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A Comparative Indoor and Outdoor Air Quality in Uyo Metropolis, Niger Delta, Nigeria

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ABSTRACT

The aim of this research was to determine the indoor and outdoor air quality of some locations within Uyo metropolis, the capital of Akwa Ibom State, a major oil producing state in Nigeria. At each location, noxious gases and other parameters were determined. Results obtained showed that the air quality in the selected homes were reflections of the gases produced near the homes. Indoor CO (mg/dm^3) ranged from $14.3 \pm 1.50 - 42.5 \pm 2.38$ and $18.1 \pm 0.10 - 39.3 \pm 0.50$ for the outdoor. The indoor SOx (mg/dm^3) ranged from $0.1 \pm 0.00 - 0.8 \pm 0.46$ while the outdoor level was $0.20 \pm 0.04 - 1.5 \pm 1.03$. Indoor H_2S (mg/dm^3) ranged from $0.1 \pm 0.00 - 0.7 \pm 0.57$ and $0.2 \pm 0.06 - 1.5 \pm 1.03$ for outdoor. NH_3 (mg/dm^3) ranged from $0.1 \pm 0.14 - 6.3 \pm 0.50$ and $1.0 \pm 0.05 - 5.3 \pm 1.52$ for the indoor and outdoor, respectively. Generally, most of the readings were within statutory limits indicating that indoor air are of acceptable quality excepting at few locations where raised values were obtained because of prevailing activities within the neighbourhood of the sampling locations. The health implications of some gaseous pollutants determined have been reported.

Key words: Indoor & Outdoor Air Quality; Uyo metropolis; Niger Delta region; gaseous pollutants; Health hazards.

INTRODUCTION

The average person spends approximately 90% of their time indoors. Recent studies have indicated that indoor air is often dirtier and / or contains higher levels of contaminants than outdoor air. Because of this and increased awareness regarding poor indoor air quality (IAQ), it is not surprising that the number of reported employee complaints of discomfort and illness in non-industrial workplaces is increasing [7].

Beginning in the mid-1970s, IAQ complaints increased for two reasons. The reason is the impact of energy crisis. To reduce heating and cooling costs, buildings have been made "airtight" with insulation and sealed windows. In addition, the amount of outside air introduced into buildings has been reduced. The second reason is that more chemical containing products, office supplies, equipment, and pesticides have been introduced into the office environment increasing employee exposure (Encyclopedia of Earth, 2008). These changes created IAQ health problems known as Sick Building Syndrome (SBS) or Building Related Illnesses (BRI) [18].

Int. J. Chem., Environ, Pharm. Res.
Vol.1, No.3, 51-62(2010), Special issue

Contaminants which contribute to poor indoor air quality can be attributed to both outside air and inside air [15]. Outside air contaminants can be introduced into a building through the ventilation intakes, doors, building envelope, and windows. Outside air contaminants include vehicular exhausts, industrial emissions, microbiologicals and pollen. Inside air contaminants are emitted from building materials and furnishings, appliances, office equipment and supplies, biological organisms, and of course, pollutants introduced by the building occupants themselves. Inside air contaminants also include tobacco smoke, volatile organic compounds, combustion gases such as carbon monoxide, and occupant – generated bio-effluents. The concentration of these contaminants in building can increase if ventilation systems are inadequately designed, maintained and operated or if strong local contaminant source are not controlled [18].

A wide variety of substances are emitted by building construction materials and interior furnishings, appliances, office equipment, and supplies, human activities, and biological agents. For example, formaldehyde is emitted from various wood products, including particle board, plywood, pressed-wood, panelling, some carpeting and backing, some furniture and dyed materials, urea-formaldehyde insulating foam, some cleaners and deodorizers, and from press textiles. Volatile organic compounds, including alkanes, aromatic hydrocarbons, esters, alcohols, aldehydes, and ketones are emitted from solvents and cleaning compounds, paints, glues, caulks, and resins, spray propellants, fabric softeners and deodorizers, unvented combustion sources, dry-cleaning fluids, arts and crafts, some fabrics and furnishings, stored gasoline, cooking, building and roofing materials, waxes and polishing compounds, pens and markers, binders and plasticizers. Pesticides also contain a variety of toxic organic compounds [11].

Homes in cities/towns experience environmental disturbances existing in the air they breathe due to various activities going on in the city and its effects on health [5,16]. Air pollution has a long-term effect on human health. Air contaminants shorten human life and the effects of poor indoor air quality have also been expressed in homes closer to petrol stations, industries, factories and refuse gathering points. Owing to these health effects, most countries have implemented mechanical ventilation systems for air pollution regulations. The above-mentioned activities go on in Uyo metropolis hence the need to carryout the indoor air quality study.

Air qualities in homes and environment have provided a reliable means of accessing the level of pollutants in the atmosphere [18]. Nowadays, there is increasing environmental contaminants which have been reported of having adverse health effect on population of individuals occupying a particular apartment. There is therefore a great need to carryout the indoor air quality studies at homes in Uyo metropolis to ascertain how safe most homes could be with respect to indoor air quality.

This research is carried out to assess the indoor air quality of Uyo metropolis considering the indoor and outdoor activities around the sampling points. This research work has the aim of determining the indoor air quality in Uyo metropolis. It will also access the outdoor air quality to see if there is a difference between the two at any particular location.

In this study, indoor and outdoor air quality in some locations in Uyo, Akwa Ibom State was estimated with highly sensitive portable digital in-situ gas monitors. Gases estimated included NO_x, SO_x, H_2S, CO, NH_3, Cl and HCN. Heat radiation, temperature, pressure/direction of wind and wind speed were estimated with each respective instrument. The sample collection was scattered and spread across the Uyo metropolis.

