (Hill, 1997)

1.4.3 Point Sources

Point sources include major industrial facilities like chemical plants, steels mills, oil refineries, power plants, and hazardous waste incinerators. Point sources are defined as those that emit 10 tons per year of any of the criteria or hazardous air pollutants or 25 tons per year of a mixture of air toxics (Hill, 1997). Nationwide point sources like power plants, petroleum refineries, fertilizer manufacturers, industrial papers mills, copper smelter and iron and steel mills contribute the majority of sulphur dioxide emissions accounting for 90% of this criteria air pollutant. Point sources (predominantly electrical utilities and industrial boilers) are also major emitters of nitrogen oxides (NO_x) accounting for about 40% of total release. Point source are less important sources of VOC's releasing less than 15% of total volatile organic compounds (Smith *et al.,* 2003).

1.4.4 Indoor Sources

The sources are combustion sources such as oil, kerosene, gas, coal, wood, and tobacco products. Other sources are emissions from building materials and furnishings, deteriorated asbestos, wet or damp carpet, radon, pesticides, furniture made of pressed wood products, household cleaning agents, personal care products, central heating or cooling systems, humidification devices and other indoor sources (Smith, 2002). The relative importance of any single source depends on how much of pollutant it emits and how hazardous those emissions are. Factors such as how old the source is, and whether it is improperly maintained are significant. For example an improperly adjusted gas stove can emit significantly more CO than one that is properly adjusted (WHO, 2013).

1.5 FACTORS AFFECTING INDOOR AIR QUALITY

The overall quality of indoor air is influence by meteorological variables and air pollutants. The meteorological variables affecting air pollutants are: Temperature, Humidity and Air movement.

The common air pollutants include; respirable suspended particulates, volatile organic compounds, second-hand tobacco smoke, formaldehyde, asbestos, radon and its decay products, combustion gases, ozone, respiratory products and body odours, micro-organisms

1.6 The Meteorological Variables

The physical parameters such as temperature, humidity and air movement are important known indoor air quality parameters as they could affect people's perception of the indoor air quality. The levels of indoor air pollutants could be affected by the aforementioned parameters (Smith *et al.,* 2002).

1.6.1 Temperature

Air temperature has the most direct effect on human comfort. The temperature of the indoor environment is influenced by some factors such as the temperature control of the air conditioning and solar heat gain. Others are heat sources from lighting, electrical equipment, computers and water heaters. Also, temperature between rooms or locations within a room may vary due to large window areas or large vertical surfaces thereby causing discomfort to building occupants.

1.6.2 Humidity

Humidity influences thermal comfort by affecting the human's body ability to lose body heat through perspiration. It is more difficult to lose heat in humid conditions and the consequent effect is raising the body temperature and occupants feel sticky. Low relative humidity causes occupants discomfort, leads to dryness of eyes, noses and throat. Relative humidity can affect the release rate of many indoor air pollutants, their concentrations in the air, and the potential growth of mold organisms. Research has shown that high-relative humidity levels also support the growth of dust mites, mold count levels and bacteria levels that can lead to increased allergy symptoms and reduce indoor air quality.

1.6.3 Air movement

Air movement is important in dispersing or diluting air pollutants accumulated in an indoor environment .The required level of air flow is dependent on temperature and humidity, that is, in the humid dry season, greater air movement can help produce a more comfortable environment. Also, improved or balanced ventilation systems in ventilation ducts may facilitate air movement and producing a conducive atmosphere thereby making occupants to feel comfortable.

1.7 AIR POLLUTANTS AND THEIR EFFECTS

1.7.1 Respirable particulates.

Particulates are defined as suspended air borne particles which may be solid or liquid matter with a nominal aerodynamic diameter of 10 micrometers (µm) or less. Sources of indoor particulates are categorized as microbial particulates (e.g. bacteria, virus, mould, and spores), animal and plant particulates (e.g. pollen, insect parts, and bye-products), mineral particulates (e.g. asbestos and man-made mineral fibres), combustion particulates (e.g. tobacco smoke, emissions from cooking, heating appliances, and incense burning), and radioactive particulates (e.g. radon decay products attached to other particles). (Felicia *et al,* 2002).

The hazards which particulates present depend on the size, shape, density and chemical reactivity of the particles. Smoke particles from combustion can cause respiratory irritation and infection and aggravation of the respiratory or cardiovascular diseases. Household dust could cause nasal and eye irritation problem. Fibre glass dust could cause itching and irritation to the skin, eyes and upper respiratory system.

1.7.2 Volatile Organic Compounds (VOC's)

Volatile organic compounds (VOCs) are defined as organic compounds which easily evaporate at room temperature and enter the atmosphere. They exist in indoor environment as colourless gases and are emitted as gases from certain solids or liquid. VOC's include a variety of chemicals, some of which may have short and long term adverse health effects. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. VOC's are emitted by a wide array of products numbering in the thousands. Examples include paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbonless copy paper, graphics and craft materials including glue and adhesives, permanent markers, and photographic solutions (USEPA, 2001).

All of these products can release organic compounds during usage, and, to some degree, when they are stored.

Volatile organic compounds may migrate from the subsurface into the overlying buildings through a process known as is vapour intrusion. Building depressurization may cause these vapours to enter the home through cracks in the foundation. Depressurization can be caused by a combination of wind effects and stack effects, which are the result of heating within the building and/or mechanical ventilation.

Many researchers have reported that exposure to high levels of VOC's can result to toxicological effects on the central nervous system, liver, kidney, and blood of the human body. People that are hypertensive can have severe reactions to a variety of VOC's at low concentration. Exposure to benzene for long periods may increase the risk of cancer.

1.7.3 Second-hand Tobacco Smoke

Second- hand tobacco smoke is a collective name for a complex mixture of chemicals generated during the burning and smoking of tobacco products. It is tobacco smoke which affects persons other than active smoker and contains about 4000 organic compounds (Georges *et al,* 2010). Second- hand tobacco smoke includes both a gaseous and a particulate phase, with particulate hazards arising from levels of carbon monoxide and very small particulates which get past the lung's natural defenses. Smoking of cigarette leads to the emission of both mainstream and side stream smoke (Maziak *et al,* 2008). Mainstream smoke is the smoke exhaled by the smoker which has passed through the cigarette and the smoker's lungs, while side stream smoke is emitted from the burning tobacco at the tip of the cigarette. Side stream smoke is more dangerous because the components are unfiltered. Most of these contaminants include N-Nitrosodimehtylamine, 2-Naphthylamine, 4-amino biphenyl and toluene. Others are Carbon monoxide, benzene, formaldehyde, aniline, benzo(a)pyrene and poly aromatic hydrocarbon(PAH). Tobacco smoke contains over 4000 chemical compounds with about 500 in gas phase. Many toxic agents and about 60 known carcinogens have been identified in cigarette smoke. Some of the reported adverse health effects which are strongly associated with the exposure include chronic bronchitis, sudden infant death syndrome and acute stroke resulting from disease of blood (WHO, 2009).

1.7.4 Formaldehyde

Formaldehyde is an organic chemical that is prevalent in the indoor environment. It is a colourless gas with a pungent odour from a family of gases called aldehydes. It is commonly used as a preservative in medical laboratories and mortuaries (Coggon *et al.,* 2003). It is found in products such as, particles boards, household products, glues, permanent press fabrics, paper product coatings, fibre board and plywood (Pinkerton, 2004). Indoor sources include paper products such as glossary bags, sax paper, facial tissues, paper towels, disposable sanitary products, stiffeners, wrinkle resisters, and water repellants. Others are floor coverings such as; rugs, linoleum and carpets adhesive binder. Also, urea-formaldehyde foam insulation (UFFI), germicides, paints, plastics, ceiling tiles and panels are other strong sources found indoors (USEPA, 1992). Formaldehyde exposure is most common through gas phase inhalation. Air-borne concentration can cause eye, nose and respiratory irritation and sensitization to cause pharyngitis and asthma. It has also been reported to be a human carcinogen linked to nasal and lung cancer (Beane & Blaire, 2009).

1.7.5 Asbestos

Asbestos is a collective term referring to a group of naturally occurring hydrate silicate minerals crystallized in form of long, strong and flexible fibres which can be separated into bundle of fibrils (Weill, 1979). Sources of indoor asbestos are building installations in form of asbestos sprays, asbestos spray, asbestos textured paints, ceiling tiles, pipe lagging and vinyl floor tiles (Commins, 1985). Others are insulation boards, electrical switch boxes and flexible joints in air handling units (Fischer and Meyer, 1983). Again, the degree of health hazard of Asbestos Containing Materials (ACM) depends on the ease of the crumbling of materials when dry (friability) .Exposure to asbestos fibres has been linked to asbestosis (a scaring of lung tissue), lung cancer, and cancer of the lining of the chest or abdominal cavity (Sawyer, 1979).

1.7.6 Radon and its Decay Products

Radon is invisible radioactive atomic gases that result from the radioactive decay of radium (WHO, 2009). It is found in rock formation as granite and disintegrates radioactively when granite is used in concrete for building construction. Radon is heavy gas and thus will tend to accumulate at the floor level if the building is not well ventilated (Hunter, 2005). Again, radon can diffuse into the indoor air from soil gas by seeping up through cracks or openings in the ground (Durrani, 1997) Exposures to radon gas can increase the risk of cancer of building occupants (Miles & Sinnaeve, 1988).

1.7.7 Ozone

It is a colourless, odourless gas that is majorly generated by certain equipment that utilizes ultra-violet light or causes ionization of air (Curtis *et al*., 2006). Sources of ozone in indoor environment may come from some types of air cleaners such as electric or ion generators, and from certain industrial processes such as ozone treatment of bottled water (Last, 2001). Others are some office equipment such as laser printers and photocopying machines (WHO, 1999). Outdoor ozone is also an important contributor to indoor ozone depending on the concentration outdoors and the air exchange rate with indoor environments. Reaction between ozone and substances including skin oils and cosmetics can produce toxic chemicals as by-products. Ozone is irritating to lung tissue and has been described as causing serious adverse health respiratory effect (Ostro, 2004).

1.7.8 Respirable products and body odours

Human respirable products such as carbondioxide and body odours can affect indoor air quality. The concentration of carbondioxide in human exhaled air is about 3.8 % Also, it is an indoor pollutant emitted by humans and correlates with human metabolic activity. The lower the concentration of carbon dioxide, the fresher the air supplies.

Body odours can be unpleasant and the use of chemical deodorizers or perfumes to mask body odours may create more pollution problems than they solve.

1.7.9 Micro-Organisms and other allergens

Micro-organisms are another potential source of indoor air pollution, and can cause more serious problems than some chemical air pollutants (Donwes *et al.,* 2003). The three main types of micro-biological pollutants are bacteria, fungi, (mould and yeast), and viruses (Peccia *et al.,* 2009).

Bacteria are found in air- conditioned buildings and water or condensation in ventilation systems (Falkinhim *et al., 2009*). The presence in an indoor environment of high counts of some harmful bacteria such as staphylococcus epidermidis, Micrococcus and flavobacterium can be regarded as indicators of inadequate ventilation. Also, these bacteria and other complex groups such as thermophilic actinomycetes and Bacillus subtilis have been reported to be etiologic agents of hypersensitivity lung disease, and naturally their counts tend to be higher in overcrowded buildings (Fields *et al.,* 2002. Cone, 1998).

Fungal growth is promoted by high humidity and materials with moisture content (Thatcher & Layton., 1995). The most common causes of fungal growth in buildings are condensation on improperly insulated air-ducts, and water damage on carpets (Ahmad *et al*., 2001). Other causes may come from rain entering an inadequately sealed building, dirt on surfaces and accumulation of moisture on buildings (Rintala, *et al*., 2008). Cladosporium and Alternaria are fungal spores that can grow and accumulate indoors and chronic exposure can induce human allergic or asthmatic reactions (Haleem *et al,* 2012).

Viruses have been associated with low absolute humidity with increased viral infections such as cold or influenza (Lamoth *et al.,* 2010). They are normally transferred from person to person through aerosols of body fluids (Falkinhim *et al.,* 2009). Also, several evidences (Bholah & Sutratty, 2002) have suggested that rhinovirus can induce adverse respiratory effects such as air-way inflammation, decreased lung function, exacerbation of asthma and childhood disease such as measles.

1.7.10 Hydrogen Sulphide Gas (H_2S)

Hydrogen sulphide gas is a colourless gas with distinctive odour of rotten eggs. Hydrogen sulphide odour perception is highly variable within the human population ranging from 0.008-0.2ppm (Amoore & Hautala, 1983; Beauchamps *et al,* 1984). It is flammable in air at concentration between 4-46% by volume (Sax & Lewis, 1989) and burns with a pale blue flame. It is only moderately soluble in water and has a density of 1.39 g/l at 25^0c and l atm. It is toxic and corrosive if moist. Typical concentration ranges of H_2S in dilute volcanic plumes are 0.1-0.5ppm compared to atmosphere background of 0.00005-0.024ppm and the gas has a resident time of approximately 24 hours (Oppenheimer *et al;* 1995).

The indoor sources of this pollutant might come from the decay of organic matter and stagnant waters in gutters and sinks. Low concentrations of H_2S are readily detected by smell but because prolonged exposure to the gas dulls the sense of smell. This is a very unreliable method of hazard warning (Lide, 2003).

H_2S is a toxic gas and the health hazard depends upon both the duration of exposure and the concentration. The gas is an irritant of the lungs and at low concentration irritates the eyes and the respiratory tracts and exposure may result in headache, fatigue, dizziness staggering gait, and diarrhea, followed sometimes by bronchitis and bronchopneumonia (Sax & Lewis,1989).There is some evidence of elevated presence of adverse health symptoms in communities exposed to long term low levels of H_2S in the environment (Bales *et al,* 2002; Legator, 2001) such as in the geothermal areas, and the unpleasant smell of H_2S can be a nuisance. Sense of smell to H_2S is lost at concentration below those of harm so people may have little warning of the presence of the gas at dangerous concentration. Very large concentration result in paralysis of the respiratory center causing breathing to stop and may potentially lead to death. If death does not occur during the exposure time, recovery generally occurs without later medical complications although symptoms may occur for several months (Synder *et al,* 1995).

1.7.11 Ammonia

Ammonia is a colorless, pungent, hazardous caustic gas composed of nitrogen and hydrogen. It is a widely used hazardous chemical and has many potential applications in agriculture, industry, and commercial products including various household cleaning products. Ammonium hydroxide (aqueous) is the primary active ingredient for cleaning and disinfecting non porous surfaces in various domestic, commercial and industrial strength cleaning products. The most likely source for ammonia exposure in the general population is from the use of household cleaners containing ammonia or ammonium salts, animal waste, ammonification of humus, emissions from the soil, loss of ammonia based fertilizer from the soil and industrial emissions (ATSDR, 2002). Livestock farming and animal waste account for the biggest percentage of total ammonia emissions which are due to the decomposition of urea from large animal wastes and uric acid from poultry wastes. Indoor sources of NH_3 include human and pet metabolic processes; cigarette smoke and house hold cleaners (Suh *et al.,* 1994). Addition of urea-based antifreeze admixtures during cement mixing in construction of buildings has led to increasing indoor air pollution due to continuous transformation and emission of urea to gaseous ammonia in indoor concrete wall. (Tuomainen *et al*, 2000). Probable routes of human exposure to ammonia are inhalation, ingestion, and dermal contact. Ammonia is irritating to the eyes and respiratory tract. High concentrations cause conjunctivitis, laryngitis, and pulmonary edema, possibly accompanied by a feeling of suffocation. Persons with asthma may be particularly sensitive to exposure to ammonia.

1.7.12 Carbon Monoxide

Carbon monoxide is a colourless, odourless gas that interferes with the delivery of oxygen throughout the body. Sources of CO in residential buildings are from unvented kerosene and gas space heaters, leaking chimneys and furnaces, back-drafting from furnaces, gas water heaters, wood stoves and fire places, gas stove, generators and other gasoline powered equipment, automobile exhaust from attached garages, and tobacco smoke. Incomplete oxidation during combustion in gas ranges and unvented gas or kerosene heaters may cause high concentration of CO in indoor air. Worn or poorly adjusted and maintained combustion devices (e.g. boilers, furnaces) can be significant sources. Auto, truck, or bus exhaust from attached garages, nearby roads or parking areas can also be a source.

At low concentration, fatigue in healthy people and chest pain in people with heart diseases may be experienced. At high concentration, impaired vision and coordination, headaches, dizziness, confusion, nausea are symptom of CO pollution. CO can be fatal at a very high concentration. Acute effects due to the formation of carboxyhaemoglobin in the blood inhibits O_2 intake. At moderate concentrations, angina, impaired vision and reduced brain function may result.

1.7.13 Methane

Methane is a colourless odourles gas that is widely found in nature. It can be produced by the decomposition of plant and animal matter which makes it prevalent near landfills. Methane is also one of the principal components of natural gas. It is produced by anaerobic bacteria fermentation processes in water which contains substantial quantities of organic matter, such as swamps marshes, rice fields and lakes (Malcolm, 1992).

$2\{CH_2O\}$ (bacteria action) $\rightarrow CO_{2\,(g)} + CH_{4\,(g)}$

Smaller amounts are emitted into the air from seepage of natural gas from the forest fires some of which are due to natural causes and industrial and from natural gas leak in most equipment used in residential building.

It is highly combustible flammable and can form an explosive mixture in air at levels as low as (5% - 15%). Large concentration in enclosed areas can lead to suffocation as it decreases the amount of available oxygen in the air. The effects of oxygen deficiency are nausea, headache, dizziness and unconsciousness. As a result of the absorption of infrared radiation emitted from the surface of the earth, methane has been identified as a green house gas because of its potential contribution to global warming.

Methane can also be found in coal gas. Pockets of methane exist naturally underground in homes; it can be used to fuel a water heater, stoves and clothes dryer. Methane evaporates quickly and most of the methane that ends up in lakes, streams or soil is eventually released into the air. Most exposures occur when people inhale methane. Methane can go into homes through sewer traps or foundation cracks. People can be exposed by inhaling the chemical at work, cooking on a gas stove, or entering confined spaces such as manholes, silos, animal waste pits, septic tanks and sewers.

1.7.14 Sulphur dioxide

It is colourless gas with characteristic sharp pungent odour. It is moderately soluble in water forming weakly sulphurous acids (H_2SO_3). It is oxidized slowly in air to form sulphur trioxide (Bhatia, 2009)

SO_2 is produced mainly from the combustion of fossil fuels such as coal and oil and generator sets. Sulphur trioxide is also a product of SO_2 which combines with moisture in the atmosphere to form corrosive sulphuric acid (Bhatia, 2009).

Equation $2SO_2 + 2H_2O + O_2 \rightarrow 2H_2SO_4$

Its primary effects are upon the human respiratory tract producing irritation and increasing airway resistance especially to people with respiratory weaknesses and sensitized asthmatics. Exposure to SO_2 therefore increases the effort required to breathe (Bhatia, 2008). SO_2 has the potential of slowing down cilliary movements in the respiratory tract. The cilia act to clear micro-organisms and toxic particles from the respiratory tract. If these irritants reach the lungs they may possibly cause acute respiratory problems.

1.7.15 Nitrogen dioxide (NO_2)

The primary sources of NO_2 in most buildings are from unvented combustion appliances, e.g. gas stoves, kerosene heaters, vented appliances with defective installations, welding and tobacco smoke. Eye, nose and throat irritation may cause impaired lung function and increased respiratory infections in young children NO_2 acts, mainly as an irritant affecting the mucosa of the eyes, nose, throat, and respiratory tract. Extremely high-dose exposure to NO_2 may result in pulmonary edema and diffuse lung injury (Mark, 2002). Continued exposure to high NO_2 level may contribute to the development of acute or chronic bronchitis. Low level NO_2 exposure may cause increased bronchial reactivity in some asthmatics, decreased lung function in patients with chronic obstructive pulmonary disease and increased risk of respiratory infections especially in young children.

1.7.16 Naphthalene

Naphthalene is produced from coal tar fractions by distillation and crystallization. It is used as feedstock in the manufacture of phthalic anhydride for the synthesis of phthalate plasticizers and synthetic resins (Su, 2002). It is also used as feedstock for naphthalene sulfonic acids often used in the production of plasticizers for concrete, as ingredients for plasterboards, as dispersants in synthetic and natural rubbers and as tanning agents in the leather industry (Wania *et al.,* 2002). Naphthalene is also used in paints and in the production of the insecticide carbaryl, used in home yards and gardens (Preuss *et al.,* 2003). The highest indoor concentration may come from consumer products such as multipurpose solvents, lubricants, herbicides, charcoal lighters, hair sprays, moth repellent and disinfectant. Its use as a solid block deodorizer for toilets has also reported (Jantunen, 1999). Other indoor sources of naphthalene are unvented kerosene heaters, tobacco smoke, wood smoke, fuel oil and gasoline emissions. Outdoor sources which can influence indoor environment mainly originate from fugitive emissions and motor vehicle exhausts (Hoffmann, 2000). It is assessed that the primary route of exposure is inhalation (Preuss, 2003).

The principal health concerns of exposure to naphthalene are respiratory tract carcinogenicity and haemolytic anaemia in humans (Koistinen, 2008).

