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Assessment of Ambient Atmospheric Concentration of Volatile Organic Compounds in Abuja-Nigeria

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ABSTRACT

An assessment of the ambient air in Abuja have revealed the presence of various concentrations of volatile organic compounds (VOCs)/low explosive limit gases. In this study, ambient emission inventory of low explosive limit (LEL) gases such as methane were taken using BW Technology GasAlaert® Microclip (gas detection instrument) from various sample points in Abuja municipal area council, Kuje and Dobi in Gwagwalada area council. The results show that high concentration of LEL were detected in Abuja municipal area council which can be attributed to increased population growth, increased production of gaseous wastes and increased number of industries. However, no LEL was detected in Kuje area council and with only emission of gases stable at (6.97%) from point P26 to P50 in Dobi, Gwagwalada area council which was due to decomposed refuse around the market and milling machines waste within settlements, in Dobi village.

Keywords: Ambient air, VOCs/LEL, emission source, air quality.

INTRODUCTION

Urban air quality depends largely on the volatile organic compounds (VOCs)/low explosive level (LEL) gases emitted from anthropogenic and natural sources. The United States Environmental Protection agency has identified some VOCs/LEL gases such as benzene, toluene etc. as air toxics or carcinogens [1,2]. The adverse effects of VOCs include stratospheric ozone layer depletion, formation of highly toxic secondary pollutants (tropospheric ozone and peroxyacetylnitrate) and enhancement of the global greenhouse effects[3,4]. VOCs have also been confirmed to have various toxic and carcinogenic effects on human health which include eye, nose and throat irritations, headaches and nausea[5,6]. These adverse effects have become a source of major concerns in all fast growing cities worldwide[3,7]. The dominant sources of VOCs in urban areas include combustion processes utilizing fossil fuels such as vehicles, plant machineries, power generating stations; petroleum storage and distribution; solvent usages and other industrial processes [8,9]. VOCS are also emitted from industrial and domestic effluents, livestock industry (mainly diaries and feedlots), plants, microbes and fungi[10-12]. The city of Abuja is the new federal capital territory (FCT) of Nigeria. The contributions to VOCs emission from anthropogenic sources have changed drastically in recent years due to fast urbanization and industrialization. The need to assess the air quality in FCT cannot be taken out of context owing to the rapid growing population in the Federal Capital City, the outcry of electricity power outages and usage of power generating plants, emission of carbon monoxide, hydrocarbons, bush burning, use of fuel wood by house- holds, open mine quarries, methane gas from solid waste sites, etc. Measurement of VOCs concentration in a locality is vital in determining the source and transport mechanisms of pollution, in the design and implementation of effective air emission control strategies and for assessing the impacts on human health[13].

However, lack of emission data makes it difficult to carry out air pollution study, air quality modeling and to develop an effective emission control strategy[14]. Prior to this study anxiety to get data on air pollution in Nigeria was high but this was not realistic after all, as the only data available were the Federal Environmental Protection Agency (FEPA) 1992 Green book, information on Environmental issues and Nigeria Ambient Air Quality Standard (NAQS) adopted from the World Health Organization (WHO) Air Quality Guideline (AQG) and the United States Environmental Protection Agency (USEPA) Air Quality Index (AQI). Many researchers had cried out for lack of data to check air pollution in Africa either indoor or outdoor and Nigeria is not left out. The aim of this paper is to investigate the VOC/LEL gases in the ambient air of Abuja-Nigeria so as to serve as guide to effective source characterization of VOCs/LEL gases and the study of spatial and temporal variation of ambient concentrations of selected VOCs/LEL gases in Abuja.