MATERIALS AND METHODS

Description of Study Area

Uyo is the capital city of Akwa Ibom State in Nigeria. It extends between latitudes 7° 45' and 8° 05' East and between longitude 4° 50' to 5° 10' North and covers an area of about 989.96 Square kilometres (Fig. 1). By 1991, the population of the city was 118,250 [12]. According to [2] and [4], Uyo came into existence in 1905 as an administrative centre, when Mr. Brooks, Captain of the then British Army Unit conquered the area and made it the headquarters of Uyo District. Between 1960 and 1967 Uyo served as province's headquarter. From 1967-1976, it served as Divisional headquarter. In 1976, it became a local government headquarters. From 1987, it became a state capital with the creation of Akwa Ibom State as well as serving as a local government headquarters, a status it maintains till date.

The mean annual Temperature in Uyo urban is 27°C, the relative humidity varies through the year from 70 to 80 percent. The mean annual rainfall is 2484 millimetres. The city has two distinct seasons namely; dry and rainy seasons. The dry season usually starts in November and ends in March while the rainy season starts usually in April and ends in October. The prevailing wind blows from South West in the wet season and from North East in the dry season. Fig. 1 is the map of Uyo capital city showing sample sites. A total of twenty one (21) sampling sites were selected for the study within Uyo metropolis, Nigeria. The twenty one sampling locations, their coordinates and brief description and activities within the neighbourhood are presented in Table 1.

Methodology

Measurements and readings of air quality, climate and meteorological parameters were carried out at each of the 21 locations within the study area using highly sensitive portable digital in-situ gas monitors (Table 2). The gaseous parameters determined were:- Nitrogen oxides (NO_x), Sulphur oxides (SO_x), Hydrogen Suphide (H_2S), Hydrogen cyanide (HCN), Radiation, Ammonia (NH_3), Chlorine (Cl_2) and Carbon monoxide (CO) while the meteorological data collected from the field were atmospheric pressure, relative humidity, and temperature. In-situ portable pieces of equipment used for the measurement are as shown in Table 2. Four measurements were carried out for each parameter at each location at an hourly interval. Holding the gas monitors at a distance of 1.5m above ground level, the instruments were held at an arms length from the body.

Statistical Analyses

The raw field data gathered were subjected to statistical analyses using the computer SPSS package [9].

RESULTS AND DISCUSSION

The results of indoor and outdoor air quality of the 21 sampling locations within Uyo metropolis are as presented in Tables 3 and 4, respectively. Results are presented as mean and standard deviation of four hourly determinations at each of the sampling locations. All sampling points were located along the city streets traversing the entire metropolis.

Nitrogen oxides (NO_x)

The results for the levels of NO_x were compared. It was observed that similar values were obtained at three out of the 21 locations for both the indoor and outdoor air quality SP3 (0.1 ± 0.05 mg/dm^3), SP18 (0.2 ± 0.10 mg/dm^3) and SP19 (0.3 ± 0.22 mg/dm^3). The indoor values were however higher than outdoor at seven locations SP 5 (0.4 ± 0.20), SP6 (0.20 ± 0.22), SP8 (0.2 ± 0.06), SP9 (0.2 ± 0.20), SP11 (0.3 ± 0.06) SP20 (0.3 ± 0.04) and SP21 (0.6 ± 0.29) mg/dm^3. Of interest is the fact that locations Sp 5, 6, 8 and 11 are waste gathering points suggesting that this gas emits from the waste site and is blown to nearby homes. As it infiltrates into such homes, it raises the indoor levels in such homes. Indoor NO_x was also noted to be higher in the home located near a water logged gutter. Other activities near homes with higher indoor levels of NO_x are sales of petrol in nearby Petrol stations and road construction with busy machinery. At eleven of the sampling points, however, the outdoor values were higher.

Nitrogen dioxide may be generated in the manifold of power generating plant. Long term exposure to NO_2 above 563ppm may cause pulmonary diseases. The oxides of Nitrogen are usually formed at high temperature combustion e.g flares, industrial combustion and vehicle engines. Nitric oxide and nitrogen dioxide are the two major oxides of interest. NO is readily formed by partial oxidation of nitrogen and is usually emitted in the exhaust pipe of motor vehicles and the manifold of power generating equipment where rapid oxidation to NO_2 takes place. NO_2 may also be generated by oxidizing nitrogen at high temperatures. It is an acidic gas. Long-term exposure to NO_2 at high concentration may cause pulmonary disease and increase susceptibility to bacterial infection in man [1].

Sulphur Oxides (SO_x) and Hydrogen sulphide (H_2S)

In this present study, levels of SO_x determined were within the ranges of 0.2 ± 0.10 – 1.5 ± 1.03 mg/dm^3 for outdoor and 0.1 ± 0.00 – 0.8 ± 0.46 mg/dm^3 for indoor. The oxides of sulphur had the same values at three points SP 3 (0.2 ± 0.08), SP17 (0.3 ± 0.15) and SP21 (0.3 ± 0.19) mg/dm^3 while indoor values were higher at six sampling points Sp 2 (0.6 ± 0.58), SP5 (0.8 ± 0.46), SP6 (0.5 ± 0.28), SP8 (0.7 ± 0.58), SP15 (0.4 ± 0.19) and SP18 (0.6 ± 0.10) mg/dm^3. Again, homes close to the waste gathering points (SP 3, 5, 6 and 8) experienced higher indoor SOx levels. Another activity that is probably responsible for a high indoor SO_x level is emission from the industrial production of Champion Beer (Champion Breweries). SO_x was however higher in twelve (12) of the twenty one (21) locations in the outdoor environment.