1.8 OBJECTIVES OF THE STUDY

The research work aims to investigate the levels of NO_2, SO_2, CO, H_2S, CH_4, NH_3, and Particulate matters in the selected hostels in AIFCE, IMSU, FEDPOLYNEK and FUTO.

The specific objectives are to:

(i) To compare the levels with some standards such as WHO, USEPA and FEPA.

(ii) To assess the effects of human activities and time of the day on the concentration of indoor pollutants.

(iii) To determine the relationship between the measured pollutants and meteorological parameters such as: Temperature, Relative Humidity and Wind Speed.

1.9 JUSTIFICATION OF THE STUDY

Air pollutants concentrations in most residential and public buildings can be twice the concentrations in outdoor environment due to pollutants accumulation in air tight buildings, confined air spaces, overcrowded spaces and high activity areas.

Several epidemiological studies have revealed the many health implications of exposure to high pollutants concentrations in an indoor environment.

1.10 SIGNIFICANCE OF THE STUDY

Many researchers have linked extreme air pollution to so many deleterious health effects. Indoor air pollution from fuel combustion accounts for 1.6 million deaths annually or 2.7% of the global burden of disease and 50% of these deaths occur in children below 5 year (Emmanuel, 2006).

1.11 SCOPE OF THE STUDY

The study is limited to some selected hostels of tertiary institutions in Imo state, Nigeria. The institutions are: Alvan Ikoku Federal College of Education, Owerri (AIFCE), Imo State University (IMSU), Federal Polytechnic Nekede (FEDPOLYNEK) and Federal University of Technology (FUTO).

CHAPTER TWO

LITERATURE REVIEW

2.1 AIR POLLUTANTS WITH METEOROLOGICAL VARIABLES

Krishna & Adhikary (2007) studied the influence of meteorological conditions such as temperature, rainfall, humidity, atmospheric pressure, wind direction and speed on the concentrations of particulate matters between March 2003 to December 2005. Pearson's coefficient of correlation was applied to investigate the association between the measured PM and meteorological variables. The result showed that the atmospheric pressure, wind velocity and humidity were significant factors compared to others influencing PM. Furthermore, increase of rainfall and humidity has negative correlation with average PM concentration in Kathmandu valley.

Sonal & Birva (2008) investigated the effect of meteorological conditions on air quality in the City of Surat to determine the parameter that mainly affects air pollutant dispersion. The measured air quality parameters include NO_2, SO_2, and suspended particular matters (SPM), while meteorological variables are wind speed, wind direction and temperature. The result showed that as wind speed and temperature are high, the dispersion is high. Out of the three meteorological parameters, wind speed was found to affect the dispersion of pollutants the most.

Malgorzata (2011) demonstrated the different effects of ambient air pollution and meteorological factors on air pollen concentration on selected taxa in atmosphere, using volumetric method and automatic weather station. The result showed there were significant correlations between pollen counts and air pollution weather parameters. Furthermore, the strongest correlation was observed to be with mean air temperature.

Garcia (1996) conducted a research on the indoor levels of Nitrogen dioxide and Ammonia in selected buildings in Barcelona, Spain. The result showed that the observed high concentrations of these pollutants were as a result of characteristic smoking habbits of the building occupants. Multiple regression analysis showed that the principle sources of NO_2 concentrations in the indoor environment were the use of gas cooker, the absence of extractor fans when cooking, smoking and the absence of central heating systems.

Okoli *et al* (2005) investigated the levels of aerial pollutant gases such as carbon monoxide (CO), Nitrogen dioxide (NO_2) and Hydrogen sulphide (H_2S) in four female student's hostels in the Federal University of Technology Owerri, Nigeria, in the month of October, 2004. About 252 of such measurements were carried out at six sites which include toilets, bathrooms, rooms near toilets/bathroom, middle rooms, kitchen and rooms near kitchen. The results of the study indicated that all the monitored pollutants significantly exceeded FEPA ambient air quality standards, indicating that the air quality in the hostels could constitute serious health risks to students.

In an Italian population-based study, Simoni (2002) reported that the highest weekly indoor concentrations of NO_2 were determined in a rural area of the Po Delta. The result further showed that the weekly mean indoor concentration in the kitchen during winter was higher than that in summer, being 62 $\mu g/m^3$ and 38 $\mu g/m^3$, respectively. It was deduced from the result that the presence of a gas-fired heating furnace was the major factor in the elevated nitrogen dioxide concentrations.

Garcia, (2003) investigated 340 dwellings in Spain between 1996 and 1999. The result showed that the average annual indoor concentrations of nitrogen dioxide did not vary significantly with range from 12.5 to 14.7 μg/m^3. Also, respective outdoor air concentrations were slightly higher in 1996 and 1998 and slightly lower in 1997 and 1999. Typical indoor to outdoor ratios were close to one. The principal indoor sources of nitrogen dioxide in Spanish homes were attributed to the use of gas cookers, absence of an extractor fan when cooking, the absence of central heating and cigarette smoking.

Fromme *et al.,* 2007 evaluated indoor air quality in 64 schools in the city of Munich and a neighbouring district outside the city boundary. A total of 92 classrooms were monitored between 2004–2005 in the winter, and 75 rooms were also monitored in 2005 in the summer. Data on indoor air climate parameters which include air temperature and relative humidity. Consequently, air quality parameter such as Carbon dioxide (CO_2) and various dust particle fractions (PM10 and PM 2.5) were determined. The results clearly show that exposure to particulate matter in school is high. The increased PM concentrations in winter and their correlation with high CO_2 concentrations indicate that inadequate ventilation plays a major role in the establishment of poor indoor air quality.

Levy *et al.,* (1998) studied nitrogen dioxide concentrations in homes in 18 cities in 15 countries reporting two-day means. The use of a gas stove was found to be the dominant activity influencing indoor concentrations of the gas. The results obtained attributed the use of combustion space heaters to elevated nitrogen dioxide concentrations.

Georges *et al.*, (2010) investigated the indoor levels of second-hand tobacco smoke by collecting samples in 28 public venues in six Lebanese cities. The result showed unsafe levels of indoor air pollution with tobacco smoking. In order to protect public health, the authors recommend that restrictions be applied to venues where water pipe smoking occurs.

In a study by the National Institute of Occupational Safety and Health, (NIOSH,2002), which was based on five hundred complaints, inadequate ventilation and the release of contaminants from indoor and outdoor sources are the primary reasons for indoor air pollution. The result also showed that air quality in building is the result of a contest between the pollutants and the ventilation system. It further stated that other factors that can aggravate the situation are temperature humidity and microbial contamination.

Karin *et al.,* (2012) assessed the concentration of five air pollutants (NO_2 formaldehyde, SO_2, H_2S and CO) through home visits in 628 urban and rural family residences. The result showed that certain housing characteristics such as smoking and exercise. Data revealed that 30% home had quantifiable levels of SO_2 and 29% had formaldehyde while 9% and 12% of household respectively were for NO_2 and H_2S.

Ayodele & Abubakar (2010) measured the levels of SO_2 in indoor residences of Kano municipality. Samples of SO_2 gas were assessed in 1600 homes in different residential districts in the metropolis. The result showed that the distribution of SO_2 skewed towards high frequency of low concentration in some areas such as Jakara, Gwale and Kumata, while highest frequency concentration of the gas was recorded in Fagge and Goron Dutse. This was attributed to the use of fossil fuel in cooking and other combustion activities that are characteristics of the inhabitants of the area.

Neas, (1991) examined the association of respiratory symptoms with indoor nitrogen dioxide levels in more than 1500 children who were followed up for one year. About half of the children lived in homes with a major source (gas stove or kerosene heater). Household annual average levels were determined based on summer and winter measurements made in three household locations, and were 16.1 $\mu g/m^3$ for homes without a source and 44.2 $\mu g/m^3$ for homes with a source. The result showed that the annual cumulative incidence of any lower respiratory symptom (shortness of breath, chronic wheeze, chronic cough, chronic phlegm or bronchitis) was higher in those children living in homes with a source (29.0% vs 22.8%) and was higher with increasing annual average indoor nitrogen dioxide .

Abul Raheem *et al., (*2009) monitored the levels of SO_2 at Ilorin, Nigeria, using three urban classes and a control site across wet and dry seasons, between 2003 to 2006. They discovered that the wet season concentration was 15.25% lower than the dry season due to rain attenuation. The SO_2 levels were found to vary significantly with vehicular intensity and anthropogenic activities decreased during wet season.

Okolo *et al.,* 2012, investigated the aerial concentration of indoor gaseous air pollutants; CO, CH_4, H_2S and NO_2 in some selected pig pen in Owerri, in the month of August 2010. The result showed that the high concentration of pollutant obtained during the period under study was due the concentrated animal feeding operation.

In a recent study to investigate the influence of some meteorological parameters on the concentration of CO in South Eastern Nigeria, Ngele *et al* (2012) discovered that all the meteorological parameters (Wind speed, temperature, relative humidity) influenced the levels of CO in the area with wind speed showing a strong correlation.

The levels of air pollutants (H_2S, NH_3, PM, NO_2, CO) in the locality of Ogbomosho, Oyo state have been studied by Ayoola *et al* ;2012. They discovered that the high concentrations of these pollutants observed during the period under study were attributed to the presence of abattoir, market place, vehicular movements and other potent sources.

High nitrogen dioxide concentrations have been associated with the use of candles and mosquito coils. In chamber tests study by Lee & Wang, 2006, maximum nitrogen dioxide concentrations up to 92 $\mu g/m^3$ were observed during incense burning. Also, Pennanem (1997) reported high values of nitrogen dioxide up to 7530 $\mu g/m^3$ in enclose ice arenas with inadequate ventilation from the exhaust emissions of propane- and petrol-fuelled ice resurfacing machines

Brauer *et al.,* (1991) monitored eleven homes in Boston, Massachusetts and found average indoor ammonia levels of 19.3 ppb in the winter and 8.1 ppb in the summer, and average outdoor ammonia level were 1.1ppm and 19 ppb in the winter and summer, respectively.

Suh *et al.,* (1992) also monitored some selected residential buildings in union town, Pennsylvania. The average indoor levels of ammonia was 21.0ppb and an average outdoor level was 0.3 ppb showing high level of concentration of the gas in the indoor environment which was as a result of pollutant accumulation.

Hulin, (2010) carried out a study to investigate and compare the potential effects of indoor air pollutants on asthma in urban and rural houses. Two case control population composed of children living in the city country side were used as the basis for the assessment. The study revealed that the levels of nitrogen dioxide, fine particulates and volatile organic compounds (formaldehyde acetaldehyde, benzene, toluene, ethylbenzene and xylenes) at homes in urban dwellings were found to be higher than the rural homes, with concentration up to two times higher.

Ayodele & Abubakar (2009) also investigated the indoor levels of sulphur dioxide in 1600 homes in Kano metropolis. The higher levels of the gas as was observed during the study period was attributed to closed structured building pattern, substandard housing conditions, use of firewood and poor home environment within the city. Also significant portion of the cooking was discovered to be taking place in conditions where much of the air borne effluents were released into living areas.

Sait *et al.,* 2011 assessed the levels of some volatile organic compounds (VOC's) in classroom, Kindergartens and outdoor playground of three primary school in Turkey during the spring, winter and fall terms. The study revealed that Benzene, Toluene and Formaldehyde were the most abundant compounds with indoor concentrations of 29 mg/m^3, 87 mg/m^3 and 106 mg/m^3 respectively. Again, Naphthalene and xylene were also discovered but in lower concentrations.

Okoli *et al.,* (2012) investigated the levels of indoor ammonia, carbon monoxide, methane, hydrogen sulphide and nitrogen dioxide in selected Pig pens in Nigeria. The result showed that concentrated animal feeding operations (CAFO) were responsible for high levels of the gases observed during the study period.

Pat & Nkwocha (2012) assessed the impact of saw mill industry on air quality in selected location at a community in Akwa -Ibom State. The result showed narrow and wide variations in the diurnal concentration of the monitored air pollutants. Three of the pollutants; CO_2, PM_{10} and VOC's exceeded the FEPA standards by 72% and 37% respectively.

Suh *et al.,* (1994) conducted a study in 47 state colleges, Pennsylvania homes in Eastern U.S. It was found that the measured indoor levels of NH_3 in the residential homes were significantly higher indoors than outdoors. The average indoor level was found to be 19.9 ppb and the outdoor level was 1.7ppb.

2.2 HEALTH EFFECTS OF AIR POLLUTANTS

Florey (1979) conducted studies to measure indoor nitrogen dioxide in the United Kingdom. It was reported that the children living in homes that cooked with gas had more respiratory illness. In the children who lived in gas-cooking homes, the study revealed that the prevalence of respiratory illness increased with increasing bedroom nitrogen dioxide level with 44%, 59% and 71%, respectively in those exposed to 0–37.6 $\mu g/m^3$, 37.6–75.2 $\mu g/m^3$ and 75.2 $\mu g/m^3$.

Garrett (1998) carried out a study on children living in Victoria, Australia over a one-year period. Indoor nitrogen dioxide was measured on five occasions in three locations in the home and the frequency recorded of eight respiratory symptoms during the year of observation. From the result, respiratory symptoms were associated with the presence of a gas stove but not with any of the other sources of indoor nitrogen dioxide (gas heaters or smoking in the home). Also, respiratory symptoms, but not peak flow variability, were more frequent in children with higher bedroom levels of nitrogen dioxide but not kitchen or lounge levels.

Tawari & Abowei, (2012) carried out an extensive air quality assessment to investigate the impact of air pollutants on the health of residents in selected communities in Niger Delta area of Nigeria. Two communities, one with high industrial presence (Eleme) and the other with low industrial presence (Ahoada East) were selected. Questionaire and hospital records were employed for this study. The final result indicated that 60.9% of respondents at Eleme were the major reason for the observed ill health such as skin outgrowths and other respiratory disorders. Also, Ahoada East was 4.5% with less health side effect.

Smith *et al.,* (2002) also reported that particulates from cigarette smoke and gas phase components can adversely affect cilliary function. They discovered that nitrogen dioxide can adversely affect both mucociliary apparatus and humoral and cellular immune defenses.

In a similar study, Smith *et al.,* (1994 reported that sulphur dioxide and particulates can reduce the efficacy of host defenses against microbial agents and respiratory tract inflammation, while ozone was also reported to increase bronchoalveolar permeability and impaired macrophage function.

Bennett *et al.,* (2002) reported that particulates from diesel exhaust can cause chronic inflammation of respiratory tract, epithelia cell, hyperplacia, impaired alveolar clearance, pulmonary fibrosis and compromised pulmonary function.

Jostes (1996) provided an overview of the genetic, cytogenetic and carcinogenic effects of indoor radon on building residents. The study reported that radon and radon progeny cause cell transformation, changes in chromosome structure and gene mutations containing a wide range of deletions, as well as base-pair changes. It was further ascertained that it is possible that even exposure to low radon concentrations such as in homes adds to the genetic load for cancer.

CHAPTER THREE

MATERIALS AND METHOD

3.1 THE STUDY AREA

Imo state is situated in the southern rain forest vegetation belt of Nigeria. It lies between latitude 5^0 and 6^0N and longitude 6^0 15 ' and 7^0 34 ' E (Figure 1.1). The area is dominated by plains 200m above sea level except for elevation associated with the Okigwe uplands. It has an annual rainfall of about 1700- 2500mm (Ofomata, 1975). The climate of the study area follows a tropical pattern with the rainy season lasting for between seven and eight months between April and October with an interruption in August and the dry season running through November till February.

In this study, four tertiary institutions were selected for air quality assessment. The institutions were; Alvan Ikoku Federal College of Education (AIFCE), Imo State University (IMSU), Federal Polytechnic Nekede (FEDPOLYNEK) and Federal University of Technology Owerri (FUTO). The sample locations cut across two local government areas with AIFCE and IMSU located in Owerri Municipal Council and FEDPOLY and FUTO located in Owerri West Local Government Area.

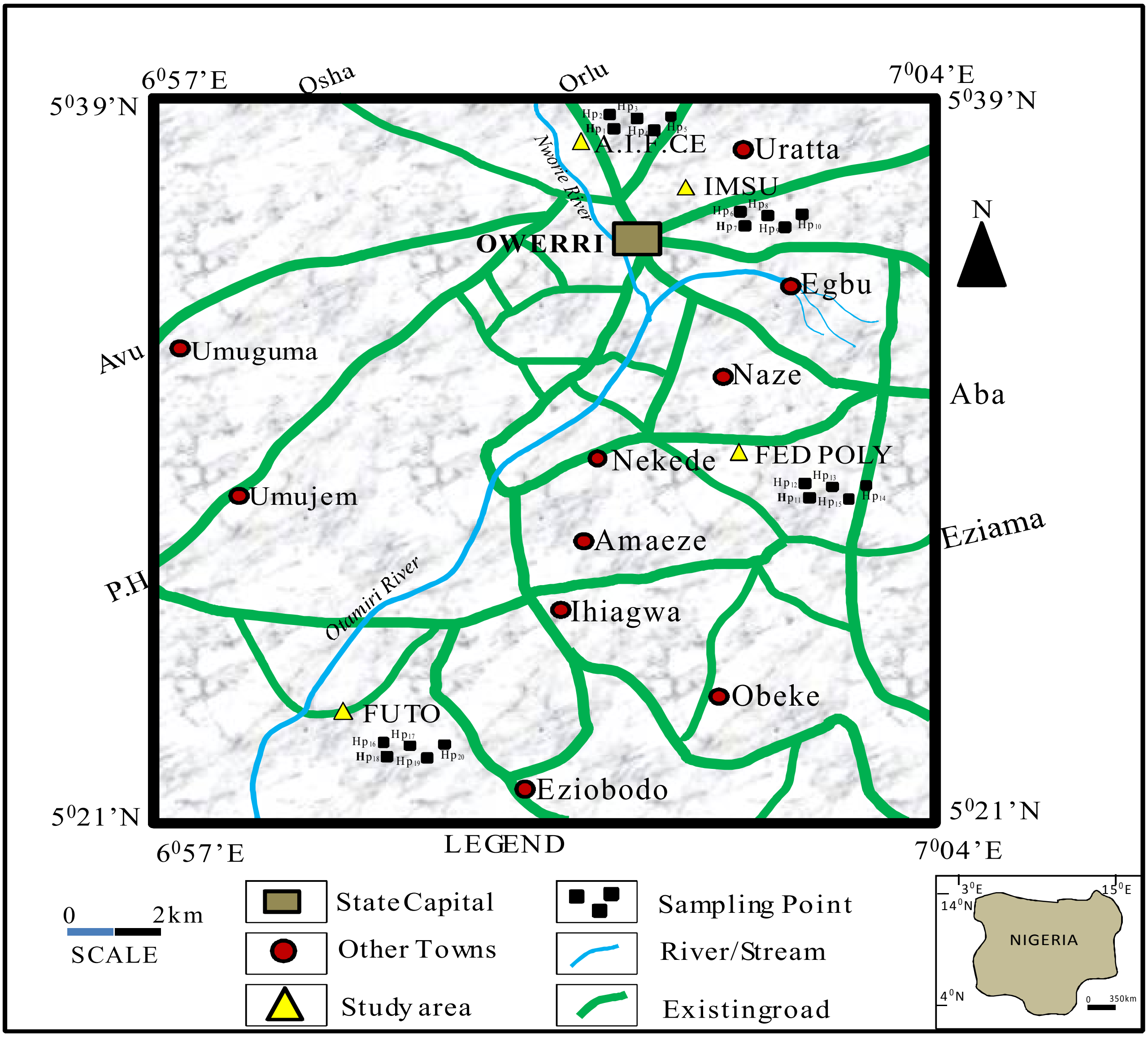


Fig. 1.1 Map showing the study area

TABLE 3.1 SAMPLE LOCATIONS

S/No	Sample Areas	Sampling Points	Designation	No of Occupants
1	Alvan Ikoku Federal College of Education Owerri	HP1	Hostel A	608
		HP2	Hostel B	726
		HP3	Hostel C	580
		HP4	Hostel E	620
		HP5	Hostel F	518
2	Imo state university Owerri IMSU	HP6	Gold Angel	225
		HP7	Victory Hostel	218
		HP8	Kezrald Suites	305
		HP9	Merit Hostel	285
		HP10	Success Lodge	315
3	Federal Polytechnic Owerri FEDPOLYNEK	HP11	Jumbo Hall	874
		HP12	Hall B	718
		HP13	Hall D	658
		HP14	Kelvix Hostel	412
		HP15	God's Own Lodge	286
4	Federal University of Technology Owerri (FUTO)	HP16	Hostel A	815
		HP17	Hostel B	808
		HP18	Hostel C	915
		HP19	Hostel D	780
		HP20	Hostel E	607

3.2 Data Collection

The levels of pollutants from the four institutions were monitored for a period of six months and reported. Five hostels each located at IMSU vicinity and hostels located within AIFCE, FEDPOLYNEK and FUTO campuses with number of rooms ranging from 50 to 100, and population of students ranging from 250 to 800 people were selected for the study. Seven pollutants which include, NO_2, SO_2, H_2S, NH_3, CO, CH_4 and Particulate matters and four meteorological variables including relative humidity, wind speed, temperature, and irradiance were monitored. These pollutants were chosen based on numerous reported public health impacts and compatibility with available monitors. Readings were gathered for six months set periods beginning from February 2012 to July 2012. The samples were randomly collected in selected rooms in each Hostel including the passages, Kitchens, general sitting rooms and toilet areas so as to cover major anthropogenic activities going on the entire building (hostel). The concentrations of pollutants from different points in each hostel were used to estimate the total weighted pollutants generated indoors from each hostel. The assessment in each hostel was carried out once in a week, and in two sessions; that is, morning and afternoon per day. The morning session ranged from 8am to 11 am, while the afternoon session ranged from 2pm to 4 pm. The sampling period cut across rainy and dry season which amounts to a total of 960 observations. The sampling procedure followed WHO guidelines for assessment of indoor air quality parameters.