VOCS/LEL GASES

VOCs are emitted as gases from certain solids and liquids. They include a variety of chemicals, some of which may have short time and long time adverse health effects[15]. The USA Environmental protection agency (USEPA) for regulatory purposes gave a broad definition of VOCs as any volatile compound of carbon except those specifically exempted[1]. Those exempted are non reactive and slow reactive VOCs.However, VOCs may also be defined as organic chemical with high vapour pressure at ordinary, room temperature conditions. This is due to their low boiling points, which causes large numbers of molecules to evaporate from the liquid or solid form of the compound into the surrounding air. For instance, formaldehyde with a low boiling point of -19^{o}C (-2^{0}F), slowly leaves the paint into the air [9],[16] .VOCs are of numerous types. They include both man- made and naturally occurring chemical compounds [17]. Some common examples include: Acetone, Benzene, Ethylene glycol, Formaldehyde, Methylene chloride, Perchloroethylene, Toluene, Xylene, 1, 3- butadiene.

SOURCE CHARACTERIZATION

The principle of source characterization or apportionment study is to identify and quantify the various sources contributing to the VOC levels within the urban air shed[3]. Source characterization is also used to understand the behaviour of trace gases and aerosols on transcontinental and intercontinental scales, and their impact on air quality and climate. A very popular study is the intercontinental chemical transport experiment – phase B (INTEX-B) aircraft experiments which was conducted in 2006 with the first part focussing on Mexico City pollution and the second part focussing on the transport, transformation and evolution of Asian pollution to North America. Whole air samples were collected on board aircraft and were analysed for selected VOCs [7,18], reported that several studies have been carried out in the United States, Europe and Asia on the source apportionment of VOCs in ambient air using source receptor models such as Chemical Mass Balance (CMB), Positive Matrix Factorization (PMF), UNMIX and Principal Component analysis/Absolute principal Component Scores (PCA/APCS).

In 2004, source apportionment of Mumbai city in India was conducted by Srivastava using CMB 8.0 and he identified evaporative emissions to be predominant. Also, [19,20]Srivastava et al. identified emissions from diesel internal combustion as among the predominant sources of VOCs in the city of Delhi, India. Receptor modelling (positive matrix factorization) was employed as factor analysis techniques that identified three source factors (gasoline vehicle exhaust, diesel vehicle exhaust and paint production and application) for the suburban site of Izmir, Turkey[3]. Similar studies was also conducted by [7]sanchez et al., 2008 of Corpus Christi, a growing industrialized urban area located along the Gulf of Mexico in South Texas where two continuous ambient monitoring stations (CAMS) were set up to monitor the VOC concentrations in the urban atmosphere identified refinery operation, flare emissions and secondary industrial processes as major source categories. Other reported source characterization study include eastern China[21]; Santiago, Chile[22]; Los Angeles area [23] and Texas, Houston[24]; identifying various major sources such as vehicular emissions, biofuel burning, fuel evaporation, gasoline exhaust, refinery and petrochemical operations, evaporative emissions etc. The various possible VOCs from house products are shown on **Table- 1.**

Table 1: House-hold products and the possible volatile organic compounds release by them.

Examples of Household Products	**Possible VOC Ingredients**
Fuel containers or devices using gasoline, kerosene, fuel oil and products with petroleum distillates: paint thinner, oil-based stains and paint, aerosol or liquid insect pest products, mineral spirits, furniture polishes	BTEX (benzene, toluene, ethylbenzene, xylene), hexane, cyclohexane, 1,2,4-trimethylbenzene
Personal care products: nail polish, nail polish remover, colognes, perfumes, rubbing alcohol, hair spray	Acetone, ethyl alcohol, isopropyl alcohol, methacrylates (methyl or ethyl), ethyl acetate
Dry cleaned clothes, spot removers, fabric/ leather cleaners	Tetrachloroethene (perchloroethene (PERC), trichloroethene (TCE))
Citrus (orange) oil or pine oil cleaners, solvents and some odor masking products	d-limonene (citrus odor), a-pinene (pine odor), isoprene
PVC cement and primer, various adhesives, contact cement, model cement	Tetrahydrofuran, cyclohexane, methyl ethyl ketone (MEK), toluene, acetone, hexane, 1,1,1-trichloroethane, methyl-iso-butyl ketone (MIBK)
Paint stripper, adhesive (glue) removers	Methylene chloride, toluene, older products may contain carbon tetrachloride
Degreasers, aerosol penetrating oils, brake cleaner, carburetor cleaner, commercial solvents, electronics cleaners, spray lubricants	Methylene chloride, PERC, TCE, toluene, xylenes, methyl ethyl ketone, 1,1,1-trichloroethane
Moth balls, moth flakes, deodorizers, air fresheners	1,4-dichlorobenzene, naphthalene
Refrigerant from air conditioners, freezers, refrigerators, dehumidifiers	Freons (trichlorofluoromethane, dichlorodifluoromethane)
Aerosol spray products for some paints, cosmetics, automotive products, leather treatments, pesticides	treatments, pesticides Heptane, butane, pentane
Upholstered furniture, carpets, plywood, pressed wood products	Formaldehyde