It is worth noting that the highest value of outdoor SO_x was obtained at location SP 16 with a value of 1.5 mg/dm^3 against the least value of 0.02 mg/dm^3. This was three times the value at the corresponding location for the indoor air quality. Again this value was obtained at a waste gathering point. This again suggests strongly that waste gathering is a potent contributor to poor air quality. One of the oxides of sulphur is sulphur dioxide. Exposure limits of this gas are fixed by different regulatory bodies as follows: (i) American Conference of Governmental Industrial Hygienists [1] (TLV) - 2 mg/dm^3; (ii) Occupational Safety and Health Administration (OSHA) (PEL) - 5 mg/dm^3 (TWA) and (iii) NIOSH (IDLH) – 100 mg/dm^3 [1,16,17].

SO_x vapours are extremely irritating to the throat, mucous membrane and upper respiratory tract. Concentrations between 1 mg/dm^3 and 5 mg/dm^3 can produce one health problem or the other including constriction of bronchiole tube to pulmonary oedema and even death. Short exposures to concentrations as low as 1 mg/dm^3 may produce reversible decrease in lung function. Long term exposures may result in dental caries, loss of fillings, gum disorders and the rapid and painless destruction of teeth (Chemtrade, 2007). In Nigeria, FEPA guidelines recommend outdoor SO_x concentration of 0.1 mg/dm^3 hourly [6].

The concentration of indoor SO_x obtained in the present study was between 0.1 ± 0.00 and 0.8 ± 0.46 mg/dm^3. This level is low when compared with the ACGIH, OSHA and NIOSH limits of 2 mg/dm^3, 5 mg/dm^3 and 100 mg/dm^3, respectively. Indoor Hydrogen Sulphide gas was higher than outdoor in seven (7) out of the twenty one (21) locations SP 3 (0.4 ± 0.21), SP5 (0.7 ± 0.57), SP8 (0.7 ± 0.56), SP11 (0.7 ± 0.47), SP17 (0.4 ± 0.08), SP18 (0.3 ± 0.21) and SP19 (0.6 ± 0.05) mg/dm^3 under study. Of the seven locations, SP 3, 5, 8 and 11 are waste gathering points while the other three high indoor values were obtained from a petrol station, Champion Breweries and water logged gutter. It was only at SP 15 that the value of H_2S concentration of indoor and outdoor did not vary (0.3 ± 0.13 mg/dm^3). This was because no obvious activity was recorded at this location. The H_2S concentrations in the rest of the thirteen sampling points were higher in the outdoor air. It was also observed that the outdoor H_2S at location 16 was highest with a value of 1.5 mg/dm^3. The least value was 0.2 mg/dm^3 at SP 11 and 18. H_2S concentrations at locations SP 11 and 18 are higher in the indoor environment suggesting that aside from waste gathering, indoor H_2S is also contributed by some indoor activities/sources.

Sulphur dioxide (SO_2) is one major air pollutant. It is usually formed from the oxidation of sulphur containing fuels and biomass. It is an acidic gas. Hydrogen sulphide (H_2S) gas is extremely toxic, odorous and corrosive, can be present in natural gas in certain areas and can be released by sulphate reducing bacteria in certain marine environments. Exposure to SO_2 at high concentrations could stimulate broncho-constriction (as in asthma) and mucus secretion as well as irritate the eyes in man ([1]. Long-term exposure to lower concentration may result in death from cardiac and/or respiratory diseases and increased prevalence of related symptoms. Sustained exposure to H_2S gas above 0.06 mm/dm^3 could result in death [14]. These gases are corrosive. They do not only eat up metals but sometimes cement work, like statues, houses and paintings. When in contact with these materials, they wear them out, disfiguring them beyond recognition or up to the level of eliminating them.

Int. J. Chem., Environ, Pharm. Res.
Vol.1, No.3, 51-62(2010), Special issue

Carbon Monoxide (CO)

Indoor concentrations of CO were higher at SP 14 (35.9 ± 3.07), SP18 (41.3 ± 3.40), SP19 (42.5 ± 2.38) and SP20 (39.5 ± 2.38) mg/dm^3. Activities contributing to the observed values are waste gathering/Traffic control point, Champion beer brewery activities, Water logged gutters/Hotel and Petrol sales. This gives a picture that the source of CO is manly vehicular emissions. SP 14 is a traffic control point where vehicles stop until it reaches their turn to move. During such times, the engines are left running. At SP 18 (Champion brewery) there is probably the utilization of fuels/machines that generate CO such as generating plants. At location SP 19, there is a Hotel that probably uses generating plant as power source given the poor state of electricity supply in the metropolis. At location SP 20, (petrol station and Clinic), CO comes from vehicular exhaust gases of vehicles waiting to buy petrol as well as generating plants used within the Clinic premises. These emissions/sources affect the nearby homes directly and for many hours within 24 hour period. At location SP 4, the indoor CO is high (34 mg/dm^3). This is probably contributed by generating plant serving a funeral home (mortuary) and an auto mechanic welding workshop. All other locations had higher levels of CO in the outdoor environment air.