These concentrations of the pollutants were measured using Gasman gas monitors made of Crowcon gasman instruments, with models 1458C, 1918B, 1236A, HS0504, and 1113AC for CO, SO_2, NO_2, NH_3 and H_2S respectively while particulate matter concentrations were measured with Riken Keiti suspended particulate monitor NP-23714. Pollutants measurements were reported in ppm except particulate matters (PM) that was reported in µg/m[3].

The gas monitors operate with metal oxide (SnO_2) sensing principle. The monitors were located or positioned 1.5m above the floor level so that the pollutants were measured at about the sitting and breathing zone.

The values meteorological parameters were also taken at the same height using portable Multi-digital environmental meter model DLAF800, which gives direct onset reading of each parameter by mere selecting and switching to the required parameter on the instrument. Regression analysis was employed to further establish the level of relationship between the measured meteorological parameters and indoor pollutants.

3.3 Multiple regression modeling

The dependencies of the concentration of indoor pollutants monitored with the meteorological parameters were evaluated by multiple regression analysis using software known as the statistical package for social sciences (SPSS). This approach even though may not be the most effective in the interpretation of the obtained data is adpted here for ease of interpretation. The linear regression model was adopted to ascertain the variation in the average monthly air pollutants concentrations as a function of meteorological parameters which is expressed in equation form.

$$Y_i = F\ (a+X_1b_1+ X_2b_2 + X_3b_3 + e_i)$$

Where,

b= serial number of pollutants, Y = Pollutant, X_1 = Air Temperature (^{0}C), X_2 = Relative Humidity (%), X_3 = Wind Speed (m/s), X_4 = Irradiance (W/m_2), e = Error term.

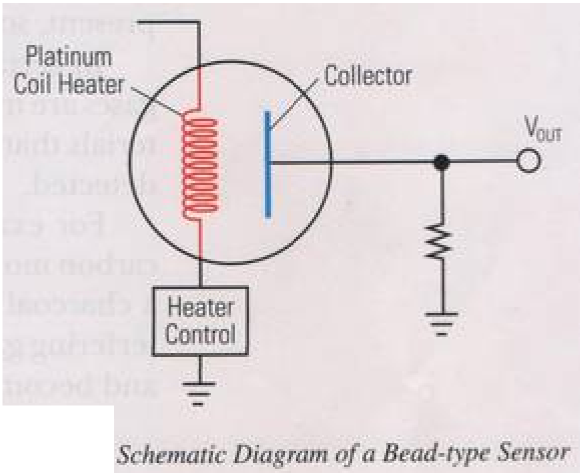
3.4.1. THE THEORY OF OPERATION OF METAL OXIDE GAS SENSING DEVICE.

A typical gas monitor consists of a sensor which is a transducer that detects gas molecules and which produces an electrical signal with a magnitude proportional to the concentration of the gas.

The model of monitors used in assessing the gases consist of sensors made of tin oxide. This metal oxide is prepared and processed into a paste and contains a heating element made of platinum alloy wire used to regulate the sensor temperature. The sensor exhibits different temperature gas response characteristics at different temperature ranges.

In the presence of a gas, the tin oxide causes the gas to dissociate into charged ions or complexes which results in transfer of electrons. The built-in heater, which heats the metal oxide materials to an operational temperature range that is optimal for the gas to be detected is regulated and controlled by a specific circuit.

A pair of biased electrodes is imbedded into the metal oxide to measure its conductivity. The changes in conductivity of the sensor resulting from the interaction with the gas molecules is measured as signal.



Schematic diagram of Bead-type sensor

Figure 3.2 schematic diagrams of Bead-type Metal-oxide sensors

Fig 3.3 The monitors used

Generally, reducing gases increase the conductivity of the SnO_2 gas sensing material while oxidizing gases decrease its conductivity. The reaction of oxygen species on the surface of the sensor with gaseous pollutants or the competitive adsorption and replacement of the adsorbed oxygen result in an increased conductivity. The simplified reaction steps are described in Equations (3.1, 3.2 & 3.3) and Fig 3.2 below

$$e^- + O_2 \longrightarrow O2^- \qquad 3.1$$

$$O_2 \longrightarrow 2O \qquad 3.2$$

$$e^- + O \rightarrow O^- \qquad 3.3$$

As shown in Fig 3(below), when exposed to reducing gas like CO, surface reactions such as; $CO + O^-_{ads} \rightarrow CO_2 + e^-$ and $2CO + O_2^-{}_{, ads} \longrightarrow 2CO_2 + e^-$ release electrons back to the SnO_2 and lead to a decrease in the resistance of a space charge layer.

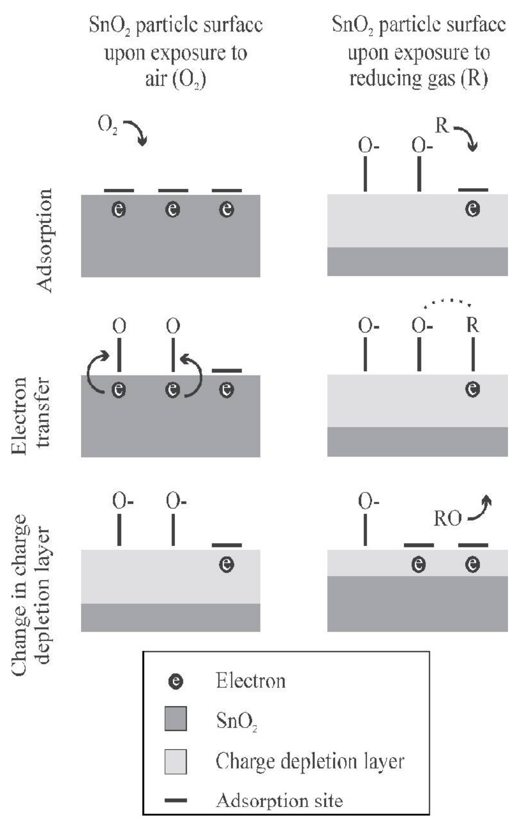


Fig 3.3 Schematics indicating the mechanism leading to SnO_2 sensor response to oxidizing and reducing gases ***(Barsan and Weimar, 2003).***

CHAPTER FOUR

RESULTS AND DISCUSION

The Average monthly variations of the monitored indoor pollutants; NO_2, CO, H_2S, NH_3, SO_2, CH_4 and particulate matters in the hostels of the four tertiary institutions are contained in Tables 4.1 to 4.48. Also, Figures 4.1 to 4.12 clearly show the graphical illustration of the variation of the pollutants across the months.

The monthly variation of temperature with relative humidity was shown in figures 4.13 to 4.20. Tables 4.49 to 4.52 show the statistical summary of the pollutants and meteorological variable for the period of the study. Again, Tables 4.53 to 4.55 gave the results of the regression analysis of the monitored pollutants with meteorological variables.

The results of the two-way analysis of variance for all the pollutants are showed in Tables 4.56 to 4.62.

4.1 RESULTS

Table 4.1 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE FEBRUARY 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.02	0.04	0.01	0.024	0.022	0.023	0.0153	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.45	4.00	3.80	3.76	3.74	3.750	0.2784	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.008	0.072	0.01	0.31	0.29	0.30	0.0364	-	0.107	-
Methane	CH_4	ppm	0.00	0.01	0.00	0.002	0.004	0.003	0.0052	-	-	-
Sulphur dioxide	SO_2	ppm	0.02	0.03	0.05	0.034	0.032	0.033	0.0153	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.009	0.013	0.014	0.013	0.011	0.0120	0.0026	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	40.5	56	44.5	46.0	48.0	47	8.047	150-250	150	150
Air Temperature	T	°C	30.60	30.00	30.00	30.3	30.1	30.200	0.3464			
Relative Humidity	RH	%	62.60	62.00	62.00	62.4	62.2	62.300	0.3000			
Wind Speed	WS	m/s	0.50	0.50	0.70	0.7	0.5	0.600	0.1000			
Irradiance	IRR	W/m^2	543.00	540.00	544.00	543.3	541.3	542.333	2.0817			

Table 4.2 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE

FEBRUARY 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.03	0.05	0.02	0.034	0.031	0.033	0.0153	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.00	4.50	3.50	3.00	5.00	4.000	0.5000	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.005	0.065	0.047	0.038	0.040	0.039	0.0308	-	0.107	-
Methane	CH_4	ppm	0.00	0.01	0.00	0.004	0.002	0.003	0.0052	-	-	-
Sulphur dioxide	SO_2	ppm	0.06	0.03	0.05	0.046	0.048	0.047	0.053	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.022	0.021	0.022	0.023	0.021	0.022	0.0003	-	-	-
Particulate Matter	PM	$\mu g/m^3$	50	65	55	55.6	57.6	56.67	7.638	150-250	150	150
Air Temperature	T	°C	35.50	35.00	35.40	35.4	35.2	35.300	0.2646			
Relative Humidity	RH	%	50.40	50.50	50.00	49.3	51.3	50.300	0.2646			
Wind Speed	WS	m/s	0.30	0.30	0.40	0.32	0.34	0.333	0.0577			
Irradiance	IRR	W/m^2	618.00	619.00	618.00	619	620	618.333	0.05774			

Table 4.3 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE
MARCH 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.02	0.05	0.03	0.02	0.04	0.033	0.0153	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.58	5.26	4.20	4.74	4.72	4.730	0.7495	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.046	0.049	0.049	0.049	0.047	0.048	0.0017	-	0.107	-
Methane	CH_4	ppm	0.003	0.00	0.01	0.005	0.003	0.0043	0.0051	-	-	-
Sulphur dioxide	SO_2	ppm	0.10	0.03	0.03	0.043	0.063	0.0533	0.0404	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.040	0.039	0.035	0.039	0.037	0.0380	0.0026	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	40	58	50	48	50	49.333	0.918	150-250	150	150
Air Temperature	T	°C	31.20	31.00	31.50	30.2	32.2	31.23	0.2517			
Relative Humidity	RH	%	78.10	78.60	78.00	77.2	79.2	78.23	0.3215			
Wind Speed	WS	m/s	0.30	0.35	0.30	0.32	0.30	0.3167	0.0289			
Irradiance	IRR	W/m^2	336.00	335.00	335.00	336.3	334.3	335.33	0.5774			

Table 4.4 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE
MARCH 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.06	0.05	0.03	0.044	0.042	0. 045	0.9978	0.062	0.053	0.06
Carbon monoxide	CO	ppm	6.50	7.50	6.00	6.6	6.4	6.6667	0.7638	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.074	0.040	0.060	0.04	0.06	0.0580	0.0171	-	0.107	-
Methane	CH_4	ppm	0.01	0.00	0.01	0.007	0.005	0.0063	0.0055	-	-	-
Sulphur dioxide	SO_2	ppm	0.15	0.08	1.50	0.058	0.056	0.05767	0.8004	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.040	0.039	0.047	0.043	0.041	0.0420	0.0044	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	65	72	85	73	75	74.0	10.149	150-250	150	150
Air Temperature	T	°C	34.50	35.00	35.00	34.9	34.7	34.8333	0.02887			
Relative Humidity	RH	%	53.40	58.20	58.60	56.83	56.63	56.7334	2.8937			
Wind Speed	WS	m/s	0.90	0.90	0.80	0.96	0.76	0.8657	0.0577			
Irradiance	IRR	W/m^2	878.00	879.00	872.00	886.3	866.3	876.3333	3.7859			

Table 4.5 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE
APRIL 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.019	0.020	0.017	0.021	0.018	0.019	0.005	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.50	3.60	3.40	2.50	4.50	3.50	0.126	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.028	0.026	0.030	0.027	0.029	0.028	0.0013	-	0.107	-
Methane	CH_4	ppm	0.0025	0.0026	0.024	0.0027	0.0023	0.0025	0.001	-	-	-
Sulphur dioxide	SO_2	ppm	0.030	0.050	0.010	0.040	0.029	0.030	0.013	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.010	0.030	0.00	0.00	0.00	0.010	0.004	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	37.1	36.0	39.0	35.0	38.10	37.0	0.58	150-250	150	150
Air Temperature	T	°C	30.0	28.10	27.10	29.10	31.10	29.1	1.23			
Relative Humidity	RH	%	72.11	70.10	68.10	71.10	69.10	70.11	1.86			
Wind Speed	WS	m/s	0.466	0.74	0.751	0.77	0.75	0.7651	0.06			
Irradiance	IRR	W/m^2	127.0	125.0	129.0	126.0	128.0	127.0	0.81			

Table 4.6 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE

APRIL 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.028	0.030	0.026	0.027	0.029	0.028	0.005	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.80	3.70	3.90	4.00	3.60	3.80	0.146	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.03	0.02	0.01	0.04	0.05	0.030	0.008	-	0.107	-
Methane	CH_4	ppm	0.003	0.001	0.00	0.003	0.004	0.002	0.001	-	-	-
Sulphur dioxide	SO_2	ppm	0.030	0.032	0.033	0.034	0.031	0.032	0.003	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.018	0.014	0.021	0.017	0.020	0.019	0.0022	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	43.0	44.0	45.0	42.0	41.1	43.0	2.36	150-250	150	150
Air Temperature	T	°C	31.1	30.0	33.0	29.0	32.0	31.0	0.62			
Relative Humidity	RH	%	65.6	66.5	67.6	64.5	63.5	65.6	1.28			
Wind Speed	WS	m/s	0.31	0.30	0.33	0.34	0.29	0.31	0.05			
Irradiance	IRR	W/m^2	726	730	722	727	728	726	1.58			

Table 4.7 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE
MAY 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.003	0.004	0.002	0.004	0.002	0.0030	0.0010	0.062	0.053	0.06
Carbon monoxide	CO	ppm	2.200	2.600	2.800	2.63	2.43	2.5333	0.3055	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.010	0.030	0.020	0.03	0.01	0.0200	0.0100	-	0.107	-
Methane	CH_4	ppm	0.002	0.003	0.003	0.003	0.001	0.0023	0.0006	-	-	-
Sulphur dioxide	SO_2	ppm	0.010	0.002	0.010	0.014	0.012	0.0133	0.0058	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.010	0.020	0.005	0.012	0.013	0.0117	0.0076	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	0.90	15	12	10.3	8.3	9.3	7.428	150-250	150	150
Air Temperature	T	°C	28.100	28.300	28.000	28.14	28.12	28.1333	0.1528			
Relative Humidity	RH	%	73.400	73.200	73.000	74.2	72.4	73.2000	0.2000			
Wind Speed	WS	m/s	0.200	0.250	0.200	0.31	0.11	0.2167	0.0289			
Irradiance	IRR	W/m^2	328.000	127.000	126.000	128	126	127.0000	1.0000			

Table 4.8 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE MAY 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.003	0.004	0.002	0.004	0.002	0.0030	0.0010	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.300	4.400	2.80	3.60	3.40	3.5000	0.8185	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.010	0.040	0.010	0.03	0.010	0.0200	0.0173	-	0.107	-
Methane	CH_4	ppm	0.001	0.002	0.003	0.003	0.001	0.0020	0.0010	-	-	-
Sulphur dioxide	SO_2	ppm	0.010	0.020	0.030	0.001	0.003	0.0200	0.0100	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.000	0.030	0.010	0.014	0.012	0.0133	0.0153	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	9.0	10.000	8.00	10.0	8.00	9.00	0.1	150-250	150	150
Air Temperature	T	°C	32.900	32.000	32.000	32.4	32.2	32.3000	0.5196			
Relative Humidity	RH	%	66.700	66.500	66.000	66.3	66.5	66.4000	0.3606			
Wind Speed	WS	m/s	0.700	0.600	0.500	0.7	0.5	0.6000	0.1000			
Irradiance	IRR	W/m^2	625.000	625.000	625.000	626	624	625.0000	0.0000			

Table 4.9 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE
JUNE 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.005	0.02	0.01	0.012	0.010	0.0117	0.0076	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.00	3.50	2.80	3.2	3.0	3.1000	0.3606	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.040	0.093	0.056	0.064	0.062	0.0630	0.0272	-	0.107	-
Methane	CH_4	ppm	0.00	0.01	0.00	0.004	0.002	0.0033	0.0058	-	-	-
Sulphur dioxide	SO_2	ppm	0.008	0.01	0.01	0.01	0.008	0.0093	0.0012	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.043	0.048	0.044	0.046	0.044	0.0450	0.0026	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	18	21	9	15	17	16	6.245	150-250	150	150
Air Temperature	T	°C	23.00	23.50	23.00	23.17	23.15	23.1667	0.2887			
Relative Humidity	RH	%	87.90	87.10	87.00	88.3	86.3	87.3333	0.4933			
Wind Speed	WS	m/s	1.30	1.30	0.90	1.17	1.15	1.1667	0.2009			
Irradiance	IRR	W/m^2	44.00	44.00	46.00	43.6	45.6	44.6667	1.1547			

Table 4.10 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE
JUNE 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.01	0.01	0.01	0.008	0.01	0.0093	0.0012	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.34	3.20	4.00	3.74	3.94	3.8467	0.5853	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.080	0.043	0.081	0.07	0.05	0.0680	0.0217	-	0.107	-
Methane	CH_4	ppm	0.01	0.01	0.20	0.08	0.06	0.0733	0.1097	-	-	-
Sulphur dioxide	SO_2	ppm	0.01	0.01	0.01	0.002	0.004	0.0039	0.0012	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.059	0.059	0.068	0.063	0.061	0.0620	0.0052	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	18	23.6	12	18.8	19.8	17.867	5.801	150-250	150	150
Air Temperature	T	°C	25.20	25.30	25.50	26.33	24.33	25.3333	0.1528			
Relative Humidity	RH	%	80.20	81.10	80.50	80.58	80.55	80.5667	0.4041			
Wind Speed	WS	m/s	0.60	0.59	0.50	0.66	0.46	0.5633	0.0551			
Irradiance	IRR	W/m^2	44.00	45.00	44.00	44.34	44.32	44.3333	0.5774			

Table 4.11 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE

JULY 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.02	0.008	0.006	0.012	0.010	0.0113	0.0076	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.05	2.50	3.80	3.46	3.44	3.4500	0.8322	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.080	0.085	0.078	0.07	0.09	0.0810	0.0036	-	0.107	-
Methane	CH_4	ppm	0.01	0.06	0.00	0.033	0.013	0.0233	0.0321	-	-	-
Sulphur dioxide	SO_2	ppm	0.02	0.005	0.01	0.013	0.014	0.0117	0.0076	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.063	0.064	0.068	0.066	0.064	0.0650	0.0026	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	20	25	15	22	18	20	5	150-250	150	150
Air Temperature	T	°C	27.90	26.50	27.60	27.32	27.34	27.3333	0.7371			
Relative Humidity	RH	%	80.50	81.00	81.60	81.04	81.01	81.0333	0.5508			
Wind Speed	WS	m/s	0.40	0.40	0.35	0.37	0.39	0.3833	0.0289			
Irradiance	IRR	W/m^2	339.00	340.00	339.00	338	340	339.3333	0.5774			

Table 4.12 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR AIFCE JULY 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.03	0.01	0.007	0.018	0.015	0.0157	0.0125	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.15	3.80	3.00	3.63	3.67	3.6500	0.5895	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.135	0.110	0.160	0.15	0.13	0.1350	0.0250	-	0.107	-
Methane	CH_4	ppm	0.01	0.02	0.10	0.042	0.044	0.0433	0.0493	-	-	-
Sulphur dioxide	SO_2	ppm	0.01	0.02	0.03	0.011	0.013	0.0187	0.0121	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.083	0.089	0.092	0.087	0.089	0.0880	0.0046	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	21.5	20.6	15	18.03	20.03	19.033	3.522	150-250	150	150
Air Temperature	T	°C	30.40	30.50	31.00	30.64	30.62	30.6333	0.3215			
Relative Humidity	RH	%	71.60	72.50	71.50	71.76	71.96	71.8667	0.5508			
Wind Speed	WS	m/s	1.20	1.30	1.10	1.1	1.2	1.2000	0.1000			
Irradiance	IRR	W/m^2	420.00	423.00	424.00	423	421	422.3333	2.0817			