SOURCE: New York, Health Department, FEB. 2011

LOCATION AND DESCRIPTION OF THE STUDY AREAS

Abuja Municipal Area Council (AMAC) is the largest and most developed of the six area councils, while Kuje Area Council falls within the semi-urban settlement location of the Federal Capital Territory. The bulk of the built-up area of AMAC is made up of the Federal Capital City (FCC). The FCC has five main districts, namely Asokoro, Maitama, Garki, Wuse, and Central Area and other newly developed districts Apo, Gaduwa, Gudu, Lokugoma, Kaura, Durumi, Katampe, Gwarimpa, other districts such as Kagini, Karsana, Karmo, etc, has shown recent developmental growth in the FCC. **Figure 1** gives the boundary location of the study areas.

The Gwagwalada is located between latitude $8^{0}45^{1}$and $9^{0}15^{1}$ north of the equator and longitude $6^{0}45^{1}$and A $7^{0}15^{1}$ east of the Greenwich meridian, AMAC is located between latitude $8^{0}40^{1}$ and $9^{0}20^{1}$ north of the equator and longitude $6^{0}40^{1}$ and $7^{0}40^{1}$ east of the Greenwich meridian. While Kuje Area Council is located between latitude $8^{0}40^{1}$ and $9^{0}00^{1}$ north of the equator and longitude $7^{0}00^{1}$ and $7^{0}40^{1}$ east of the Greenwich meridian. The Abuja FCT has a land mass of approximately 8000sq km of which the FCC occupies about 250sq km with population recent census at 778,567 for AMAC, 97,367 for Kuje and 157,770 for Gwagwalada Area council ,(Federal Republic of Nigeria Official Gazette, 2007).