In Santiago, Chile, a work on influence of Atmospheric Air pollution on Indoor Air Quality: Comparison of Chemical Pollutants and Mutagenicity levels was carried out. The work was to monitor the pollutants levels especially during traffic rush hours and also assess the effect of other contributions by the indoor sources to poor indoor air quality. The importance of infiltration of outdoor air on indoor air quality was also studied. In this study, the CO concentrations ranged from 1.0 to 73 mg/dm^3 and 0.5 to 93 mg/dm^3 for indoors and outdoors, respectively. The highest running 8 – hour average levels measured was 16 and 18 mg/dm^3, respectively.

A recent baseline survey conducted in two districts of Zimbabwe found that women and young children spend an average of 5 hours per day in the kitchen area, where air pollution levels from biomass fuel combustion for cooking tend to be very high. The measured levels of CO in the kitchen were in the range of 300 – 1000 mg/dm^3 [10]. In the present study, the concentration of outdoor CO was within the range 18.1 ± 0.10 and 46.30 ± 0.96 mg/dm^3. The indoor values ranged between 10.7 ± 0.45 and 42.5 ± 2.38 mg/dm^3. These values were above some regulatory standards [6] and need being monitored before highly toxic levels are reached.

The world health organisation recommends average carbon monoxide levels of no more than 9 mg/dm^3 over 8 hour period and no more than 36 dm^{-3} for a one hour period. In large cities members of the police on traffic duty have to be swapped at regular intervals to prevent excessive exposure to carbon monoxide. FEPA guidelines/Limits recommend outdoor CO levels of 10 mg/dm^3 hourly [6]. Carbon monoxide (CO) is a colorless, odorless, tasteless gas. It is emitted from a number of anthropogenic, natural sources and produced in the atmosphere from oxidation of CH_4. Major sources of anthropogenic emissions are technological processes e.g. fossil fuel combustion and production, deforestation/land use changes and biomass burning.

Prolonged and excessive exposure to ambient accumulation of high CO values could bring about formation of carboxy-haemoglobin and prevent oxygenation of the blood leading to suffocation and consequent death [1]. Young and elderly persons as well as individuals with cardiovascular diseases and respiratory problems are most at risk from exposure to this gas [14]: Lower concentrations strains the heart and causes nausea, fatigue, dizziness and reduce visual sensitivity in the dark [5]. When carbon monoxide is inhaled into the lungs, it bonds with haemoglobin in blood, which forms carboxyhemoglobin (COHb). This condition displaces oxygen in the blood stream and affects all major organs and muscles.

Ammonia (NH_3)

Ammonia gas was higher in indoor air than outdoor air at five locations SP 1 (2.8 ± 0.50 mgdm^{-3}), SP 4 (2.1 ± 1.22), SP 5 (6.3 ± 0.50), SP 16 (2.9 ± 0.17), SP 18 (2.4 ± 0.53) and SP 21 –(1.9 ± 0.16) mg/dm^3. The lowest value for indoor NH_3 concentration was 0.1 mg/dm^3 at SP 11 (0.1 ± 0.06) and SP12 (0.1 ± 0.14) mg/dm^3. Most of the locations had higher NH_3 in the outdoor environment with such values as

Int. J. Chem., Environ, Pharm. Res.
Vol.1, No.3, 51-62(2010), Special issue

5.3 ± 1.52, 3.9 ± 0.67, 3.0 ± 0.00, 5.1 ± 1.51, 2.8 ± 0.59, and 3.2 ± 0.17 mg/dm^3 for SP 6, 10, 11, 12, 13, 15 and 18 respectively. The highest indoor concentration of NH_3 at SP 5 (6.3 mg/dm^3) suggest that some activities within the home contribute to this high value. The highest outdoor value of 5.3 mg/dm^3 (SP 6) did not have a pronounced effect on the indoor environment (0.3 mg/dm$^{3)}$. Also the outdoor concentration of 3.9 mg/dm^3 at SP10 did not affect the indoor environment drastically (0.3 mg/dm^3). Also at SP 13, the outdoor value was 5.1 mg/dm^3 while the indoor concentration was 3.1 mg/dm^3, a similar indoor concentration where the outdoor concentration is 3.2 mg/dm^3 (SP8). At this SP 8 the outdoor concentration was 3.2 mg/dm^3 (SP 8) with an indoor concentration of 3.1 mg/dm^3. At this SP8, the indoor and outdoor concentrations are almost the same suggesting minimal influence of outdoor ammonia concentration on indoor environment.

Ammonia (NH_3) is the most abundant basic chemical substance in the atmosphere and the third most abundant Nitrogen compound. Major sources of ammonia include anaerobic decomposition of organic matter, animals and their wastes, biomass burning, soil humus formation and application of anhydrous NH_3 to cropland. Other sources include industrial emissions [16]. Ammonia reacts rapidly with strong acids e.g. H_2SO_4 and HNO_3 to produce ammonium salts. Thus NH_3 plays an important role in removing SO_2 and NO_2 from the atmosphere. It could also cause bronchial asthma in man.

Chlorine (Cl_2)

Chlorine was higher in the indoor than outdoor air at 11 sampling points SP (30.6 ± 0.05), SP4 (0.7 ± 1.15), SP5 (0.9 ± 0.25), SP7(0.5 ± 0.10), SP10 (0.6 ± 0.30), SP11 (0.6 ± 0.08), SP13 (0.2 ± 0.00), SP16 (0.3 ± 0.10), SP18 (0.9 ± 0.87), SP19 (3.3 ± 0.31) and SP20 (0.9 ± 0.39) mg/dm^3. The indoor concentration of 3.3 ± 0.31 mg/dm^3 (SP19) could be viewed as being contributed by the water logged gutter. The next value of 3.2 ± 4.60 mg/dm^3 (SP1) was obtained in the outdoor environment where a paint mixing depot is located. It is likely that the paint material emits this chemical into the outdoor environment. Aside from these two locations, every other 19 locations (both indoor and outdoor) have concentrations that are below 1.0 mg/dm^3. It was obvious that most homes use Cl containing materials. According to [17] studying occupational health risks (OHRS) at five occupational sites in Uyo metropolis, the value for chlorine was 0.5 mg/dm^3 and was obtained at a waste disposal site. Other locations sampled had values such as 0.2 and 0.3 mg/dm^3.