Table 4.13 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR IMSU

FEBRUARY 2012 (MORNING) 10:00AM-11:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.04	0.05	0.03	0.042	0.038	0.040	0.0100	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.25	5.00	5.50	4.93	4.91	4.92	0.6292	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.055	0.025	0.055	0.044	0.046	0.045	0.0173	-	0.107	-
Methane	CH_4	ppm	0.01	0.01	0.00	0.007	0.005	0.006	0.0055	-	-	-
Sulphur dioxide	SO_2	ppm	0.03	015	0.06	0.007	0.009	0.008	0.0624	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.030	0.022	0.023	0.026	0.024	0.025	0.0044	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	52.5	60.5	56.0	56.32	56.34	56.33	4.01	150-250	150	150
Air Temperature	T	°C	32.50	32.00	32.00	32.16	32.18	32.17	0.2887			
Relative Humidity	RH	%	58.00	59.00	59.00	56.66	60.67	58.66	0.5774			
Wind Speed	WS	m/s	0.30	0.30	0.04	0.20	0.22	0.213	0.1501			
Irradiance	IRR	W/m^2	618.00	618.00	618.00	619	615	617.3	1.1547			

Table 4.14 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR IMSU FEBRUARY 2012 (AFTERNOON) 3:00PM-4:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.12	0.05	0.03	0.068	0.066	0.067	0.0473	0.062	0.053	0.06
Carbon monoxide	CO	ppm	5.8	6.0	6.5	6.30	5.90	6.100	0.3606	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.050	0.010	0.090	0.04	0.06	0.050	0.0400	-	0.107	-
Methane	CH_4	ppm	0	0	0.01	0.004	0.002	0.003	0.0058	-	-	-
Sulphur dioxide	SO_2	ppm	0.03	0.18	0.15	0.012	0.014	0.013	0.0794	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.033	0.036	0.036	0.036	0.034	0.035	0.0017	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	65	59.2	50	57.07	59.06	58.07	7.564	150-250	150	150
Air Temperature	T	°C	37.3	37.2	37.1	36.90	37.5	37.200	0.1000			
Relative Humidity	RH	%	45.8	45.3	45	45.36	45.38	45.367	0.4041			
Wind Speed	WS	m/s	3	3.1	3.2	2.9	3.3	3.100	0.1000			
Irradiance	IRR	W/m^2	905	906	904	903	907	905.000	1.0000			

Table 4.15 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR IMSU
MARCH 2012 (MORNING) 10:00AM-11:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.04	0.05	0.02	0.046	0.044	0.045	0.0153	0.062	0.053	0.06
Carbon monoxide	CO	ppm	6.05	7.12	5.00	6.058	6.056	6.057	1.0600	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.0682	0.0681	0.0686	0.066	0.07	0.068	0.0003	-	0.107	-
Methane	CH_4	ppm	0.002	0.00	0.001	0.004	0.002	0.003	0.0000	-	-	-
Sulphur dioxide	SO_2	ppm	0.01	0.03	0.06	0.055	0.057	0.056	0.0252	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.041	0.039	0.040	0.03	0.05	0.040	0.0010	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	81.5	60	90	78.17	76.17	77.17	15.462	150-250	150	150
Air Temperature	T	°C	31.60	31.60	31.00	31.50	31.30	31.400	0.3464			
Relative Humidity	RH	%	74.00	74.30	74.00	73.1	75.1	74.100	0.2732			
Wind Speed	WS	m/s	0.80	0.7	0.80	0.9	0.8	0.800	0.0000			
Irradiance	IRR	W/m^2	370.00	371.00	371.00	368.7	372.6	370.7	0.5774			

Table 4.16 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR IMSU MARCH 2012 (AFTERNOON) 3:00PM-4:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.04	0.8	0.15	0.06	0.04	0.05	0.4107	0.062	0.053	0.06
Carbon monoxide	CO	ppm	7.56	9.25	8.23	8.33	8.34	8.35	0.8510	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.071	0.072	0.072	0.074	0.070	0.072	0.0003	-	0.107	-
Methane	CH_4	ppm	0.008	0.00	0.001	0.002	0.004	0.003	0.0044	-	-	-
Sulphur dioxide	SO_2	ppm	0.03	1.05	0.05	0.039	0.037	0.38	0.5832	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.051	0.054	0.051	0.04	0.06	0.05	0.0017	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	90	60	100	84.3	82.3	83.3	2.0817	150-250	150	150
Air Temperature	T	°C	33.9	33.2	33	33.39	33.36	33.37	0.4726			
Relative Humidity	RH	%	59.1	59	59.2	58.7	59.13	59.10	0.1000			
Wind Speed	WS	m/s	0.2	0.25	0.3	0.28	0.22	0.25	0.0500			
Irradiance	IRR	W/m^2	733	734	733	733	735	733.33	0.5774			

Table 4.17 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR IMSU
APRIL 2012 (MORNING) 10:00AM-11:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.02	0.04	0.03	0.00	0.01	0.02	0.006	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.1	2.9	3.0	3.2	2.8	3.0	0.134	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.028	0.026	0.027	0.030	0.029	0.028	0.0021	-	0.107	-
Methane	CH_4	ppm	0.003	0.001	0.005	0.000	0.002	0.003	0.001	-	-	-
Sulphur dioxide	SO_2	ppm	0.06	0.04	0.03	0.05	0.02	0.040	0.003	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.020	0.012	0.01	0.04	0.03	0.020	0.001	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	41.0	42.0	38.1	40.0	39.1	40.0	1.732	150-250	150	150
Air Temperature	T	°C	27.5	26.6	29.6	28.5	20.6	28.6	2.06			
Relative Humidity	RH	%	74.5	71.6	72.4	73.6	70.6	72.6	3.16			
Wind Speed	WS	m/s	0.21	0.20	0.19	0.22	0.23	0.21	0.008			
Irradiance	IRR	W/m^2	184	186	188	187	185	186	0.92			

Table 4.18 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR IMSU
APRIL 2012 (AFTERNOON) 3:00PM-4:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.03	0.04	0.05	0.06	0.02	0.04	0.0158	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.11	6.10	3.12	2.10	5.10	4.10	0.153	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.03	0.01	0.02	0.05	0.04	0.03	0.0126	-	0.107	-
Methane	CH_4	ppm	0.002	0.001	0.00	0.004	0.003	0.002	0.001	-	-	-
Sulphur dioxide	SO_2	ppm	0.030	0.027	0.028	0.029	0.031	0.029	0.009	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.030	0.032	0.033	0.031	0.034	0.032	0.01	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	44.0	45.1	46.0	48.1	47.0	46.0	1.68	150-250	150	150
Air Temperature	T	°C	32.10	34.10	33.10	30.00	31.00	32.10	0.92			
Relative Humidity	RH	%	64.0	56.0	60.10	61.0	59.0	60	2.01			
Wind Speed	WS	m/s	0.25	0.27	0.26	0.27	0.24	0.25	0.06			
Irradiance	IRR	W/m^2	655	653	654	651	652.1	653.0	1.82			

Table 4.19 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR IMSU
MAY 2012 (MORNING) 10:00AM-11:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.001	0.003	0.002	0.003	0.001	0.002	0.0010	0.062	0.053	0.06
Carbon monoxide	CO	ppm	1.400	1.600	1.500	1.3	1.7	1.500	0.1000	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.040	0.020	0.030	0.04	0.03	0.030	0.0100	-	0.107	-
Methane	CH_4	ppm	0.002	0.005	0.002	0.002	0.004	0.003	0.0017	-	-	-
Sulphur dioxide	SO_2	ppm	0.001	0.003	0.002	0.003	0.002	0.002	0.0010	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.010	0.010	0.010	0.009	0.02	0.010	0.0000	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	7.50	8. 50	7.90	8.96	6.97	7.96	0.5030	150-250	150	150
Air Temperature	T	°C	29.000	28.600	29.50	28.02	30.03	29.03	0.4509			
Relative Humidity	RH	%	71.000	71.000	72.00	72.32	69.33	71.33	0.5774			
Wind Speed	WS	m/s	0.300	0.300	0.200	0.24	0.28	0.266	0.0577			
Irradiance	IRR	W/m^2	157.00	154.000	156.0	156.7	154.6	155.7	1.5275			

Table 4.20 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR IMSU
MAY 2012 (AFTERNOON) 3:00PM-4:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.004	0.003	0.005	0.003	0.004	0.0010	0.0014	0.062	0.053	0.06
Carbon monoxide	CO	ppm	1.8	1.5	1.50	1.70	1.600	0.1732	0.125	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.020	0.020	0.03	0.01	0.020	0.0000	0.016	-	0.107	-
Methane	CH_4	ppm	0.003	0.004	0.003	0.005	0.004	0.0010		-	-	-
Sulphur dioxide	SO_2	ppm	0.004	0.001	0.002	0.004	0.003	0.0017	0.0022	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.01	0.02	0.01	0.03	0.020	0.0100	0.001	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	14.0	18.0	17.0	13.0	15.00	2.646	0.152	150-250	150	150
Air Temperature	T	°C	33.0	33.2	32.2	34.20	33.20	0.2000	0.245			
Relative Humidity	RH	%	62.5	62.3	61.47	63.48	62.47	0.1528	0.26			
Wind Speed	WS	m/s	0.5	0.4	0.48	0.46	0.47	0.0577	0.023			
Irradiance	IRR	W/m^2	635	633	633	635	634.0	634.0	1.26			

Table 4.21 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR IMSU

JUNE 2012 (MORNING) 10:00AM-11:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.006	0.008	0.01	0.007	0.007	0.008	0.0020	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.50	2.60	2.10	2.63	2.83	2.733	0.9095	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.071	0.072	0.092	0.088	0.067	0.078	0.0118	-	0.107	-
Methane	CH_4	ppm	0.00	0.12	0.01	0.043	0.044	0.043	0.0666	-	-	-
Sulphur dioxide	SO_2	ppm	0.01	0.009	0.01	0.01	0.008	0.009	0.0006	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.076	0.075	0.074	0.074	0.076	0.075	0.0010	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	5	15	20	14.33	12.33	13.33	7.638	150-250	150	150
Air Temperature	T	°C	24.10	24.00	24.10	23.06	25.05	24.06	0.0577			
Relative Humidity	RH	%	86.30	86.50	86.20	86.34	86.32	86.33	0.1528			
Wind Speed	WS	m/s	0.70	0.70	0.60	0.66	0.68	0.67	0.0577			
Irradiance	IRR	W/m^2	61.00	63.00	61.00	62.67	60.68	61.67	1.1547			

Table 4.22 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR IMSU

JUNE 2012 (AFTERNOON) 3:00PM-4:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.01	0.005	0.02	0.014	0.01	0.012	0.0076	0.062	0.053	0.06
Carbon monoxide	CO	ppm	2.50	4.26	3.80	3.50	3.54	3.520	0.9128	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.135	0.164	0.169	0.017	0.018	0.156	0.0184	-	0.107	-
Methane	CH_4	ppm	0.01	0.00	0.001	0.005	0.003	0.004	0.055	-	-	-
Sulphur dioxide	SO_2	ppm	0.02	0.008	0.00	0.01	0.008	0.009	0.0101	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.123	0.129	0.126	0.120	0.140	0.153	0.0030	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	25	20	16	21.3	19.3	20.33	4.509	150-250	150	150
Air Temperature	T	°C	28.70	27.90	28.50	27.36	29.37	28.37	0.4163			
Relative Humidity	RH	%	76.40	77.00	76.10	77.5	75.5	76.50	0.4583			
Wind Speed	WS	m/s	0.90	0.80	0.90	0.86	0.88	0.87	0.0577			
Irradiance	IRR	W/m^2	392.00	390.00	392.00	392.3	390.3	391.3	1.1547			

Table 4.23 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR IMSU JULY 2012 (MORNING) 10:00AM-11:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.01	0.02	0.03	0.03	0.01	0.020	0.0100	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.5	3.6	5.6	4.24	4.22	4.23	1.1846	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.240	0.270	0.240	0.24	0.26	0.25	0.0173	-	0.107	-
Methane	CH_4	ppm	0.01	0.001	0	0.005	0.003	0.004	0.0055	-	-	-
Sulphur dioxide	SO_2	ppm	0.02	0.006	0.005	0.02	0.009	0.010	0.0084	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.25	0.15	0.25	0.24	0.20	0.22	0.0577	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	31.5	8	20.6	19.03	21.04	20.03	11.760	150-250	150	150
Air Temperature	T	°C	33.5	33	33	34.17	32.16	33.17	0.2887			
Relative Humidity	RH	%	67.7	67.5	67	67.38	67.42	67.40	0.3606			
Wind Speed	WS	m/s	0.3	0.3	0.2	0.29	0.25	0.27	0.0577			
Irradiance	IRR	W/m^2	612	613	610	610.6	612.7	611.7	1.5275			

Table 4.24 AIR POLLUTANTS CONCENTRATIONS AND METEOROLOGICAL VARIABLES FOR IMSU JULY 2012 (AFTERNOON) 3:00PM-4:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.01	0.02	0.03	0.03	0.01	0.020	0.0100	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.5	3.6	5.6	4.24	4.22	4.23	1.1846	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.240	0.270	0.240	0.24	0.26	0.25	0.0173	-	0.107	-
Methane	CH_4	ppm	0.01	0.001	0	0.005	0.003	0.004	0.0055	-	-	-
Sulphur dioxide	SO_2	ppm	0.02	0.006	0.005	0.02	0.009	0.010	0.0084	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.25	0.15	0.25	0.24	0.20	0.22	0.0577	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	31.5	8	20.6	19.03	21.04	20.03	11.760	150-250	150	150
Air Temperature	T	°C	33.5	33	33	34.17	32.16	33.17	0.2887			
Relative Humidity	RH	%	67.7	67.5	67	67.38	67.42	67.40	0.3606			
Wind Speed	WS	m/s	0.3	0.3	0.2	0.29	0.25	0.27	0.0577			
Irradiance	IRR	W/m^2	612	613	610	610.6	612.7	611.7	1.5275			

Table 4.25 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK FEBRUARY 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.03	0.03	0.04	0.014	0.012	0.0130	0.0061	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.50	3.80	4.00	4.11	4.15	4.1333	0.7572	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.042	0.010	0.020	0.030	0.034	0.0327	0.0021	-	0.107	-
Methane	CH_4	ppm	0.009	0.000	0.00	0.002	0.004	0.0027	0.0046	-	0.2	-
Sulphur dioxide	SO_2	ppm	0.02	0.01	0.01	0.004	0.002	0.0030	0.0026	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.012	0.010	0.011	0.036	0.034	0.0350	0.0040	-	-	-
Particulate Matter	PM	$\mu g/m^3$	32.5	25	20	22.66	20.7	21.667	7.638	150-250	150	150
Air Temperature	T	°C	29.00	29.60	29.80	29.7	29.5	29.6000	0.1732			
Relative Humidity	RH	%	74.20	74.50	74.00	74.28	74.26	74.2667	0.2517			
Wind Speed	WS	m/s	0.90	0.09	0.08	0.85	0.81	0.8333	0.0577			
Irradiance	IRR	W/m^2	335.00	336.00	335.00	388	390	389.3333	1.1547			

Table 4.26 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK FEBRUARY 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.02	0.04	0.05	0.038	0.036	0.037	0.0153	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.90	4.00	4.50	4.12	4.14	4.133	0.3215	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.034	0.040	0.030	0.036	0.034	0.035	0.0050	-	0.107	-
Methane	CH_4	ppm	0.00	0.00	0.01	0.005	0.004	0.003	0.0058	-	-	-
Sulphur dioxide	SO_2	ppm	0.30	0.008	0.01	0.02	0.009	0.010	0.0122	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.029	0.025	0.036	0.031	0.029	0.030	0.0056	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	39.5	2.80	25	30.82	30.84	30.83	7.654	150-250	150	150
Air Temperature	T	°C	35.40	35.80	35.10	35.41	35.45	35.433	0.3512			
Relative Humidity	RH	%	62.20	62.00	62.50	62.21	62.25	62.233	0.2517			
Wind Speed	WS	m/s	0.30	0.30	0.30	0.3	0.3	0.3	0.0000			
Irradiance	IRR	W/m^2	1047.00	1045.00	1046.00	1017	1015	1016.00	1.0000			

Table 4.27 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK
MARCH 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.02	0.009	0.01	0.014	0.012	0.0130	0.0061	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.60	3.80	5.00	4.14	4.12	4.1333	0.7572	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.031	0.035	0.032	0.032	0.034	0.0327	0.0021	-	0.107	-
Methane	CH_4	ppm	0.00	0.008	0.00	0.004	0.001	0.0027	0.0046	-	-	-
Sulphur dioxide	SO_2	ppm	0.01	0.01	0.005	0.007	0.009	0.0080	0.0026	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.031	0.039	0.035	0.034	0.036	0.0350	0.0040	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	30	20	15	20.67	22.66	21.667	7.638	150-250	150	150
Air Temperature	T	°C	29.80	29.50	29.50	30.6	28.6	29.6000	0.1732			
Relative Humidity	RH	%	74.50	74.00	74.30	75.26	73.26	74.2667	0.2517			
Wind Speed	WS	m/s	0.90	0.80	0.80	0.81	0.85	0.8333	0.0577			
Irradiance	IRR	W/m^2	390.00	388.00	390.00	390.3	388	389.3333	1.1547			

Table 4.28 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK
MARCH 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.01	0.03	0.02	0.020	0.018	0.0193	0.0110	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.00	4.00	5.50	4.6	4.4	4.5000	0.8660	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.041	0.041	0.042	0.040	0.042	0.041	0.0003	-	0.107	-
Methane	CH_4	ppm	0.00	0.00	0.001	0.002	0.004	0.0003	0.0006	-	-	-
Sulphur dioxide	SO_2	ppm	0.03	0.01	0.01	0.018	0.02	0.0167	0.0115	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.036	0.038	0.040	0.040	0.036	0.0380	0.0020	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	25	30	45	33.34	33.35	33.333	10.408	150-250	150	150
Air Temperature	T	°C	38.10	38.10	38.60	36.27	37.26	38.2667	0.2887			
Relative Humidity	RH	%	49.40	49.40	49.00	50.26	48.26	49.2667	0.2309			
Wind Speed	WS	m/s	0.70	0.60	0.70	0.7	0.5	0.6667	0.0677			
Irradiance	IRR	W/m^2	980.00	978.00	983.00	981.0	979.0	980.3333	2.5166			

Table 4.29 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK
APRIL 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.023	0.024	0.022	0.021	0.020	0.022	0.0182	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.00	5.00	1.00	3.00	0.60	3.00	0.036	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.019	0.020	0.021	0.017	0.018	0.019	0.015	-	0.107	-
Methane	CH_4	ppm	0.002	0.003	0.004	0.001	0.001	0.002	0.004	-	-	-
Sulphur dioxide	SO_2	ppm	0.007	0.009	0.006	0.005	0.00	0.007	0.001	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.008	0.001	0.007	0.009	0.006	0.008	0.001	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	22.0	18.0	21.0	20.0	19.0	20.0	0.52	150-250	150	150
Air Temperature	T	°C	25.6	24.5	23.6	26.6	27.5	25.6	1.51			
Relative Humidity	RH	%	75.1	76.1	74.2	77.2	78.2	76.2	1.51			
Wind Speed	WS	m/s	0.32	0.30	0.33	0.31	0.34	0.32	0.06			
Irradiance	IRR	W/m^2	184.0	187.0	186.0	188.0	166.00	1.26				

Table 4.30 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK APRIL 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.025	0.027	0.023	0.024	0.026	0.025	0.008	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.60	3.50	5.60	2.50	1.50	3.60	0.0126	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.02	0.01	0.03	0.05	0.04	0.03	0.008	-	0.107	-
Methane	CH_4	ppm	0.003	0.001	0.005	0.004	0.00	0.003	0.001	-	-	-
Sulphur dioxide	SO_2	ppm	0.016	0.014	0.015	0.018	0.017	0.016	0.01	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.02	0.04	0.03	0.02	0.05	0.02	0.006	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	25.1	26.0	24.0	27.1	23.0	25.0	0.52	150-250	150	150
Air Temperature	T	°C	30.7	31.8	32.8	28.7	29.8	30.8	0.82			
Relative Humidity	RH	%	53.5	52.5	54.5	50.4	51.3	52.5	1.26			
Wind Speed	WS	m/s	0.42	0.41	0.40	0.44	0.43	0.42	0.04			
Irradiance	IRR	W/m^2	730	722	726	727	725	726	0.92			

Table 4.31 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK MAY 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.0040	0.0020	0.0030	0.004	0.002	0.0030	0.0010	0.062	0.053	0.06
Carbon monoxide	CO	ppm	1.5400	1.5100	1.4500	1.52	1.54	1.5000	0.0458	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.0100	0.0100	0.0100	0.03	0.008	0.0100	0.0000	-	0.107	-
Methane	CH_4	ppm	0.0040	0.0030	0.0020	0.005	0.001	0.0030	0.0010	-	-	-
Sulphur dioxide	SO_2	ppm	0.0150	0.0160	0.0120	0.016	0.012	0.0143	0.0021	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.0060	0.0030	0.0060	0.007	0.003	0.0050	0.0017	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	10.0	9.0	11.0	8.0	12.0	10.0	0.1000	150-250	150	150
Air Temperature	T	°C	26.5000	26.2000	26.3000	26.35	26.31	26.3333	0.1528			
Relative Humidity	RH	%	81.6000	80.3000	81.0000	80.94	80.98	80.9667	0.6506			
Wind Speed	WS	m/s	0.7000	0.6000	0.5000	0.8	0.4	0.6000	0.1000			
Irradiance	IRR	W/m^2	125.000	123.000	124.000	126	122	124.000	1.000			