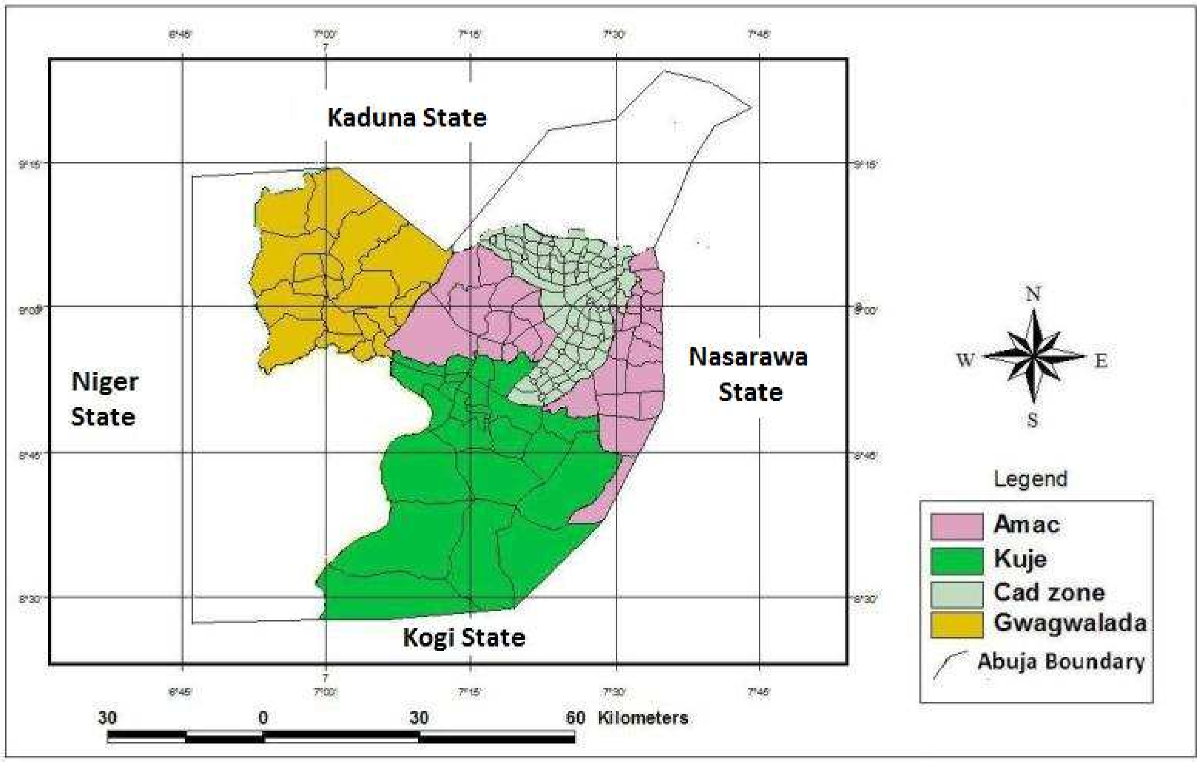

Fig. 1: Map Showing Abuja Municipal, Kuje and Gwagwalada Area Councils of FCT Nigeria

Source: Adapted from Department of Geography and Environmental Management, University of Abuja, FCT, Nigeria 2010

CLIMATE

The climate of the Federal Capital Territory (FCT) is the hot, humid, and tropical type. It is such that its major elements have regimes that are transitional from those of the Southern and the Northern parts of the country.

From the available information extrapolated from adjacent weather stations, the study area has temperatures ranging from 21^0 C – 26.7^0C yearly and a total annual rainfall of approximately 1,650mm. About 60% of the annual rains fall during the month of July, August and September Nigeria Metrological Agency[25]. A crucial climatic characteristic of this area is the frequent occurrence of squall lines heralded by thunder storms, lightening, strong winds and rainfall of high intensity [26].

The temperature is highest and greatest diurnal ranges during the dry season months, when the maximum temperature ranges between 30^0C or 35^0C. During the rainy seasons on the other hand, the maximum temperature ranges between 25^0C and 30^0C[25].

METHODOLOGY

The ambient emission inventory of low explosive limit (LEL) gases such as methane were taken using BW Technology GasAlaert® Microclip (gas detection instrument) from densely and less densely populated area of AMAC. Similar procedure was also repeated for Kuje and Dobi in Gwagwalada area council. The field observations were done in compliance with the 8 hourly intervals in strict compliance meeting all regulatory world standards. Three different readings were taken each day (morning, afternoon and evening) for three different days in a week with the time and dates duly noted. This was done for all sample points, 50 observations three times each day for three times in a week was taken for all locations (2,700 data collected). Data for Wet season and Dry seasons were taken.

RESULTS AND DISCUSSION

The result of the emission inventory of LEL gases are presented in **Figures 2 to 6** below according to the respective area councils.