Hydrogen Cyanide (HCN)

The concentration of hydrogen cyanide gas was diffused. Most of the locations had similar concentrations (indoor and outdoor) of HCN. Values obtained were mostly 1.0 mg/dm^3 in a previous work carried out in Uyo metropolis. Hydrogen cyanide (HCN) occurs in the atmosphere in low background levels. It reacts relatively slowly with OH.

Humidity

High humidity gives rise to mold growth and moisture indoors is associated with a higher prevalence of occupant respiratory problems. In homes where cellulosic materials (paper and wood, wall etc) become moist and fail to dry within about 12 to 18 hours, mold mildew can propagate releasing spores into the air. These spores are allergens that can aggravate some health conditions such as asthma. Mold growth can be controlled by maintaining humidity level at about 50% and below [18].

CONCLUSION

Out of the twenty one locations studied, it was observed that there were differences in the indoor and outdoor concentrations of the gases under study. In most of the cases, the outdoor values were higher than the indoor. Hydrogen cyanide gas was peculiar in that fifteen out of the twenty one locations had similar values for both indoor and outdoor suggesting that most of the activities around the sampling sites did not emit HCN. Also, there is the possibility that most of the homes studied did not use HCN-containing house hold materials. The indoor concentrations of Chlorine were higher than outdoor at eleven locations. This gave an indication that all of this chlorine did not come from outdoor air. It was generally observed that

Int. J. Chem., Environ, Pharm. Res.
Vol.1, No.3, 51-62(2010), Special issue

waste gathering points generated high concentrations of the gases like NH_3, SO_x, H_2S and Cl which in turn affected the indoor concentrations. Specific activities in the study area were seen to generate specific gaseous pollutants. For instance; carbon monoxide was high where generating plants were used. It was also high at traffic control points as well as petrol stations. The high values at petrol stations were probably due to emissions from the vehicles that buy petrol from these stations.

Another peculiar observation from the study is that activities that went on beyond 8 hours generated pollutants at high levels and this raised the indoor levels of such pollutants. For instance, indoor CO was higher than outdoor near clinics/private hospitals, Hotels with prolong period of generating plant usage. It can therefore be summarized that indoor and outdoor air quality are generally influenced by the activities going on in the vicinity of such homes.

The various gaseous pollutants listed in this study, for example, carbon monoxide, hydrogen cyanide and hydrogen sulphide can cause asphyxia by interfering with oxygen transport. At low concentrations, these gases poison cytochromes and cause the rapid onset of headache, dizziness, vomiting and confusion. At high concentrations they are very rapidly lethal. Exposure to them should be highly regulated.