Table 4.32 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK
MAY 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.0040	0.0020	0.0030	0.005	0.001	0.0030	0.0010	0.062	0.053	0.06
Carbon monoxide	CO	ppm	1.5400	1.5100	1.4500	1.7	1.3	1.5000	0.0458	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.0100	0.0100	0.0100	0.008	0.03	0.0100	0.0000	-	0.107	-
Methane	CH_4	ppm	0.0040	0.0030	0.0020	0.005	0.001	0.0030	0.0010	-	-	-
Sulphur dioxide	SO_2	ppm	0.0150	0.0160	0.0120	0.016	0.012	0.0143	0.0021	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.0060	0.0030	0.0060	0.007	0.003	0.0050	0.0017	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	10	9	11	8.0	12.0	10	1.0000	150-250	150	150
Air Temperature	T	°C	26.5000	26.2000	26.3000	26.31	26.35	26.3333	0.1528			
Relative Humidity	RH	%	81.6000	80.3000	81.0000	80.98	80.94	80.9667	0.6506			
Wind Speed	WS	m/s	0.7000	0.6000	0.5000	0.4	0.8	0.6000	0.1000			
Irradiance	IRR	W/m^2	125.0000	123.0000	124.0000	126	122	124.0000	1.0000			

Table 4.33 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK
JUNE 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.01	0.008	0.02	0.015	0.011	0.0127	0.0064	0.062	0.053	0.06
Carbon monoxide	CO	ppm	2.10	1.80	3.10	2.31	2.35	2.3333	0.6807	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.40	0.065	0.060	0.065	0.045	0.0550	0.0132	-	0.107	-
Methane	CH_4	ppm	0.00	0.00	0.008	0.001	0.005	0.0027	0.0046	-	-	-
Sulphur dioxide	SO_2	ppm	0.01	0.008	0.01	0.007	0.001	0.009	0.0012	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.050	0.030	0.040	0.06	0.02	0.0400	0.0100	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	0.60	1	15	5.33	9.33	7.333	0.7095	150-250	150	150
Air Temperature	T	°C	263	26.50	26.00	26.29	26.25	26.2667	0.2517			
Relative Humidity	RH	%	85.60	85.80	86.00	85.6	86.0	85.8000	0.2000			
Wind Speed	WS	m/s	0.30	0.30	0.20	0.5	0.1	0.2667	0.0577			
Irradiance	IRR	W/m^2	86.00	86.50	86.00	86.14	86.18	86.1667	0.2887			

Table 4.34 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK
JUNE 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.01	0.01	0.005	0.006	0.01	0.0082	0.0029	0.062	0.053	0.06
Carbon monoxide	CO	ppm	2.50	3.80	4.10	3.45	3.49	3.4667	0.8505	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.020	0.070	0.090	0.08	0.04	0.0600	0.0361	-	0.107	-
Methane	CH_4	ppm	0.01	0.00	0.02	0.016	0.012	0.014	0.0100	-	0.2	-
Sulphur dioxide	SO_2	ppm	0.02	0.01	0.01	0.015	0.011	0.013	0.0064	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.057	0.056	0.058	0.055	0.059	0.057	0.0010	-	-	-
Particulate Matter	PM	µg/m³	15	20	8.0	12.33	16.33	14.33	6.028	150-250	150	150
Air Temperature	T	°C	29.20	29.80	29.30	29.41	29.45	29.43	0.3215			
Relative Humidity	RH	%	79.90	79.50	79.60	80.66	78.65	79.66	02082			
Wind Speed	WS	m/s	2.10	1.90	2.00	0.8	2.2	2.0000	0.1000			
Irradiance	IRR	W/m²	176.00	175.00	176.50	175.2	177.2	175.98	0.2887			

Table 4.35 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK
JULY 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.005	0.02	0.004	0.006	0.01	0.009	0.0103	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.00	4.20	3.50	3.54	3.58	3.564	0.6028	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.062	0.090	0.083	0.076	0.080	0.078	0.0146	-	0.107	-
Methane	CH_4	ppm	0.002	0.00	0.001	0.002	0.001	0.008	0.0010	-	-	-
Sulphur dioxide	SO_2	ppm	0.001	0.01	0.02	0.008	0.03	0.014	0.0095	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.055	0.051	0.056	0.052	0.056	0.054	0.0026	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	9	20	15	12.67	16.66	14.66	5.508	150-250	150	150
Air Temperature	T	°C	28.90	28.50	28.50	28.65	28.61	28.63	0.2309			
Relative Humidity	RH	%	75.60	76.00	75.40	74.66	76.66	75.66	0.3055			
Wind Speed	WS	m/s	0.40	0.40	0.50	0.53	0.33	0.43	0.0577			
Irradiance	IRR	W/m^2	280.00	281.00	280.00	282.2	278.3	280.3	0.5774			

Table 4.36 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FEDPOLYNEK
JULY 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.002	0.01	0.04	0.018	0.016	0.017	0.0200	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.50	4.20	5.00	4.26	4.20	4.233	0.7506	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.079	0.075	0.092	0.080	0.084	0.082	0.0089	-	0.107	-
Methane	CH_4	ppm	0.01	0.00	0.001	0.004	0.002	0.0037	0.0055	-	-	-
Sulphur dioxide	SO_2	ppm	0.006	0.01	0.02	0.014	0.010	0.0120	0.0072	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.061	0.071	0.075	0.09	0.05	0.0700	0.0056	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	20	18.5	25	19.17	23.17	21.17	3.403	150-250	150	150
Air Temperature	T	°C	32.70	33.00	32.80	33.83	31.84	32.833	0.1528			
Relative Humidity	RH	%	68.90	67.90	65.00	68.27	66.26	67.2667	2.0257			
Wind Speed	WS	m/s	0.70	0.70	0.60	0.56	0.77	0.66	0.0577			
Irradiance	IRR	W/m^2	628.00	626.00	628.00	630.3	624.3	627.33	1.1547			

Table 4.37 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO FEBRUARY 2012 (MORNING) 10:00AM-11:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.008	0.02	0.03	0.021	0.017	0.019	0.0110	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.0	2.92	3.5	3.12	3.16	3.140	0.3143	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.010	0.030	0.020	0.03	0.01	0.020	0.0100	-	0.107	-
Methane	CH_4	ppm	0.01	0.00	0.009	0.004	0.008	0.006	0.0055	-	-	-
Sulphur dioxide	SO_2	ppm	0.01	0.007	0.02	0.14	0.10	0.012	0.0068	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.030	0.025	0.029	0.030	0.026	0.028	0.0026	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	25	30	28	28.67	26.67	27.67	0.2517	150-250	150	150
Air Temperature	T	°C	30.4	29.8	30.5	29.23	31.23	30.233	0.3786			
Relative Humidity	RH	%	72.6	72.5	72	73.36	71.37	72.367	0.3215			
Wind Speed	WS	m/s	04	0.35	0.45	0.3	0.5	0.400	0.0500			
Irradiance	IRR	W/m^2	372	370	368	374	371	371.0	0.5774			

Table 4.38 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO FEBRUARY 2012 (AFTERNOON) 3:00PM-4:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.01	0.03	0.04	0.029	0.025	0.027	0.0153	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.8	3.4	3.9	4.0	3.4	3.700	0.2646	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.059	0.010	0.030	0.36	0.30	0.033	0.0246	-	0.107	-
Methane	CH_4	ppm	0.01	0.008	0.01	0.01	0.008	0.009	0.0012	-	-	-
Sulphur dioxide	SO_2	ppm	0.01	0.009	0.03	0.014	0.018	0.016	0.0118	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.031	0.027	0.032	0.04	0.02	0.030	0.0026	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	30.5	31.5	27	28.66	30.67	29.67	2.363	150-250	150	150
Air Temperature	T	°C	34.6	34.6	34.2	35.46	33.47	34.46	0.2309			
Relative Humidity	RH	%	64.1	64.2	64.0	64.12	64.0	64.10	0.1000			
Wind Speed	WS	m/s	0.7	0.7	0.65	0.7	0.66	0.68	0.0289			
Irradiance	IRR	W/m^2	842	840	841	843	839	841.0	1.0000			

Table 4.39 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO

MARCH 2012 (MORNING) 10:00AM-11:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.009	0.01	0.008	0.007	0.011	0.0090	0.0010	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.1	3.1	3.25	3.50	3.46	3.483	0.5393	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.027	0.031	0.026	0.030	0.026	0.0280	0.0026	-	0.107	-
Methane	CH_4	ppm	0.001	0.01	0	0.003	0.004	0.0037	0.0054	-	-	-
Sulphur dioxide	SO_2	ppm	0.02	0.01	0.008	0.010	0.015	0.013	0.0064	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.024	0.023	0.028	0.023	0.027	0.0250	0.0026	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	28	29.2	30	28.06	30.06	29.067	1.007	150-250	150	150
Air Temperature	T	°C	32.6	32.5	33	31.6	33.7	32.7000	0.2646			
Relative Humidity	RH	%	70.2	70	70.1	68.10	72.10	70.1000	0.1000			
Wind Speed	WS	m/s	0.6	0.6	0.6	0.4	0.8	0.6000	0.0000			
Irradiance	IRR	W/m^2	420	420	421	422.3	418.3	420.33	0.5774			

Table 4.40 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO
MARCH 2012 (AFTERNOON) 3:00PM-4:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.01	0.02	0.03	0.03	0.01	0.020	0.0100	0.062	0.053	0.06
Carbon monoxide	CO	ppm	5.5	4.0	3.2	4.20	4.26	4.233	1.1676	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.039	0.038	0.040	0.040	0.038	0.039	0.0010	-	0.107	-
Methane	CH_4	ppm	0.00	0.01	0.01	0.006	0.008	0.007	0.0058	-	-	-
Sulphur dioxide	SO_2	ppm	0.02	0.06	0.005	0.030	0.026	0.028	0.0284	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.035	0.034	0.036	0.033	0.037	0.035	0.0010	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	30	30	35	31.59	31.55	31.57	2.887	150-250	150	150
Air Temperature	T	°C	35.4	36	35.6	35.65	35.69	35.67	0.3055			
Relative Humidity	RH	%	51.2	50.1	52	51.20	51.0	51.10	0.9539			
Wind Speed	WS	m/s	0.2	0.35	0.2	0.24	0.26	0.250	0.0866			
Irradiance	IRR	W/m^2	724	723	728	723	727	725.0	2.6458			

Table 4.41 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO
APRIL 2012 (MORNING) 8:00AM-9:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.014	0.015	0.016	0.017	0.012	0.014	0.007	0.062	0.053	0.06
Carbon monoxide	CO	ppm	2.70	2.90	2.80	3.0	2.6	2.8	0.158	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.019	0.018	0.017	0.020	0.016	0.018	0.0016	-	0.107	-
Methane	CH_4	ppm	0.0037	0.0035	0.0034	0.007	0.003	0.0035	0.0012	-	-	-
Sulphur dioxide	SO_2	ppm	0.009	0.01	0.008	0.0033	0.006	0.008	0.0011	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.011	0.014	0.012	0.007	0.010	0.012	0.0016	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	19.0	18.0	20.0	0.013	17.0	19.0	0.581	150-250	150	150
Air Temperature	T	°C	29.6	29.5	29.4	21.0	29.3	29.5	2.05			
Relative Humidity	RH	%	76.2	76.3	76.4	76.0	76.1	76.20	3.01			
Wind Speed	WS	m/s	0.32	0.34	0.33	0.30	0.31	0.32	0.03			
Irradiance	IRR	W/m^2	286	288	285	284	287	286	0.016			

Table 4.42 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO APRIL 2012 (AFTERNOON) 1:00PM-2:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.010	0.012	0.011	0.09	0.008	0.010	0.00152	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.20	3.00	3.30	3.40	3.10	3.2	0.731	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.028	0.026	0.027	0.29	3.030	0.028	0.006	-	0.107	-
Methane	CH_4	ppm	0.004	0.006	0.003	0.002	0.005	0.004	0.0001	-	-	-
Sulphur dioxide	SO_2	ppm	0.01	0.008	0.007	0.009	0.011	0.009	0.001	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.025	0.024	0.027	0.023	0.026	0.025	0.001	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	22.0	24.0	23.0	20.0	21.0	22.0	1.95	150-250	150	150
Air Temperature	T	°C	34.6	35.6	36.6	33.6	32.5	34.6	1.613			
Relative Humidity	RH	%	56.6	54.5	55.5	58.5	57.5	56.5	1.58			
Wind Speed	WS	m/s	0.61	0.63	0.60	0.59	0.62	0.61	0.0158			
Irradiance	IRR	W/m^2	1114.0	1116.0	1115.0	1113.0	1112.0	1114.0	1.581			

Table 4.43 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO
MAY 2012 (MORNING) 10:00AM-11:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.0040	0.0060	0.0050	0.006	0.004	0.0050	0.0010	0.062	0.053	0.06
Carbon monoxide	CO	ppm	1.5400	1.5100	1.4500	1.48	1.52	1.5000	0.0158	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.0100	0.0200	0.0100	0.014	0.012	0.0133	0.0058	-	0.107	-
Methane	CH_4	ppm	0.0200	0.0100	0.0300	0.01	0.03	0.0200	0.0100	-	-	-
Sulphur dioxide	SO_2	ppm	0.0050	0.0060	0.0040	0.006	0.004	0.0050	0.0010	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.0100	0.0200	0.0100	0.013	0.014	0.0133	0.0058	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	13.500	8.200	14.300	14.0	10.0	12.000	3.315	150-250	150	150
Air Temperature	T	°C	26.9000	26.6000	26.5000	25.67	27.67	26.67	0.2082			
Relative Humidity	RH	%	79.3000	79.6000	79.8000	80.57	78.57	79.57	0.2517			
Wind Speed	WS	m/s	0.20000	0.2000	0.1500	0.17	0.19	0.1833	0.0289			
Irradiance	IRR	W/m^2	210.0000	216.0000	218.0000	214.6	218.6	214.6	4.1633			

Table 4.44 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO
MAY 2012 (AFTERNOON) 3:00PM-4:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.007	0.004	0.004	0.006	0.004	0.0050	0.0017	0.062	0.053	0.06
Carbon monoxide	CO	ppm	3.24	2.5	1.46	2.2	2.6	2.4000	0.8942	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.01	0.01	0.02	0.014	0.012	0.0133	0.0058	-	0.107	-
Methane	CH_4	ppm	0.001	0.005	0.006	0.005	0.003	0.0040	0.0026	-	-	-
Sulphur dioxide	SO_2	ppm	0.006	0.004	0.005	0.003	0.007	0.0050	0.0010	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.010	0.020	0.010	0.014	0.015	0.0133	0.0058	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	16.8	16.9	16.4	16.6	16.8	16.700	0.265	150-250	150	150
Air Temperature	T	°C	33.2	33	32	33.73	31.74	32.733	0.6429			
Relative Humidity	RH	%	64.6	64	64	64.10	64.30	64.200	0.3464			
Wind Speed	WS	m/s	0.7	0.6	0.7	0.7	0.6	0.667	0.0577			
Irradiance	IRR	W/m^2	540	542	539	538	542	540.33	1.5275			

Table 4.45 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO
JUNE 2012 (MORNING) 10:00AM-11:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.01	0.003	0.02	0.014	0.012	0.0127	0.0064	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.2	2.1	3.2	3.15	3.18	3.1667	1.0504	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.054	0.048	0.034	0.045	0.046	0.0435	0.0103	-	0.107	-
Methane	CH_4	ppm	0.01	0.002	0	0.003	0.005	0.0040	0.0053	-	-	-
Sulphur dioxide	SO_2	ppm	0.01	0.03	0.007	0.017	0.018	0.0157	0.0125	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.033	0.037	0.035	0.033	0.037	0.0350	0.0020	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	8	15	22	17.0	13.0	15.000	7.000	150-250	150	150
Air Temperature	T	°C	26.9	26.8	27.1	25.53	27.53	26.533	0.1528			
Relative Humidity	RH	%	93.1	83	83.1	84.07	82.06	83.067	0.0577			
Wind Speed	WS	m/s	0.2	0.2	0.3	0.22	0.24	0.2333	0.0577			
Irradiance	IRR	W/m^2	91	91	92	93.33	89.33	91.333	0.5774			

Table 4.46 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO
JUNE 2012 (AFTERNOON) 3:00PM-4:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.03	0.01	0.03	0.024	0.022	0.0233	0.0115	0.062	0.053	0.06
Carbon monoxide	CO	ppm	4.2	3.1	2.6	3.20	3.40	3.3000	0.8185	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.04	0.08	0.03	0.06	0.04	0.0500	0.0265	-	0.107	-
Methane	CH_4	ppm	0.02	0.001	0	0.006	0.008	0.0070	0.0113	-	-	-
Sulphur dioxide	SO_2	ppm	0.03	0.01	0.01	0.018	0.015	0.0167	0.0115	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.045	0.043	0.050	0.05	0.03	0.0400	0.0036	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	27	7.0	16	15.07	17.07	16.067	10.017	150-250	150	150
Air Temperature	T	°C	30.6	30.6	30.5	31.56	29.56	30.56	0.0577			
Relative Humidity	RH	%	75.5	75.4	73.5	75.48	76.47	75.466	0.0577			
Wind Speed	WS	m/s	0.8	0.8	0.7	0.54	0.56	0.68	0.4215			
Irradiance	IRR	W/m^2	344	345	342	342	344	343.67	1.5275			

Table 4.47 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO
JULY 2012 (MORNING) 10:00AM-11:00AM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.005	0.02	0.008	0.012	0.010	0.011	0.0079	0.062	0.053	0.06
Carbon monoxide	CO	ppm	2.5	2	1.6	2.06	2.00	2.033	0.4509	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.050	0.080	0.059	0.061	0.065	0.0630	0.0154	-	0.107	-
Methane	CH_4	ppm	0.01	0	0.001	0.005	0.002	0.004	0.0055	-	-	-
Sulphur dioxide	SO_2	ppm	0.005	0.003	0.02	0.008	0.01	0.009	0.0093	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.045	0.041	0.040	0.040	0.044	0.0420	0.0026	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	0.9	15.8	25	14.9	12.9	13.900	12.162	150-250	150	150
Air Temperature	T	°C	29.6	28	29	27.87	29.87	28.8667	0.8083			
Relative Humidity	RH	%	73.6	72	71	73.2	73.2	72.2000	1.3115			
Wind Speed	WS	m/s	0.2	0.16	0.3	0.12	0.32	0.2200	0.0721			
Irradiance	IRR	W/m^2	288	285	286	286.4	286.2	286.33	1.5275			

Table 4.48 MONTHLY AVERAGE LEVELS OF INDOOR POLLUTANTS AND METEOROLOGICAL VARIABLES FOR FUTO JULY 2012 (AFTERNOON) 3:00PM-4:00PM

PARAMETERS	SYMBOL	UNIT	HP1	HP2	HP3	HP4	HP5	AVERAGE	STDVT	FEPA	WHO	USEPA
Nitrogen dioxide	NO_2	ppm	0.006	0.01	0.01	0.008	0.01	0.009	0.0023	0.062	0.053	0.06
Carbon monoxide	CO	ppm	5.1	3.5	4.2	4.25	4.28	4.2667	0.8021	11.6	25	9
Hydrogen Sulphide	H_2S	ppm	0.06	0.07	0.08	0.08	0.06	0.0710	0.0118	-	0.107	-
Methane	CH_4	ppm	0.001	0	0.02	0.006	0.008	0.0070	0.0113	-	-	-
Sulphur dioxide	SO_2	ppm	0.001	0.02	0.004	0.02	0.009	0.0100	0.0087	0.05	0.038-0.057	0.06
Ammonia	NH_3	ppm	0.055	0.059	0.060	0.057	0.059	0.0580	0.0026	-	0.2	-
Particulate Matter	PM	$\mu g/m^3$	35	25	20	26.68	26.66	26.67	7.638	150-250	150	150
Air Temperature	T	°C	33.5	32	33.1	32.88	32.84	32.86	0.7767			
Relative Humidity	RH	%	64.3	63.5	64	63.95	63.91	63.9333	0.4041			
Wind Speed	WS	m/s	0.9	0.8	0.7	0.7	0.7	0.8000	0.1000			
Irradiance	IRR	W/m^2	692	685	690	690	688	689.0000	3.6056			