AMAC

The Low Explosive Limit gases in AMAC show a high pollution level, signifying the high presence of VOCs in the atmosphere. This can be attributed to many sources. The city of Abuja being the administrative capital of Nigeria is characterized with high flow of traffic during the daytime especially during morning and evening rush hours with each vehicle emitting VOCs depending on the type of fuels used, type and age of the vehicles, flow rate and speed of the traffic as well as environmental conditions in the city and these vehicle exhausts contribute substantially to the VOCs concentration in the air. In general, the dominant anthropogenic VOC sources are Vehicular and industrial emissions from fossil fuel combustion, liquefied petroleum gas (LPG), leakages, fuel evaporation, petroleum distillation and industrial solvent[3,7].

Interest on traffic-related sources of air pollution from exposure assessors, epidemiologists, as well as toxicologists is on the increase. Ground-level traffic vehicles in urban areas are typically natural gas fueled, gasoline fueled or diesel-fueled. The physical characteristics and chemical compositions of natural gas, gasoline and diesel differs from one region of the world to the other, like benzene content[27], hampering the generalization of findings in one location to other locations. This complexity in generalization across studies is further complicated by different meteorological conditions, different percentage of heavy polluters (more motorcycles in the developing world), design of motor ways (graded or non-graded roads), driving habits, different maintenance as well as quality of and control measures for vehicles, and exposure profiles of people[28].