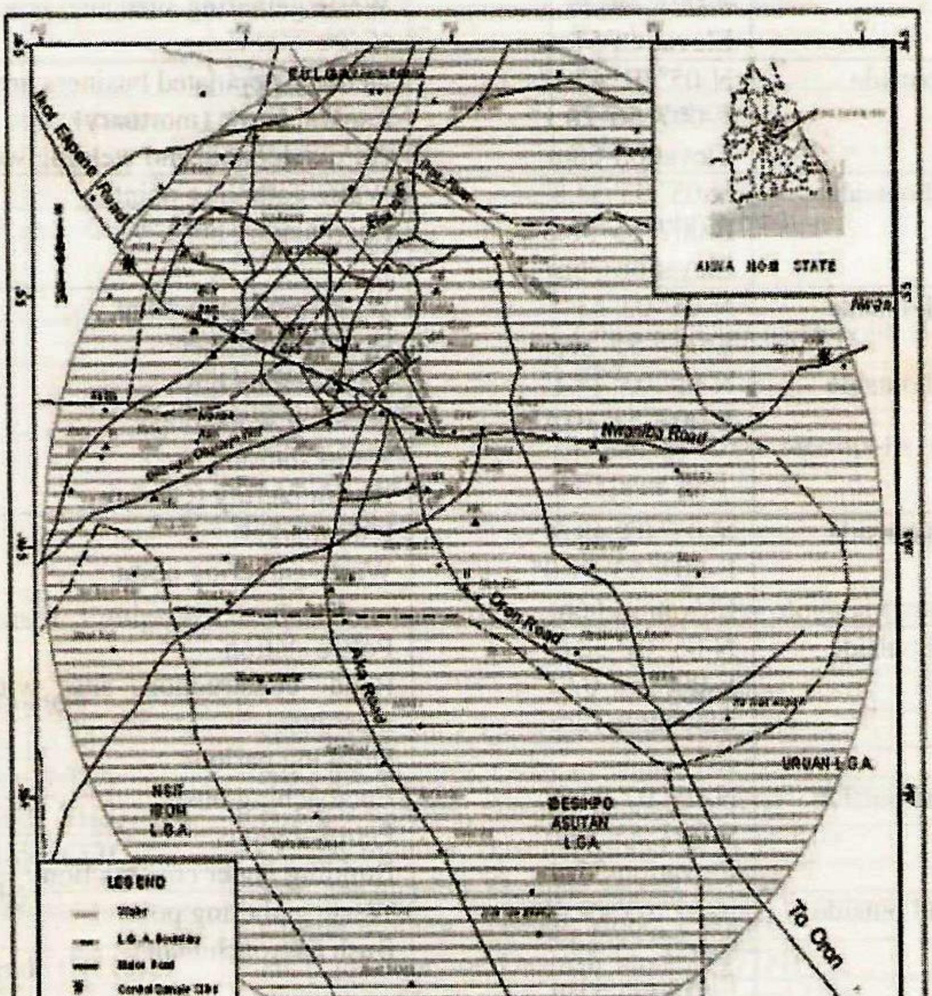

Fig.-1: Uyo Capital city showing sample sites

Int. J. Chem., Environ, Pharm. Res.
Vol.1, No.3, 51-62(2010), Special issue

Table-1: Sample Locations & Coordinates, Brief Description and Activities within their Neighbourhood

Sampling points	Coordinates	Description and activities of surrounding environment
SP1-Bedroom and outside	N-05° 01' 10.2" E-007° 56' 13.3" Elevation-66m	Paint mixing point Auto-mechanic Workshop Moving vehicles Petrol Station
SP2-Parlour and outside	N-05° 00' 03.6" E-007° 56' 55.2" Elevation-66m	Traffic control point Construction stone depot Petrol station Cyber café Refrigerator repairing shop
SP3-Bedroom and outside	N-05° 01' 37.0" E-007° 58' 38.3" Elevation-51m	Petrol station Waste gathering site
SP4-Parlour and outside	N-05° 01' 47.1" E-007° 56' 20.1" Elevation-66m	Densely populated business area Funeral home (mortuary) Auto-mechanic and welding workshop
SP5-Bedroom and outside	N-05° 03' 34.8" E-007° 55' 58.8" Elevation-36m	Waste gathering point Encroaching bush
SP6-Bedroom and outside	N-05° 02' 43" E-007° 55' 19.4"	Waste gathering point Roadside market
SP7-Bedroom and outside	N-05° 03' 44.1" E-007° 53' 10.4"	Encroaching bush Welding workshop Petrol station Health facility (Clinic)
SP8-Bedroom and outside	N-05° 02' 48.5" E-007° 53' 51.0" Elevation-66m	Itam market Waste gathering point
SP9-Bedroom and outside	N-05° 01' 38.6" E-007° 52' 07.7" Elevation-72m	Police station Road construction site with construction machines Drinking parlour
SP10-Bedroom and outside	N-05° 02' 37.7" E-007° 53' 34.6" Elevation-75m	Encroaching bush Petrol stations Building under construction
SP11-Bedroom and outside	N-05° 03' 19.4" E-007° 55' 49.7" Elevation-41m	Waste gathering point Bush encroachment
SP12-Bedroom and outside	N-05° 03' 19.4" E-007° 56' 33.8" Elevation-41m	Slaughter (with cows and goats)
SP13-Bedroom and outside	N-05° 02' 53.7" E-007° 53' 18.9" Elevation-61m	Julius Berger Camp site Petrol station

Int. J. Chem., Environ, Pharm. Res.
Vol.1, No.3, 51-62 (2010), Special issue

SP14-Bedroom and outside	N-05° 02' 10.3" E-007° 55' 23.9" Elevation-64m	Refuse drop point Traffic control point
SP15-Bedroom and outside	N-05° 01' 04.2" E-007° 52' 46.2" Elevation-65m	Bushy area
SP16-Bedroom and outside	N-05° 01' 52.9" E-009° 55' 05.7"	Waste gathering point Banks Shops
SP17-Bedroom and outside	N-05° 01' 08.3" E-007° 55' 17.5" Elevation-74m	Petrol station
SP18-Parlour and outside	N-05° 00' 02.6" E-007° 55' 06.6"	Champion Breweries
SP19-Bedroom and outside	N-05° 01' 08.3" E-007° 56' 25.2" Elevation-72m	Water logged gutter Hotel
SP20-Bedroom and outside	N-05° 00' 47.2" E-007° 57' 03.4" Elevation-71m	Petrol station Clinic
SP21-Bedroom and outside	N-05° 01.' 54.6" E-007° 55' 57.2" Elevation-79m	Encroaching bush
–	N-05° 03' 49.7" E-007° 52' 14.3" Elevation-83m	Limit of Uyo metropolis (Upwind): Nwaniba End
–	N-05° 02' 37.2" E-008° 01' 44.0" Elevation-45m	Limit of Uyo metropolis (Downwind): Ikot Ekpene End

Table- 2: Equipment used to determine the gaseous and meteorological parameters.

Parameters	Equipment
Sulphur dioxide (SO_2)	SO_2 gas monitor, Gasman Model 196484H
Nitrogen dioxide (NO_2)	NO2 gas monitor, Gasman Model 19831N
Hydrogen suphide (H_2S)	H_2S gas monitor, Gasman Model 19502H
Carbon monoxide (CO)	CO gas monitor, Gasman Model 19252H
Ammonia (NH_3)	NH_3 gas monitor, Gasman Model 19730H
Chlorine (Cl_2)	Cl_2 gas monitor, Gasman Model 19812H
Hydrogen cyanide (HCN)	HCN gas monitor, Gasman Model 19773H
Radiation	Radiation Alert monitor 4 Se International USA
Atmospheric pressure, relative humidity, temperature	Multipurpose Hydro, Baro and Thermometer (Hydro 20-100%, Thermo 10-50°C, Baro 740-777mmHg) Model1: Baro Germany
Heat radiation	Photometer (Lux meter). Model:- Lutron Lx – 101 Lux meter
Wind speed	Portable wind vane. Model :- Derta Anemo wind speed indicator
Wind direction	Magnetic compass