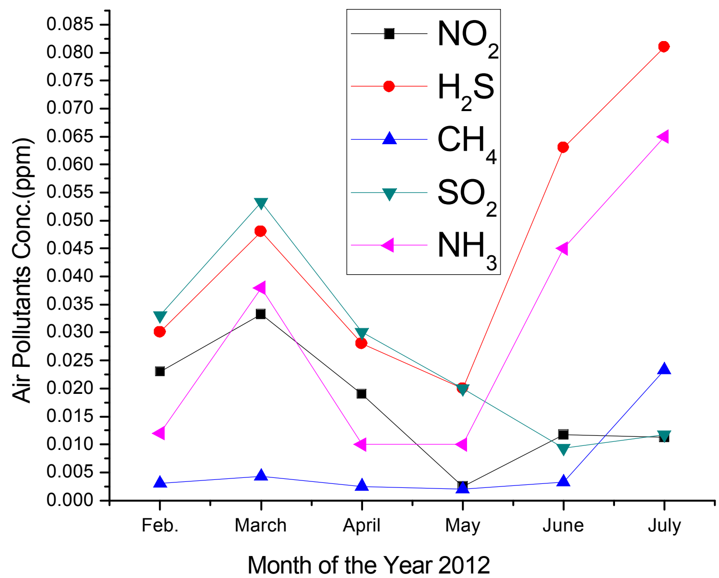


Figure. 4.1 Air Pollutants concentrations for AIFCE Morning Session

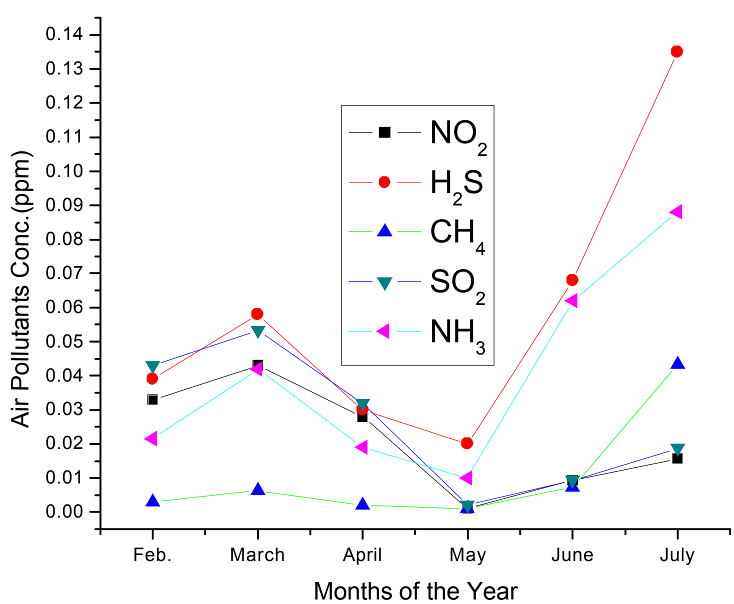


Figure 4.2 Air Pollutants concentrations for AIFCE Afternoon Session

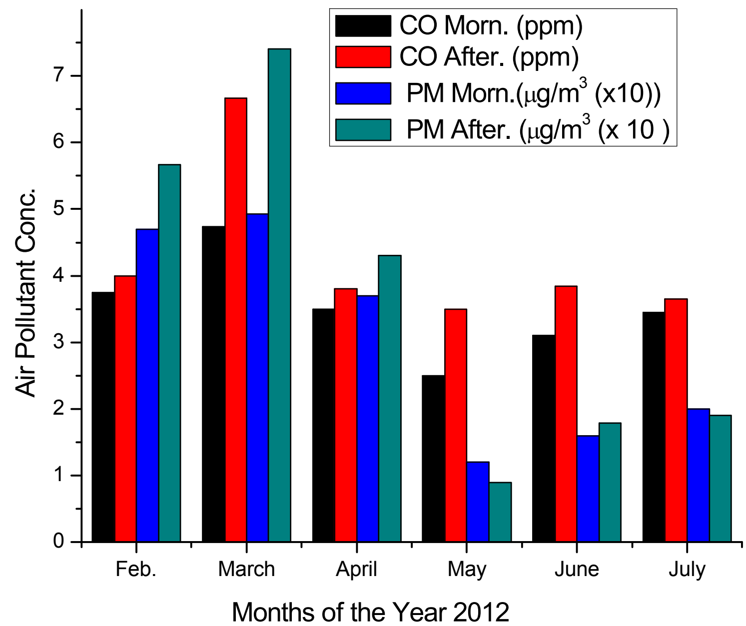


Fig 4.3 Bar showing the variation of CO and PM AIFCE for Morn. and aftern.

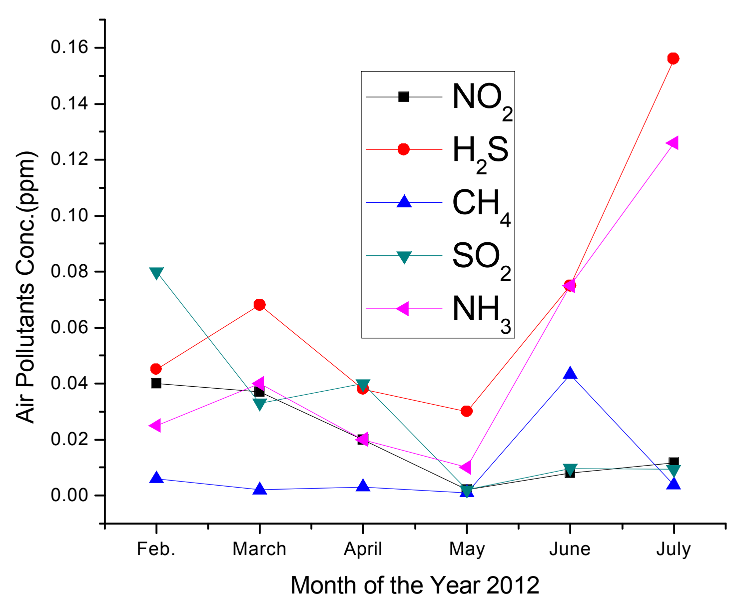


Figure. 4.4 Air Pollutants concentrations for IMSU Morning Session

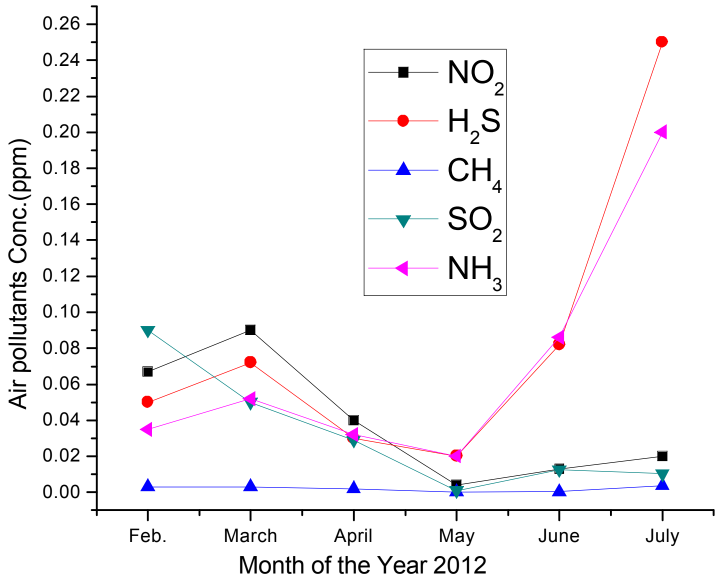


Figure. 4.5 Air Pollutants concentrations for IMSU Afternoon Session

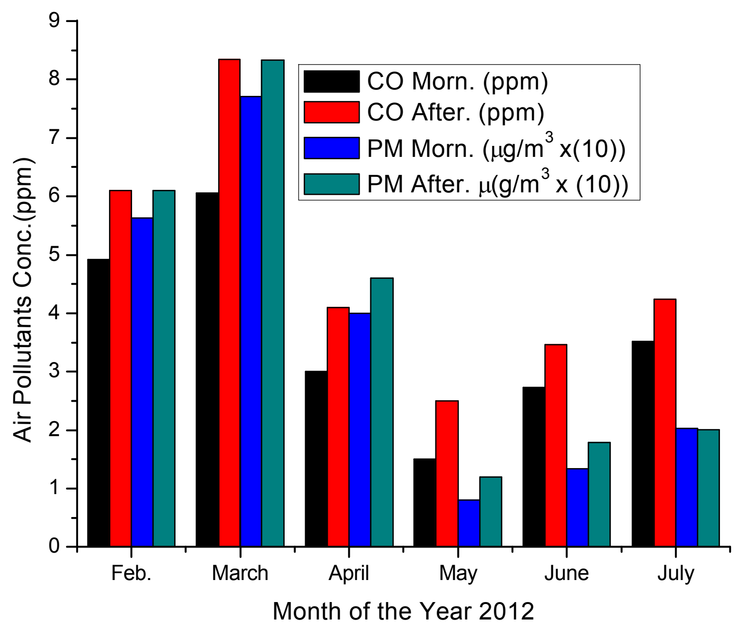


Fig. 4.6 Bar chart showing the variation of CO and PM for IMSU for morn. and After.

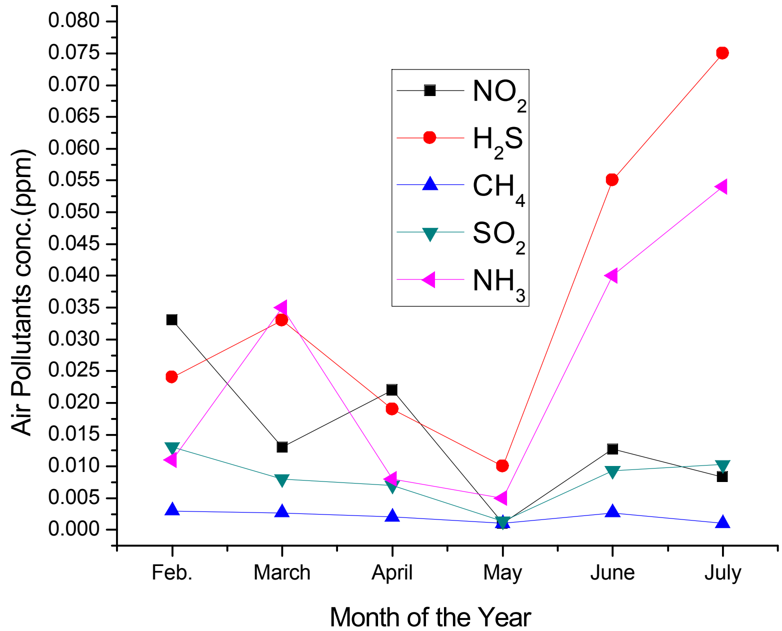


Figure 4.7 Air Pollutants concentrations for FEDPOLY Morning Session

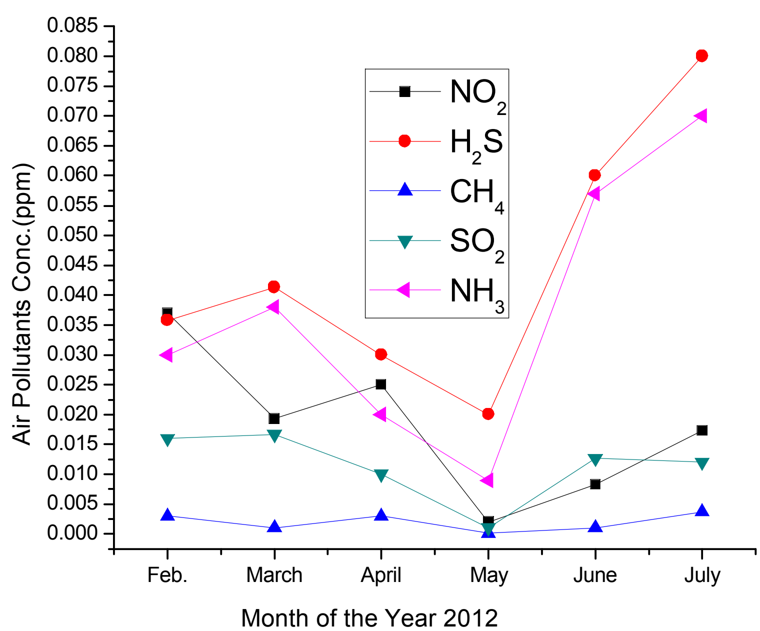


Figure. 4.8 Air Pollutants concentrations for FEDPOLY Afternoon Session

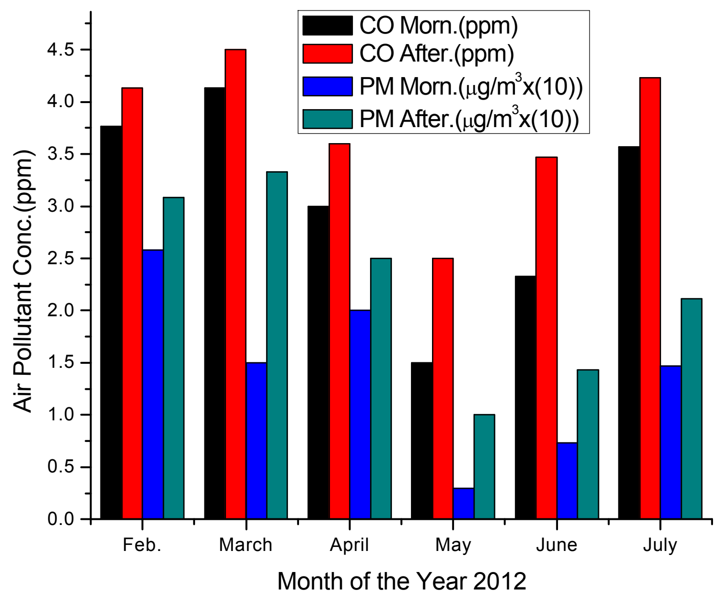


Fig. 4.9 Bar chart showing the variation of CO and PM, FEDPOLY Morn. and After.

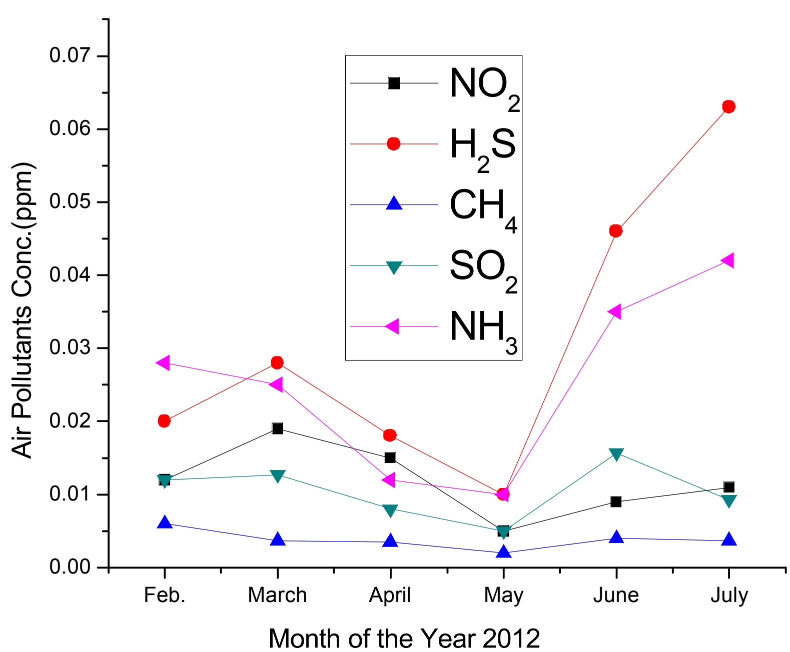


Figure. 4.10 Air Pollutants concentrations for FUTO Morning Session

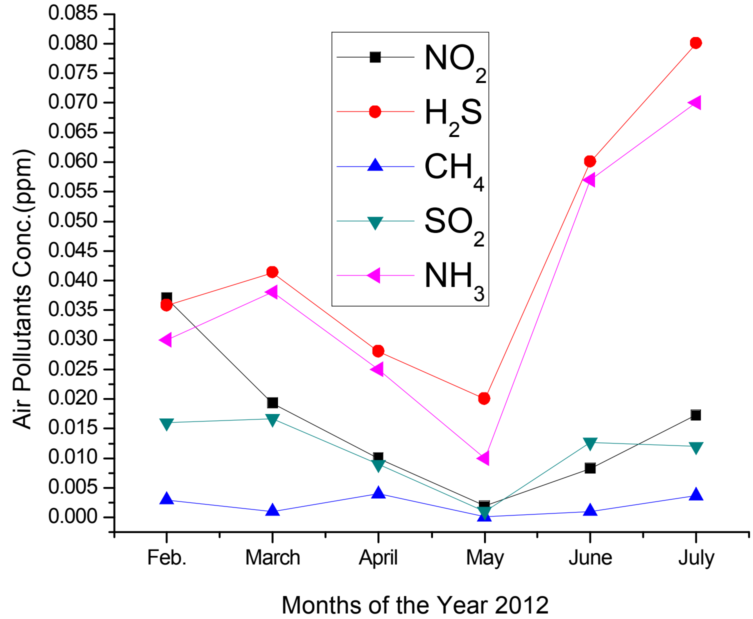


Figure. 4.11 Air Pollutants concentrations for FUTO Afternoon Session

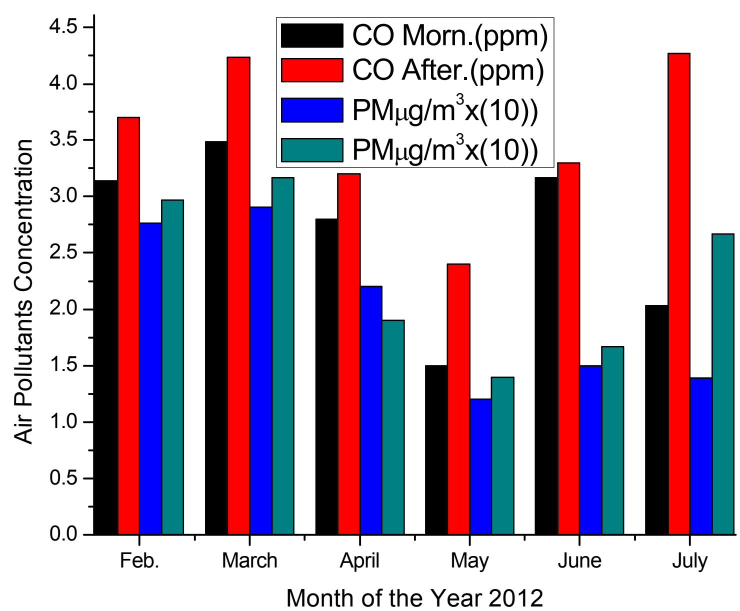


Fig. 4.12 Bar chart showing the variation of CO and PM FUTO Morn. and After.

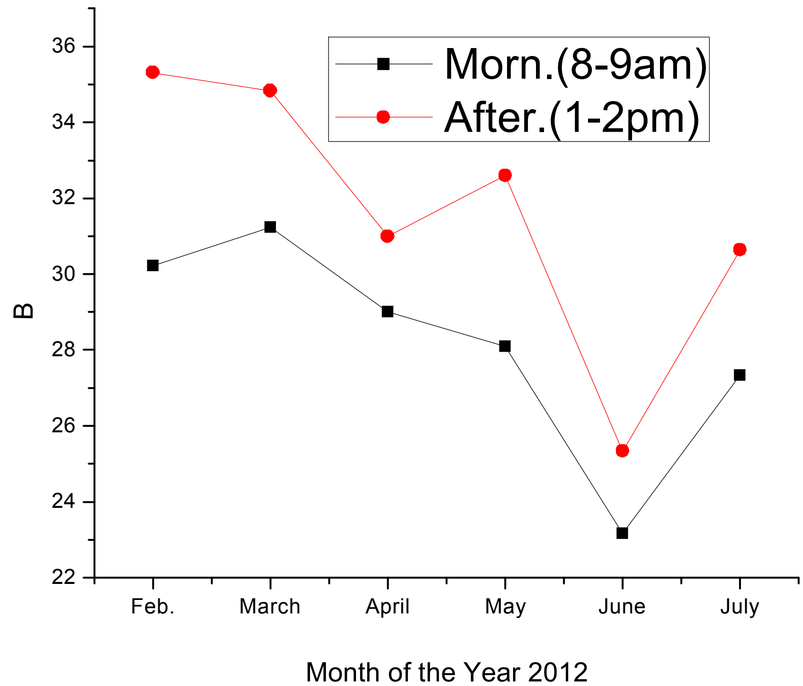


Fig. 4.13 Variation of Temperature with month of the Year, AIFCE Morn. and After.

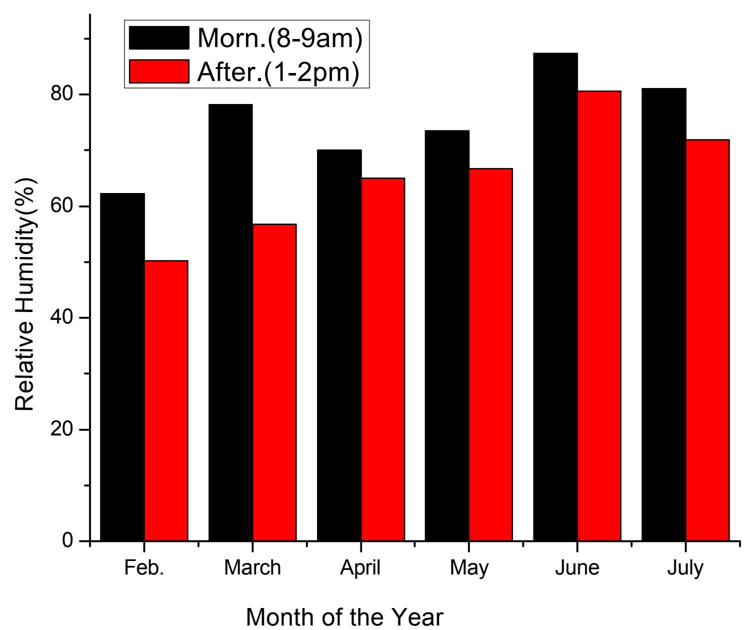


Fig. 4.14 Variation of Rel.Humidity with month of the Year, AIFCE Morn. and After.