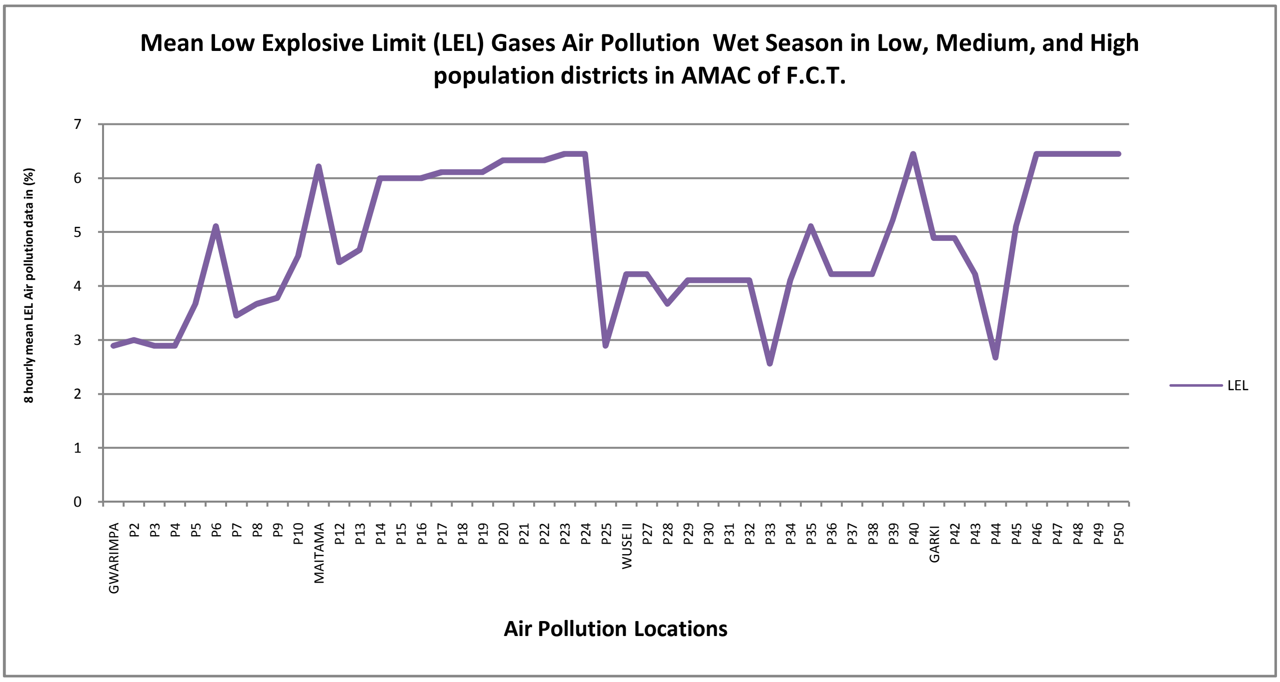

Fig. 2: Graph showing LEL gases obtained in AMAC F.C.T during Wet Season

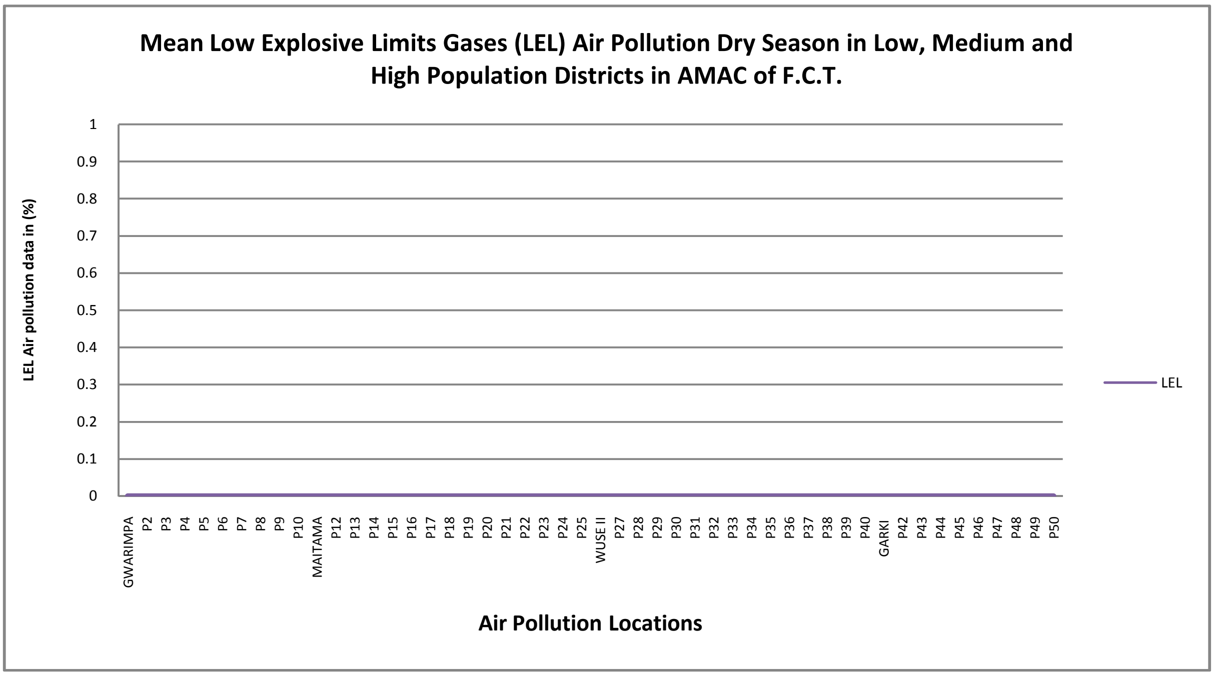

Fig.3: Graph showing LEL gases obtained in AMAC F.C.T during Dry Season

Abuja is also presently witnessing high growth of industries particularly in construction sector, quarry mining, foam manufacturing and many other small scale industries, the media industry and the tourism industry. Many volatile organic compounds (VOCs) are human- made chemicals that are used and produced in the manufacture of paints, adhesives, petroleum products, pharmaceuticals and refrigerants. Many are also compounds of fuels, solvents, hydraulic fluids, paint thinners and dry cleaning agents commonly used in urban settings such as bleach[9]. These are VOCs sources resulting from human activities. Research results show that anthropogenic sources emit about 142 teragrams of carbon per year in the form of VOCs[9].

The Isoline graph below clearly shows that Low Explosive Limit (LEL) gases were not emitted in Abuja Municipal Area Council during the dry season based on the mean field values obtained. This may be attributed to the North-East wind which blows across the Federal Capital Territory during the dry season.