Int. J. Chem., Environ, Pharm. Res.
Vol.1, No.3, 51-62 (2010), Special issue

Table-3: Indoor Air Quality in Uyo Metropolis, Akwa Ibom State, Nigeria (*mean ± standard deviation)

Sample label	NO_2 Mg/dm^3	SO_2 mg/dm^3	H_2S mg/dm^3	CO mg/dm^3	NH_3 mg/dm^3	Cl mg/dm^3	HCN mg/dm^3	Temp °C	Humidity %	Pressure mmHg
SP 1	0.2±0.06	0.3±0.05	0.5±0.05	19.2±0.15	2.8±0.50	0.4±0.00	1.0±0.00	27.7±0.21	63.5+0.58	747.5±0.00
SP 2	0.1±0.00	0.6±0.58	0.3±0.10	22.8±0.50	1.1±0.20	0.4±0.06	1.0±0.00	29.0±0.75	61.8+3.10	747.4±0.14
SP 3	0.1±0.05	0.2±0.08	0.4±0.21	23.3±0.96	3.0±0.05	0.6±0.05	1.0±0.00	30.3±2.23	62.3+5.38	747.5±0.10
SP 4	0.1±0.05	0.1±0.00	0.1±0.00	34.5±5.74	2.1±1.22	0.7±1.15	0.5±0.58	28.4±0.30	64.8+1.26	747.5±0.05
SP 5	0.4±0.20	0.8±0.46	0.7±0.57	14.3±1.50	6.3±0.50	0.9±0.25	1.0±0.00	28.8±0.13	63.8+2.06	747.5±0.00
SP 6	0.2±0.22	0.5±0.28	0.2±0.08	15.8±0.40	0.3±0.29	0.1±0.00	0.6±0.71	30.5±1.77	57.0+2.45	747.5±0.00
SP 7	0.3±0.04	0.2±0.10	0.3±0.05	20.8±1.50	1.1±0.10	0.5±0.10	1.0±0.05	26.9±0.61	64.8+1.50	747.6±0.10
SP 8	0.2±0.06	0.7±0.58	0.7±0.56	23.0±3.56	3.1±0.10	0.2±0.10	0.8±0.50	28.3±1.11	63.0+2.58	747.8±0.20
SP 9	0.2±0.20	0.2±0.20	0.1±0.00	14.6±0.75	0.7±0.42	0.3±0.06	0.1±0.06	30.2±1.53	59.8+2.98	747.5±0.14
SP 10	0.1±0.00	0.1±0.05	0.1±0.13	18.0±2.83	0.3±0.29	0.6±0.30	0.1±0.05	27.4±0.37	65.0+0.82	747.5±0.13
SP 11	0.3±0.06	0.1±0.00	0.7±0.47	25.0±0.05	0.1±0.06	0.6±0.08	0.6±0.52	28.6±0.55	62.6+1.71	747,4±0.18
SP 12	0.1±0.00	0.1±0.05	0.2±0.10	25.0±0.05	0.1±0.14	0.3±0.10	0.1±0.05	30.9±1.13	58.9+4.93	747.5±0.00
SP 13	0.1±0.00	0.1±0.05	0.2±0.00	36.0±1.18	3.1±0.14	0.2±.0.00	0.1±0.00	27.6±0.33	66.3+0.50	747.4±0.10
SP 14	0.1±0.00	0.1±0.00	0.1±0.06	35.9±3.07	2.1±0.05	0.1±0.00	0.1±0.00	28.3±1.17	62.0+3.74	747.5±0.00
SP 15	0.2±0.10	0.4±0.19	0.3±0.13	21.8±2.06	2.7±0.40	0.3±0.10	1.0±0.00	27.2±0.13	67.3+0.50	747.5±0.00
SP 16	0.2±0.10	0.5±0.09	0.5±0.37	28.0±5.48	2.9±0.17	0.3±0.10	1.0±0.00	28.2±1.30	63.8+2.22	747.5±0.00
SP 17	0.2±0.10	0.3±0.15	0.4±0.08	24.3±3.10	0.2±0.08	0.1±0.00	1.0±0.00	30.0±0.37	61.8+2.22	747.5±0.00
SP 18	0.2±0.10	0.6±0.10	0.3±0.21	41.3±3.40	2.4±0.53	0.9±0.87	1.0±0.00	27.3±0.24	66.3+0.50	747.5±0.00
SP 19	0.3±0.01	0.3±0.15	0.6+0.05	42.5±2.38	0.2±0.06	3.3±0.31	1.0±0.00	27.5±0.15	66.3+0.50	747.5±0.00
SP 20	0.3±0.04	0.3±0.10	0.3±0.24	39.5±2.38	0.2±0.06	0.9±0.39	1.0±0.00	28.9±1.10	61.0±3.65	747.4±0.00
SP 21	0.6±0.29	0.3±0,19	0.1±0.13	10.7±0.45	1.9±0.16	0.2±0.02	1.0±0.00	27.3±0.17	60.3±0.96	747.4±0.00

Table- 4: Outdoor Air Quality in Uyo Metropolis, Akwa Ibom State, Nigeria (mean ± standard deviation)