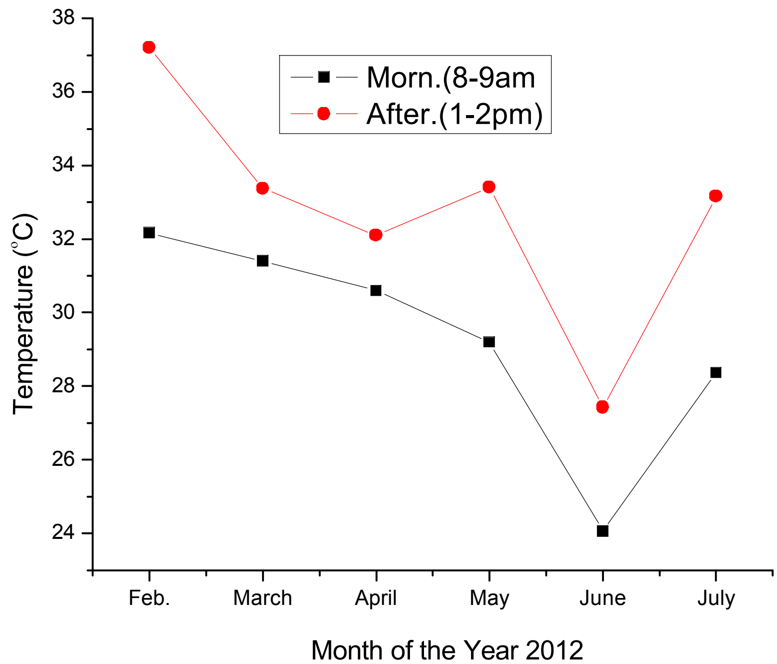


Fig. 4.15 Variation of Temperature with month of the year for IMSU Morn. and After

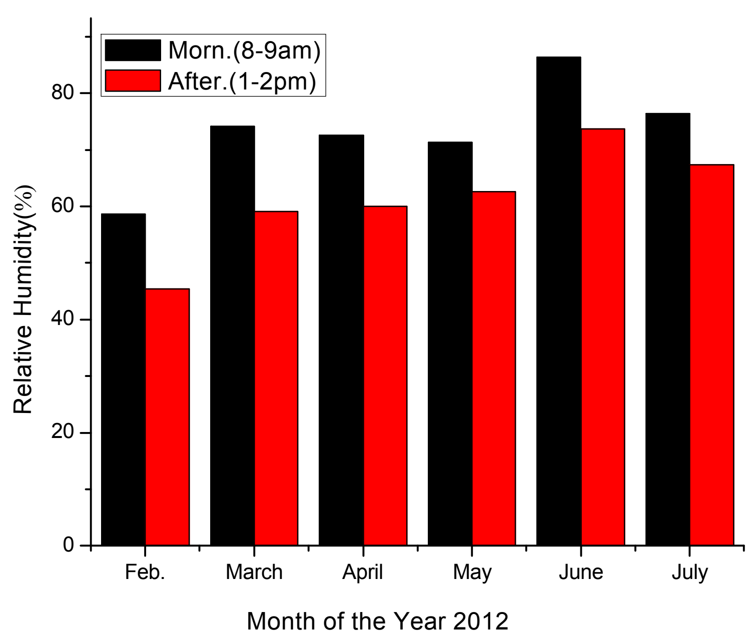


Fig. 4.16 Variation of Rel. Humidity with month of the Year (B), IMSU Morn and Aft.

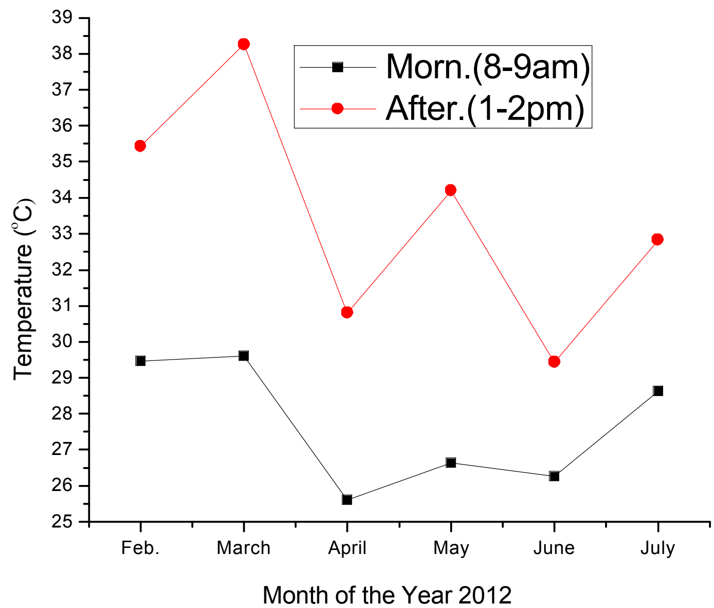


Fig 4.17 Variation of Temperature with month of the year, FEDPOLY morn. & After.

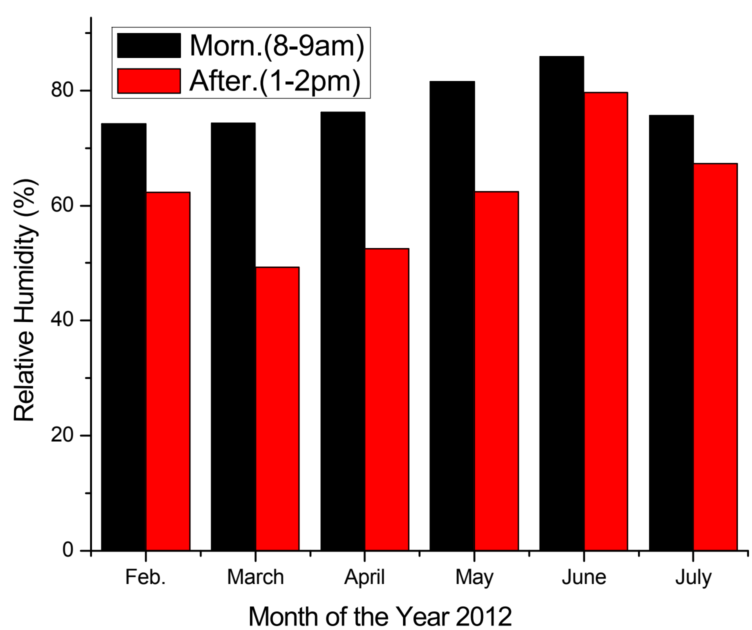


Fig 4.18 Variation of Rel. Humidity with month of the year, FEDPOLY Morn & After.

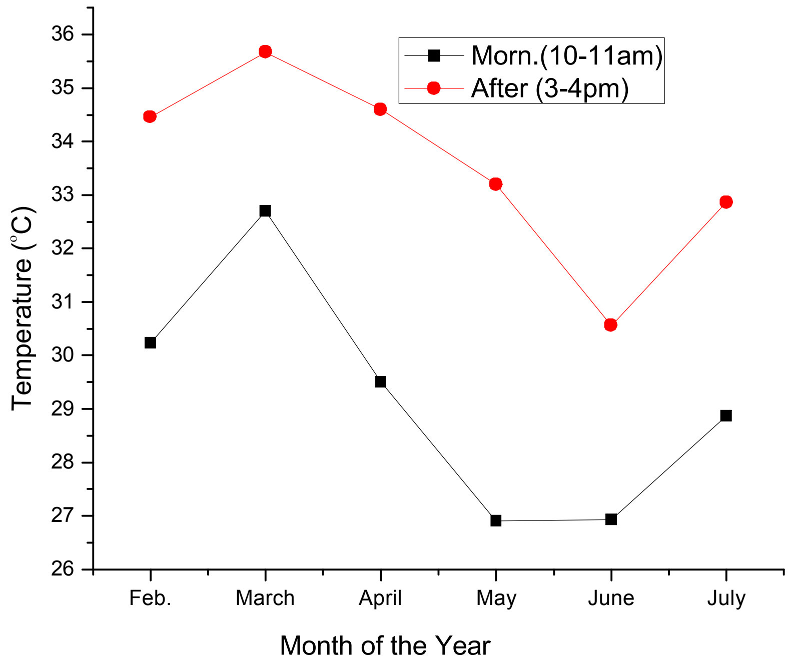


Fig 4.19 Variation of Temperature with month of the year, FUTO morn. & After.

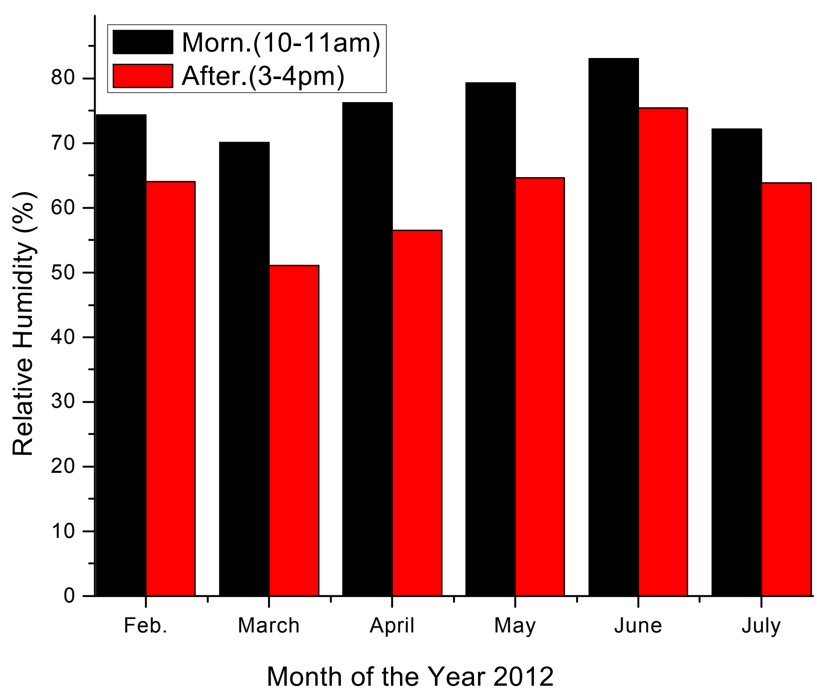


Fig. 4.20 Variation of Rel.Humidity with month of the year(B), FUTO Morn & After.

Table 4.49 STATISTICAL SUMMARY OF INDOOR AIR POLLUTANTS AND METEOROLOGICAL DATA

AIFCE

Parameter (ppm)	Min. (ppm)	Max. (ppm)	Mean (ppm)	Std.Dev (ppm)	FEPA (ppm)	WHO (ppm)
NO_2	0.002	0.045	0.035	0.008	0.062	0.053
SO_2	0.013	0.04	0.030	0.004	0.05	0.057
CO	0.53	6.67	4.70	0.134	11.6	25
H_2S	0.02	0.058	0.035	0.008	0.1	0.107
CH_4	0.002	0.003	0.004	0.002	20	-
NH_3	0.01	0.042	0.032	0.003	-	0.2
PM_{10}(µg/m^3)	9.0	74.0	38.6	0.211	150-250	150
Temp (^{o}c)	22.0	34.80	27.8	0.178	-	-
RH (%)	56.73	87.33	62.31	0.835	-	-
WS (ms^{-1}	0.3	0.9	0.5	0.025	-	-
Irradiance(W/m2)						

Table 4.50 STATISTICAL SUMMARY OF INDOOR AIR POLLUTANTS AND METEOROLOGICAL DATA

IMSU

Parameter (ppm)	Min. (ppm)	Max. (ppm)	Mean (ppm)	Std.Dev (ppm)	FEPA (ppm)	WHO (ppm)
NO_2	0.003	0.05	0.039	0.009	0.062	0.053
SO_2	0.002	0.05	0.036	0.004	0.05	0.057
CO	1.50	8.35	5.75	0.128	11.6	25
H_2S	0.03	0.082	0.046	0.006	0.1	0.107
CH_4	0.002	0.006	0.002	0.003	20	-
NH_3	0.010	0.085	0.041	0.004	-	0.2
PM_{10}(µg/m^3)	7.96	83.3	48.2	0.005	150-250	150
Temp (^{o}c)	24.06	33.37	28.6	0.166	-	-
RH (%)	59.10	86.33	60.4	0.922	-	-
WS (ms^{-1}	0.25	0.6	0.31	0.028	-	-
Irradiance(W/m2)						

Table 4.51 STATISTICAL SUMMARY OF INDOOR AIR POLLUTANTS AND METEOROLOGICAL DATA

FEDPOLYNEK

Parameter (ppm)	Min. (ppm)	Max. (ppm)	Mean (ppm)	Std.Dev (ppm)	FEPA (ppm)	WHO (ppm)
NO_2	0.003	0.029	0.018	0.005	0.062	0.053
SO_2	0.014	0.027	0.025	0.003	0.05	0.057
CO	0.40	4.50	4.10	0.118	11.6	25
H_2S	0.01	0.06	0.028	0.004	0.1	0.107
CH_4	0.00	0.001	0.004	0.000	20	-
NH_3	0.014	0.016	0.011	0.002	-	0.2
PM_{10}(µg/m^3)	10.0	33.3	25.23	0.313	150-250	150
Temp (^{o}c)	26.26	32.26	27.12	0.142	-	-
RH (%)	49.26	85.8	55.00	0.904	-	-
WS (ms^{-1}	0.15	0.1	0.09	0.024	-	-
Irradiance(W/m2)						

Table 4.52 STATISTICAL SUMMARY OF INDOOR AIR POLLUTANTS AND METEOROLOGICAL DATA

FUTO

Parameter (ppm)	Min. (ppm)	Max. (ppm)	Mean (ppm)	Std.Dev (ppm)	FEPA (ppm)	WHO (ppm)
NO_2	0.005	0.02	0.010	0.002	0.062	0.053
SO_2	0.004	0.039	0.02	0.001	0.05	0.057
CO	0.47	4.23	3.90	0.016	11.6	25
H_2S	0.013	0.05	0.02	0.003	0.1	0.107
CH_4	0.00	0.01	0.001	0.001	20	-
NH_3	0.005	0.04	0.009	0.001	-	0.2
PM_{10}(μg/m^3)	12.0	31.57	18.8	0.115	150-250	150
Temp (^{o}c)	19	35.67	20.0	0.128	-	-
RH (%)	51.10	83.07	46.50	0.819	-	-
WS (ms-^{1}	0.3	1.2	0.6	0.018	-	-
Irradiance(W/m2)						

Table 4.53: Regression model coefficients of meteorological parameters for different gaseous pollutants (NO_2, CO, H_2S, CH_4, SO_2).

Model	***Unstandardized Coefficients***		***Standardized Coefficients***	***t***	***Sig.***
	B	***Std. Error***	***Beta***		
NO_2 (constant)	.043	.081		527	.602
Air Tempt.	-.001	.002	-.133	-.291	.005
Rel. Humidity	.000	.001	-.208	-.592	.558
Wind Speed	.005	.004	.171	1.196	.240
Irradiance	2.53E-005	.000	.443	1.164	.252
F-ratio	4.141				
CO (Constant)	3.619	7.678		.471	.640
Air Tempt.	-.035	.183	-.089	-.191	.850
Rel. Humidity	-.005	.043	-.035	-.099	.922
Wind Speed	.278	.364	.111	.765	.003
Irradiance	.003	.002	.562	1.450	.156
F-ratio	3.659				
H_2S (constant)	-.080	.279		-.285	.777
Air Tempt.	-.001	.007	-.079	-.147	.884
Rel. Humidity	.002	.002	.452	1.086	.002
Wind Speed	.002	.013	.029	.173	.001
Irradiance	7.25E-005	.00	.455	1.013	.318
F-ratio	.509				
CH_4 (Constant)	.106	.084		1.260	.216
Air Tempt.	-.003	.002	-.769	-1.521	.137
Rel. Humidity	.000	.001	-.132	-.338	.008
Wind Speed	.003	.004	.125	.791	.014
Irradiance	1.38E-005	.000	.296	.638	.528
F-ratio	1.751				
SO_2 (constant)	-.033	.098		-.338	.737
Air Tempt.	.002	.002	.420	.814	.005
Rel. Humidity	-2.25E-005	.001	-.015	-.037	.145
Wind Speed	-.005	.005	-.187	-1.161	.007
Irradiance	-4.81E-006	.000	-.082	-.192	.849
F-ratio	1.347				

Table 4.54. Regression model coefficients of meteorological parameters for some pollutants (NH_3 and PM).

Model	*Unstandardized Coefficients*		*Standardized Coefficients*	*t*	*Sig.*
	B	*Std. Error*	*Beta*		
NH_3 (constant)	-.123	.236		-.522	.605
Air Tempt.	-5.80E-005	.006	-.006	-.010	.028
Rel. Humidity	.002	.001	.561	1.362	.002
Wind Speed	.001	.011	.012	.073	.943
Irradiance	6.53E-005	.000	.479	1.077	.289
F-ratio	3.691				
P.M (Constant)	9.751	11.063		.881	.384
Air Tempt.	-.068	.263	-.121	-.258	.006
Rel. Humidity	-.081	.069	-.428	-1.184	.244
Wind Speed	-.084	.525	.024	-.161	.008
Irradiance	.002	.003	.244	.626	.535
F-ratio	3.512				

Table 4.55 Regression model summary for different pollutants with the meteorological variables

Model	**R**	**R square**	**Adjusted square**	**Std. Error of Estimate**
NO_2	.712[a]	.507	.491	.01319
CO	.757[a]	.573	.557	1.24528
H_2S	.749[a]	.561	.543	.04525
CH_4	.700[a]	.490	.471	.01370
SO_2	.786[a]	.618	.604	.01585
NH_3	.770[a]	.593	.576	.03834
P.M	.734[a]	.538	.523	1.79435

a. predictors: (constant),Wind Speed, Relative Humidity, Air Temperature.

TWO-WAY ANALYSIS OF VARIANCE (ANOVA)

RANDOMIZED TIME OF THE DAYS DESIGN WITH REPETITIONS

Table 4.56. Variance Table for Sulphur Dioxide

VS	DF	SS	MS	F
Months	5	0.00448	0.00112	6.3791 **
Time of the Day	1	0.00016	0.00016	0.9318 ns
Month x Time of the Day	5	0.00016	0.00004	0.2295 ns
Repetition (Location)	60	0.00526	0.00018	
Total	71	0.01007		

Table 4.57 Variance Table for Particulate Matter

VS	DF	SS	MS	F
Months	5	97.69409	24.42352	12.9242 **
Time of the Day	1	2.61157	2.61157	1.3820 ns
Month x Time of the Day	5	1.12155	0.28039	0.1484 ns
Repetition (Location)	60	56.69238	1.88975	
Total	**71**	**158.11959**		

Table 4.58Variance Table for Nitrogen Dioxide

VS	DF	SS	MS	F
Months	5	0.00541	0.00135	13.1705 **
Time of the Day	1	0.00030	0.00030	2.9554 ns
Month x Time of the Day	5	0.00018	0.00005	0.4414 ns
Repetition (Location)	60	0.00308	0.00010	
Total	**71**	**0.00898**		

Table 4.59 Variance Table for Methane

VS	DF	SS	MS	F
Months	5	0.00119	0.00030	1.3934 ns
Time of the Day	1	0.00008	0.00008	0.3605 ns
Month x Time of the Day	5	0.00021	0.00005	0.2426 ns
Repetition (Location)	60	0.00641	0.00021	
Total	**71**	0.00788		

Table 4.60 Variance Table For Hydrogen Sulphide

VS	DF	SS	MS	F
Months	5	0.04329	0.01082	11.1963 **
Time of the Day	1	0.00155	0.00155	1.6050 ns
Month x Time of the Day	5	0.00200	0.00050	0.5162 ns
Repetition (Location)	60	0.02900	0.00097	
Total	**71**	0.07583		

Table 4.61. Variance Table for Carbon Monoxide

VS	DF	SS	MS	F
Months	5	43.55809	10.88952	12.9195 **
Time of the Day	1	7.42087	7.42087	8.8043 **
Month x Time of the Day	5	0.70426	0.17606	0.2089 ns
Repetition (Location)	60	25.28617	0.84287	
Total	**71**	**76.96939**		

Table 4.62. Variance Table for Ammonia

VS	DF	SS	MS	F
Months	5	0.02938	0.00734	9.6805 **
Time of the Day	1	0.00208	0.00208	2.7387 **ns**
Month x Time of the Day	5	0.00130	0.00033	0.4285 **ns**
Repetition (Location)	60	0.02276	0.00076	
Total	**71**	**0.05552**		

** Significant at a level of 1% of probability (p <0 .01)

* Significant at a level of 5% of probability (0.01 =< p <0 .05)

ns Non-Significant (p >=0 .05) ; where, VS = Variation Source, DF = Degree of freedom, SS = Square Sum, MS = Mean Square, F =Statistics of the test

DISCUSSIONS

4.2 AIR POLLUTANTS

4.2.1 NITROGEN DIOXIDE (NO_2)

From the results, the monthly average concentration of NO_2 for the period under study ranged from 0.0093 to 0.043ppm for AIFCE, 0.0117 to 0.05ppm for IMSU 0.008 to 0.019ppm for FEDPOLY and 0.008 to 0.02ppm for FUTO. Generally, the sources of the observed concentrations of NO_2 across the sample locations could be as a result of the use of combustion and improperly maintained appliances such as unvented kerosene and gas stoves, electrical heaters and other heating devices (Lee *et al,* 2002). The highest concentrations of NO_2 were detected at points HP7 and HP8 located at IMSU. The levels of NO_2 recorded in these locations could probably be due to so much human activities going on around the areas (outdoor air influences). Secondly, the hostels were located very close to the major road networks in the urban centre where there are a lot gaseous emissions from mobile sources (Ayodele *et al,* 2001). The lower pollutant levels in other locations could be as result of the location of the hostels in the outskirt of Owerri metropolis where there are less human activities in the outdoor environments (Okoli *et al*, 2012).