Sample label	NO_2 mg/dm^3	SO_2 mg/dm^3	H_2S mg/dm^3	CO mg/dm^3	NH_3 mg/dm^3	Cl mg/dm^3	HCN mg/dm^3	Temp °C	Humidity %	Pressure mmHg	Heat Rad.	W/S m/s	WD
SP 1	0.3±0.10	0.5±0.05	0.6±0.05	38.3±1.50	2.0±0.00	3.2±4.60	1.0±0.00	27.5±0.58	64.8±0.98	747.5±0.00	222-229**	0.5-1.0	UPW
SP 2	0.4±0.10	0.3±0.13	0.4±0.23	24.5±1.73	2.8±0.45	0.5±0.15	1.0±0.00	29.7±0.29	62.6±2.22	747.4±0.15	1194-1211	1.0-1.5	UPW
SP 3	0.1±0.05	0.2±0.10	0.3±0.05	18.1±0.10	3.0±0.08	0.4±0.06	0.1±0.05	30.8±3.30	61.5±8.63	747.5±0.00	1225-1229	1.0-1.5	DW
SP 4	0.2±0.05	0.2±0.10	0.3±0.10	46.3±0.96	1.0±0.05	0.3±0.05	1.0±0.00	27.6±0.19	68.5±0.58	747.7±0.10	212-217	0.5-15	UPW
SP 5	0.2±0.22	0.4±0.20	0.5±0.09	20.5±1.00	3.0±0.00	0.2±0.00	1.0±0.00	28.9±0.98	65.3±0.96	747.7±.00	1059-1067	1.0-2.0	UPW
SP 6	0.1±0.06	0.2±0.04	0.3±0.14	21.3±1.50	5.3±1.52	0.3±0.10	1.0±0.00	29.0±0.19	60.8±4.50	747.4±0.15	1621-1607	1.1-2.2	DW
SP 7	0.3±0.05	0.3±0.16	0.6±0.08	20.0±2.94	1.9±0.21	0.2±0.09	1.0±0.00	30.5±0.09	57.5±2.30	747.5±0.05	980-961	0.5-1.0	DW
SP 8	0.1±0.12	0.5±0.19	0.4±0.20	29±1.82	3.2±0.31	0.3±0.10	1.0±0.00	30.7±0.26	58.0±2.5	747.4+0.3	920-922	0.5-1.0	DW
SP 9	0.1±0.12	0.3±0.10	0.3±0.18	33.3±1.91	1.9±1.30	0.3±0.19	1.0±0.00	32.0±0.90	60.0±5.4	747.3±0.20	1001-1005	0.5-1.0	DW
SP 10	0.4±0.20	0.3±0.10	0.3±0.13	33.0±2.16	3.9±0.67	0.1±0.04	0.1±0.00	27.4±0.59	66.9±0.88	747.5±0.12	109-144	0.5-1.0	DW

Int. J. Chem., Environ, Pharm. Res.
Vol.1, No.3, 51-62 (2010), Special issue

SP 11	0.2±0.17	0.4±0.33	0.2±0.06	35.0±0.17	3.0±0.00	0.4±0.1	0.1±0.00	27.6±0.59	63.4±3.68	747.5±0.09	323-344	1.0-1.5	UPW
SP 12	0.4±0.04	0.4±0.06	0.5±0.00	33.2±2.3	2.8±0.30	0.6±0.66	0.1±0.00	31.2±1.43	53.2±6.66	747.5±0.26	1249-1254	1.0-1.5	UPW
SP 13	0.4±0.00	0.5±0.05	0.3±0.10	41.3±1.26	5.1±1.51	0.1±0.05	0.1±0.00	27.3±0.08	66.0±0.82	747.5±0.10	106-111	1.0-1.5	DW
SP 14	0.4±0.01	0.6±0.05	0.4±0.06	33.8±1.50	2.1±0.10	0.3±0.00	0.1±0.00	28.5±0.95	63.3±2.75	747.3±0.29	765-772	1.0-1.5	DW
SP 15	0.4±0.05	0.3±0.10	0.3±0.10	38.9±0.20	2.8±0.59	0.4±0.39	1.0±0.00	27.8±0.90	65.8±0.96	747.5±0.05	217-222	0.5-1.0	UPW
SP 16	0.4±0.21	1.5±1.03	1.5±1.03	37.0±0.82	2.0±0.06	0.1±0.00	1.0±0.00	29.0±0.15	61.3±1.71	747.5±0.00	222-227	0.5-1.0	DW
SP 17	0.4±0.06	0.3±0.05	0.3±0.05	39.3±0.50	1.6±0.97	0.1±0.00	1.0±0.00	29.1±0.71	63.3±2.06	747.5±0.00	230-235	0.5-1.0	DW
SP 18	0.2±0.10	0.2±0.10	0.2±0.10	20.0±1.63	3.2±0.17	0.7±0.25	1.0±0.00	27.2±0.10	66.8±0.50	747.5±0.00	215-230	0.6-1.0	DW
SP 19	0.3±0.22	0.5±0.31	0.5±0.31	31.8±1.71	1.7±0.81	0.3±0.10	1.0±0.00	27.4±0.27	66.0±0.82	747.5±0.00	227-232	1.0-1.5	UPW
SP 20	0.1±0.00	0.7±0.91	0.7±0.91	31.8±0.96	1.4±0.37	0.3±0.13	1.0±0.00	29.4±1.66	58.8±2.75	747.5±0.00	278-283	1.0-1.5	UPW
SP 21	0.2±0.06	0.3±0.01	0.3±0.01	29.8±0.96	0.6±0.99	0.4±0.05	1.0±0.00	26.4±0.45	59.8±6.92	747.5±0.00	207-212	1.0-1.5	DW

DW – Downward; UPW – Upward; **Ranges

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