Again, the observed levels of NO_2 during the dry season (February and March) in all locations could be attributed to temperature inversions associated with dry seasons in the outdoor which tends to accumulate such pollutants close to the ground level(Smith, 2002; Okoli *et al*, 2012; Ayodele *et al*, 2009). Furthermore, the general decrease in the levels of NO_2 in the months of June and July, Figure 2-3, could be attributed to the wash out of these pollutants by rain water in outdoor environment which will affect the indoor levels(Ayodele & Abubakar, 2009)

Nitrogen dioxide is an acid anhydride which could dissolve in rain water to form weak nitric acid containing water (acid rain) according to equation 4.1 (Dara, 1993).

$$4NO_{2(g)} + 2H_2O_{(l)} + O_{2(g)} \rightarrow 4HNO_{3\ (aq)} \qquad (4.1)$$

Table 4.58 shows that there were significant differences ($p<0.01$) in the concentrations of NO2 determined in the various hostels investigated.

4.2.2 CARBON MONOXIDE (CO)

The monthly average of CO levels shown in Figures 4.1 to 4.4 (a-b) ranged from 3.11 to 6.67 ppm for AIFCE, 2.73 to 9.25ppm for IMSU, 0.60 to 4.5ppm for FEDPOLY and 2.01 to 4.23ppm for FUTO. The highest values of CO were observed at hostels located at IMSU. These values were obtained during the months of February and March (dry season). The levels could be attributed to anthropogenic activities going on in the area including the combustion activities of road users. A major reason for this level of concentration could be poor ventilation openings in the buildings and the limited emission sources to breathing zones. The locations with lower concentration may be due to the levels of awareness of the control measures and adequate provision of openings for ventilation. Also, the levels of other pollutants were higher during the dry season than rainy season. This could also be attributed to so much accumulation of the pollutant within the ground level as a result of temperature inversion effect. The lower concentration of the CO during the rainy season has also been attributed to the washing effect by rain water and the solubility of the gas. Similar observations have been reported by some authors. (Pat & Nkwocha, 2004).

Sources of indoor CO across sample locations could be from incomplete combustion of gas and kerosene stoves and generator sets (Han & Naehe, 2006), diesel and gasoline (Jerrett *et al*, 2005). Prolonged exposure to CO is associated with severe headache, nausea, dizziness. Other effects include binding strongly with haemoglobin which prevents oxygen transportation in the blood and may lead to adverse neuro-behavioral and cardiovascular effects (Twari & Abowei, 2012).

Table 4.61 shows that there were significant differences ($p<0.01$) in the concentrations of CO determined in the various hostels investigated.

4.2.3 HYDROGEN SULPHIDE (H_2S)

The average concentration of H_2S during the period under study ranged from 0.030 to 0.135ppm for AIFCE, 0.045 to 0.25ppm for IMSU, 0.024 to 0.082ppm for FEDPOLY and 0.020 to 0.071ppm for FUTO. The highest amount was recorded in AIFCE in the month of July (rainy season). Also, close inspection of the plots in Figures 4.1 to 4.4 (a-b), June and July have the highest level of H_2S pollutant, while, Feb. March April and May (rainy season and vacation period) recorded the lower levels. The decay of food stuffs and other organic materials could account for the presence of H_2S emissions in the locations. Therefore, the high level of H_2S recorded in AIFCE may probably be due to the observed dirty environment of the hostels surroundings including the interior which could be the source of bad odour observed at sample points in AIFCE hostels. Seasonal and source variation could also be responsible for the monthly changes in the concentration of H_2S recorded across the months (FEPA, 1991). Thus, dry season with its characteristic lower relative humidity do not support the decay of substances and could account for the lower concentration of H_2S during February and March. This suggests close relation between level of H_2S pollutant in the air and the value of relative humidity. Also, less human activities during vacation period (April to May) is responsible for the low level of H_2S in the month of May. Low concentration of H_2S in the body can cause dizziness and stomach upset, while higher concentration causes rapid unconsciousness and death through respiratory paralysis and asphyxiation (WHO, 2003).

Also, Table 4.60 shows that there were significant differences ($p<0.01$) in the concentrations of H_2S determined in the various hostels investigated.

4.2.4 METHANE (CH_4)

The levels of CH_4 were within the range of 0.005 to 0.023 ppm for AIFCE, 0.003 to 0.009 ppm for IMSU, 0.001 to 0.01 ppm for FEDPOLY, and 0.00 to 0.006 ppm for FUTO. The concentrations of CH_4 did not follow a defined pattern of variation both in the time of the day and Month of the year. The low concentration shows that decaying waste and sewer gas could account for CH_4 presence across the locations. Secondly, it suggests close relation between level of CH_4 pollutant in the air and the value of relative humidity. The sources of CH_4 at these sites could be as a result of nature gas leakage and decomposition of organic waste, septic tanks and sewers or plumbing drain problems (Malcolm, 1992). High of CH_4 can lead to suffocation as it decreases the amount of available oxygen in the air (USEPA, 2010). Vacation period (May) also recorded lower value indicating the decreased effect of human activities.

Table 4.59 showed that there were no significant differences in the concentrations of CH_4 determined in the various hostels investigated.

4.2.5 AMMONIA (NH_3)

The monthly averages of ammonia are within the ranged from 0.0120 to 0.088 ppm for AIFCE, 0.025 to 0.1 ppm for IMSU, 0.011 to 0.01 ppm for FEDPOLY, 0.025 to 0.058ppm for FUTO. The results showed that the highest concentration of NH_3 was observed at IMSU the locations, during the months of June and July (rainy season). The reason for the high concentration of NH_3 at IMSU points is uncertain but may be due to the pollution level in the area. Secondly, having higher concentrations during raining season indicate that NH_3 has relation with season or with relative humidity (Ayodele & Ababakar, 2009). The sources of NH_3 are: animal waste and the use of ammonia based homemade products. (Okafor *et al,* 2009). Other sources include decomposition of urea, cigarette, smoke and the use of ammonia containing compounds for household cleaners (Holness *et al*, 1982). However, the values of NH_3 were lower in the month of May which corresponds to vacation periods, indicating decreased anthropogenic activities. Although, it is also lower in the months of Feb. and March (when compared to June and July) which corresponds to dry season when the process of ammonification is minimal due to decrease relative humidity (Okoli *et al,* 2012). Table 4.50 shows that the monthly variations of NH_3 at all locations were insignificant.

4.2.6 SULPHUR DIOXIDE (SO_2)

The results for SO_2 revealed a monthly average range of 0.009 to 0.041ppm for AIFCE, 0.0093 to 0.055ppm for IMSU, 0.0093 to 0.050ppm for FEDPOLY and 0.004 to 0.028ppm for FUTO. The highest concentration of SO_2 was recorded at IMSU, followed by AIFCE locations during the month of February (dry season) while the lowest concentration was observed in the month of July (rainy season). The seasonal variation may be as a result of temperature inversion experienced in the dry season and wash out during the rainy seasons. The high values of SO_2 as recorded in hostels at IMSU were as a result of normal students burning of fossils fuels within the hostel environs and the closeness of the hostels to the main-road which is characterized with high traffic flow where vehicular emissions influence the indoor air concentrations of pollutants (FEPA, 1991). Also the high concentration of the SO_2 could be attributed to the closed building pattern and substandard housing conditions of the hostels as was observed during the monitoring period (Ayodele & Abubakar, 2009). Furthermore, the reason for this high value may be as a result of other factors such as isolated refused dumpsite located along these hostels. Hydrogen sulphide originating from the decay of organic matter and biological reduction of sulphates especially by anaerobic bacteria is rapidly converted in the atmosphere to SO_2 by the following equation (Neill, 1993; Dara, 1993).

$$2H_2S_{(g)} + 3O_{2(g)} \rightarrow 2SO_{2\,(g)} + 2H_2O_{(g)} \qquad 4.2$$

The lower concentration of SO_2 during the months of June and July and May may be due to washing effect of water droplets according to equation 4.3 below and decreased human activities during vacation respectively.

$$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)} \qquad 4.3$$

The emission values of SO_2 showed variations across the periods of the day, locations, months and seasons but are within the limit of USEPA (2001) ambient air quality standards.

Table 4.56 shows that there were significant differences ($p<0.01$) in the concentrations of SO_2 determined in the various hostels investigated.

4.2.7 PARTICULATE MATTER (PM)

The observed levels of particulate matter (PM) ranged from 15 to 74 $\mu g/m^3$ for AIFCE, 13 to 83.3 $\mu g/m^3$ for IMSU, 7 to 33.3$\mu g/m^3$ for FEDPOLY and 13 to 31.6 $\mu g/m^3$ for FUTO. The highest value of PM was recorded at point located on AIFCE and IMSU locations. IMSU recorded the highest amount. The concentrations of the PM were high during the dry season(Feb and March).This high concentration corresponds to the period of the year when the atmosphere is dry and carries windblown dust and fumes into the residential buildings (Smith, 2000). Sources of PM as was observed in the study areas include; road construction activities, vehicular emissions, house-hold combustion i.e. gas stoves, agricultural practices, residential fire places, natural processes such as wind erosion (Samet & Krewisk, 2003). Again, these sources were more pronounced at IMSU locations than other locations and have been attributed to the higher concentrations of PM at IMSU locations. The values obtained from this study were lower than the average value of 500$\mu g/m^3$ reported in a study in Akwa Ibom metropolis (Pat & Nkwocha, 2012). Possible sources of PM in these hostels could be as a result of improperly installed or maintained combustion appliances. Exposure to high levels is associated with certain acute respiratory infections. Table 4.57 showed that there were significant differences ($p<0.01$) in the concentrations of particulate matters determined in the various hostels investigated.

4.3.0 METEOROLOGICAL VARIABLES

4.3.1 TEMPERATURE

Across the sample locations, the result indicated the average temperature values ranged from 31.4 to 37.2°C for dry season and 24.7 to 33.1°C for rainy season. The mean temperature was found to be higher in the dry season than in the rainy season, and this invariably resulted to higher evaporation tendencies. Increase in temperature leads to decrease in solubilities of gases which accounts for the observed increase in the level of the pollutants during hot afternoon sections. Although a maximum temperature is not specified in any regulatory body for most kinds of work, but the WHO recommends that the acceptable indoor air temperature should fall within the range of 22.5-25.5 °C.

4.3.2 RELATIVE HUMIDITY

The average relative humidity across the sample locations are within the range of 45.3 to 56.7% during the dry season and 62.4 to 87.3% during the rainy season. The range of RH during the dry season is within the recommended indoor air quality value of 70% while some points in the measured locations exceeded the above value.

4.3.3 WIND SPEED AND IRRADIANCE

Wind Speed. Wind speed or wind velocity reported in meter per second in the study area ranged from 0.04 to 3.2 m/s in the dry season while it ranges from 0.07 to 1.3 m/s in the rainy days. This shows that wind speed value is higher during the dry season than during the rainy season. This high value is due to the North East trade wind prevalent during the dry season in the study location. WHO recommends an acceptable level of 0.25 m/s.

4.3.4 IRRADIANCE.

The amount of atmospheric solar radiation with a wavelength of 0.4 to 1.1 micrometers in length reported in watts per square meter (Irradiance) ranged from

420 to 906 during the dry season and 92 to 612 during the rainy season. Irradiance is more pronounce during the sunny days than wet periods.

4.4.0 REGRESSION MODELING OF AIR POLLUTANTS AND METEOROLOGICAL PARAMETERS

4.4.1 EFFECT OF METEOROLOGICAL VARIABLES ON AIR POLLUTANTS

Correlation and multiple linear regression analyses were conducted to examine the relationship between indoor air pollutants and various potential predictors known as meteorological parameters. Table 4.42 and 4.43 summarize the descriptive statistics and analysis of the results. The results have shown some levels of correlation between some meteorological variables and the pollutants.

From the results, the R^2 value (coefficient of multiple determinations) of NO_2 which determines the goodness of fit of regression model is 0.507. Therefore, 50.7% of variations in NO_2 are caused or explained by the meteorological parameters (Wind speed, Relative humidity, Air Temperature and irradiance). From the meteorological variables studied; only air temperature contributed significantly to the model. Also, the F-ratio which determines the overall significance of a regression model is highly significant at 5% level of probability, $F (3, 35) = 4.141$, $p<0.05$ (i.e., regression model is a good fit of the data). This implies that the meteorological parameters significantly affected the concentration of NO_2 in the study locations.

Based on Table 4.53, the equation for the regression line for NO_2 is determined using the unstandardized coefficients. This is because the constant (beta zero) is included in the equation. The model equation is as follows.

Y=0.43-0.01(Air temperature) +0.005(Relative humidity) +0.005(Wind speed) +2.43-E005 (Irradiance). It could be deduced from the above equation that relative humidity, wind speed and irradiance positively related to NO_2 or decreased the concentration of NO_2 in the study area.

CO gave the R^2 value of 0.573, which implies that 57.3% variation in concentration of CO is explained by the meteorological variables studied. From the meteorological variables studied; only wind speed contributed significantly to the model. The F-ratio which shows the overall significance of a regression model is significant at 1% level of probability, F (4, 35) = 3.659, p<0.014 (i.e., regression model is a good fit of the data). This implies that the meteorological parameters significantly affected the concentration of CO in the study locations. From table 4.41, the equation for the regression line for CO is also determined using the unstandardized coefficients. The model equation is as follows:

Y=3.619-0.035(Air temperature) -0.005(Relative humidity) +0.278(Wind speed) +0.003 (Irradiance).

The values of the regression coefficients show that temperature and relative humidity decreased the concentration of CO while wind speed and irradiance increased the concentration of the pollutant in the studied locations.

The R^2 value of H_2S gave of 0.561, which implies that 56.1% variation in concentration of H_2S was accounted for by the meteorological parameters studied. From the result, only wind speed and relative humidity contributed significantly to the model. The F-ratio which determines the overall significance of a regression model is significant at 5% level of probability, F (4, 35) = 2.509, p<0.05. This implies that the meteorological parameters significantly affected the concentration of H_2S in the study locations. From table 4.41, the equation for the regression line for H_2S is also determined using the unstandardized coefficients. The model equation is as follows:

Y=-0.080-0.001(Air temperature) +0.002(Relative humidity) +0.002(Wind speed) +7.25E-005(Irradiance).

The values of the unstandardized coefficients show that air temperature decreased the concentration of H_2S while relative humidity, wind speed and irradiance increased the concentration of the gas across the sample locations.

The R^2 value of CH_4 was determined to be 0.470. Therefore 47.0% variations in CH_4 are caused/explained by the meteorological parameters. From the meteorological variables studied; only relative humidity contributed significantly to the model. Also, the F-ratio which determines the overall significance of a regression model is highly significant at 8% level of probability, $F(3, 35) = 1.751$, $p<0.08$ (i.e., regression model is a good fit of the data). This implies that the meteorological parameters statistically significantly jointly affected the concentration of CH_4 in the study locations.

From Table 4.41, the equation for the regression line for CH_4 is determined using the unstandardized coefficients. The model equation is as follows.

Y=0.106-0.003(Air temperature) +0.000(Relative humidity) +0.003(Wind speed) +1.38-E005 (Irradiance). It could be deduced from the above equation that air temperature decreased the concentration of air pollutants while relative humidity, wind speed and irradiance increased the concentration of the pollutant in the study area.

The R^2 value of SO_2 was determined to be 0.618. Therefore 61.8% variations in SO_2 are caused/explained by the meteorological parameters. From this study, only air temperature and wind speed contributed significantly to the model. Also, the F-ratio which determines the overall significance of a regression model is highly significant at 5% level of probability, $F (3, 35) = 1.347$, $p<0.03$ (i.e., regression model is a good fit of the data). This implies that the meteorological parameters significantly affected the concentration of SO_2 in the study locations.

From Table 4.41, the equation for the regression line for SO_2 is determined using the unstandardized coefficients. The model equation is as follows.

Y = -0.033+0.02(Air temperature) - 2.25E-005(Rel. Humidity) -0.005(Wind speed) - 4.81E-006(Irradiance).

Also, unstandardized coefficients indicate that air temperature increased the concentration of the pollutant while relative humidity, wind speed and irradiance decreased the concentration of the pollutant in the study area. Similar observation on SO_2 has been reported by Kavuri et al, (2012) and the influence of wind speed on these pollutants including CO has also been reported by Ngele et al (2012).

Tables 4.42 also show the R^2 value for NH_3 to be 0.576. This also implies that 50.7% variations in NH_3 could be explained by the meteorological parameters (Wind speed, Relative humidity, Air Temperature and irradiance). From the study, only relative humidity contributed significantly to the model. Also, the F-ratio which determines the overall significance of a regression model is highly significant at 6% level of probability, $F (3, 35) = 3.691$, $p<0.06$ (regression model is a good fit of the data). This implies that the joint effect of meteorological parameters on the concentration of NH_3 at the locations studied is statistically significant. The equation for the regression line for NH_3 is determined using the unstandardized coefficients. The model equation is as follows.

Y=-0.123-5.80E-005(Air temperature) +0.002 (Relative humidity) +0.001(Wind speed) +6.53-E005 (Irradiance).

.It can be deduced that temperature decreased the concentration of NH_3 while relative humidity, wind speed and irradiance increased the levels of the gas in the study area.

From the result, the R^2 value of PM is 0.523. Therefore, 52.3% of variations in NO_2 are caused by the meteorological parameters. From the meteorological variables studied; air temperature and wind speed contributed significantly to the model. Also, the F-ratio is highly significant at 1% level of probability, F (3, 35) = 3.512, $p<0.01$ (i.e., regression model is a good fit of the data). This implies that the meteorological parameters statistically significantly jointly affected the concentration of PM in the study locations.

Table 4.42 shows that the model equation for the regression line for PM is as follows. **Y= 9.751-0.068(Air temperature) -.081(Relative humidity) -0.084(Wind speed) +0.002 (Irradiance).** It could also be deduced that irradiance positively related to PM related or increased the concentration of PM while the remaining parameters decreased the concentration of PM in the study area.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The discharge of enormous quantities of indoor pollutants in residential buildings has evidently been associated with a growing burden of diseases. Carbon monoxide, NO_2, SO_2, PM, H_2S, CH_4 and NH_3 are some pollutants generated indoors which can build up to the levels of public health concern.

This research study has therefore revealed the concentration levels of the above mentioned pollutants in the selected hostels located in AIFCE, IMSU, FEDPOLYNEK and FUTO. The obtained results fall within the limits of FEPA, WHO, and USEPA standards.

The concentrations of pollutants in the afternoon sessions were higher than those in the morning sessions. This was as a result of increased human activities in the outdoor environment during afternoon periods which invariably influenced the hostels environment.

Concentrations of CO, NO_2, SO_2 and PM consistently increased in the months that fall within the dry season. It has been revealed that rainwater dissolves gases of the atmosphere and wash-out particulate matters .This could account for the low level during rainy season since indoor environment is seriously under the influence of outdoor pollutants. H_2S and NH_3 increased in the months of rainy seasons. This could be as decay of organic matters which are the main sources of these pollutants. Methane (CH_4) gas showed no defined pattern of variation.

The regression analysis of gaseous pollutants with meteorological parameters has shown a good correlation between them.

Finally, the results of Two- way analysis of variance (ANOVA) revealed different levels of significance ($p<0.05$, $p<0.01$) in variations of the pollutants across the months and time of the day.

5.2 RECOMMENDATION

Monitoring of indoor air pollution is a pre-requisite for pollutants control and plays a critical role in protecting the indoor environment. The sources of emission and the pollutant's pathways have to be identified and controlled. The use of air cleaning devices should be encouraged.

The use of improved stoves and fuels with low emission and improving ventilation system by increasing outdoor air supply will reliably reduce exposure to pollutants.

Finally, introducing workshops and seminars by stakeholders (Governments, Private companies, NGOs, and other concern citizens and professionals) can create

5.3 CONTRIBUTION TO KNOWLEDGE

The study has shown that Hostel environments can contain significant exposures of some indoor air pollutants that may affect the comfort and health of students.

The multiple linear model equations generated using regression analysis can be used in predicting the effect of meteorological variables.

The research study has also shown similar values of the regression coefficients which indicate uniform effect of the meteorological parameters in distributing the pollutants.

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