KUJE

Low Explosive Limit (LEL) gases were not observed to have polluted Kuje area council also. This was notice during the wet and dry season. It clearly showed that as at observation period Kuje area council atmosphere was free from LEL gases. Kuje being a satellite town located outside the city, the presence of LEL below the limit of detection can be attributed to the low population density of the area and lack of industrial activities which are the major contributory factors to the production of the gases.

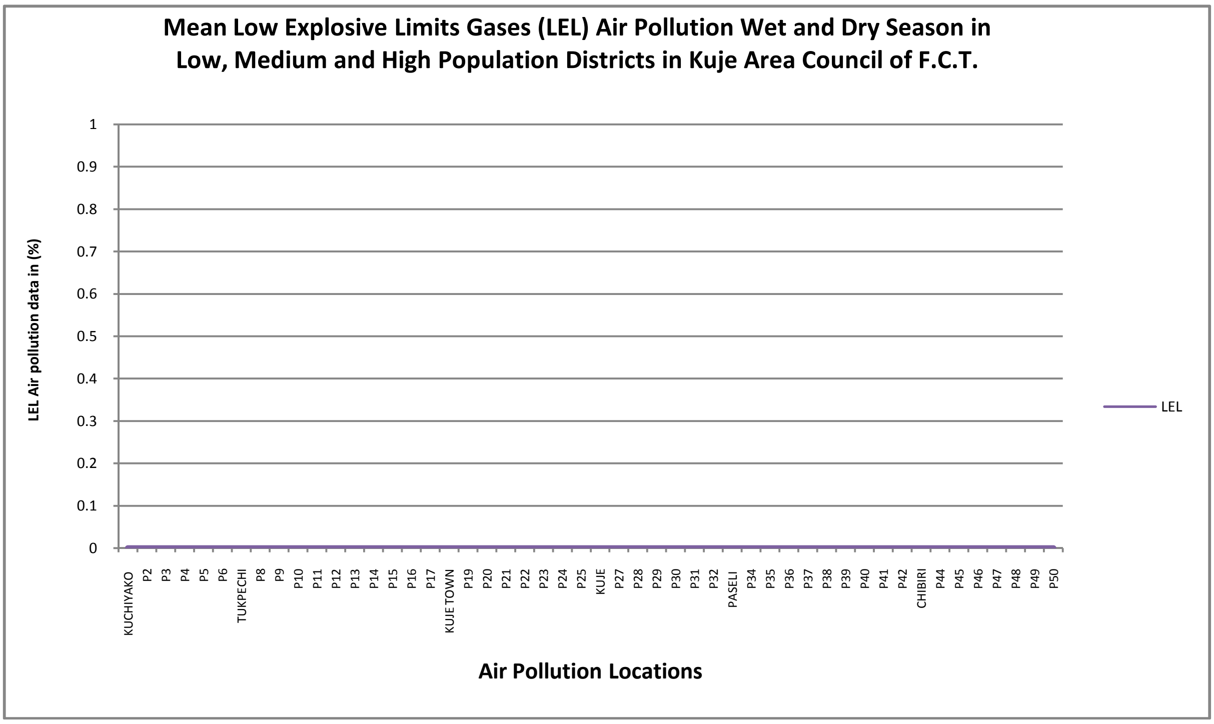

Fig.4: Graph showing LEL gases obtained in Kuje Area Council F.C.T during Wet and Dry Seasons

GWAGWALADA

The Low Explosive Limit (LEL) gases results are as presented in figures 5 and 6 for wet season and dry season respectively.

The Low Explosive Limit (LEL) gases results showed no emission of gases from location points P_1 to P_{25} and indicated emission of gases stable at (6.97%) from point P_{26} to P_{50}. The reason for this may be due to decomposed refuse around the market and milling machines waste within settlements, in Dobi village.

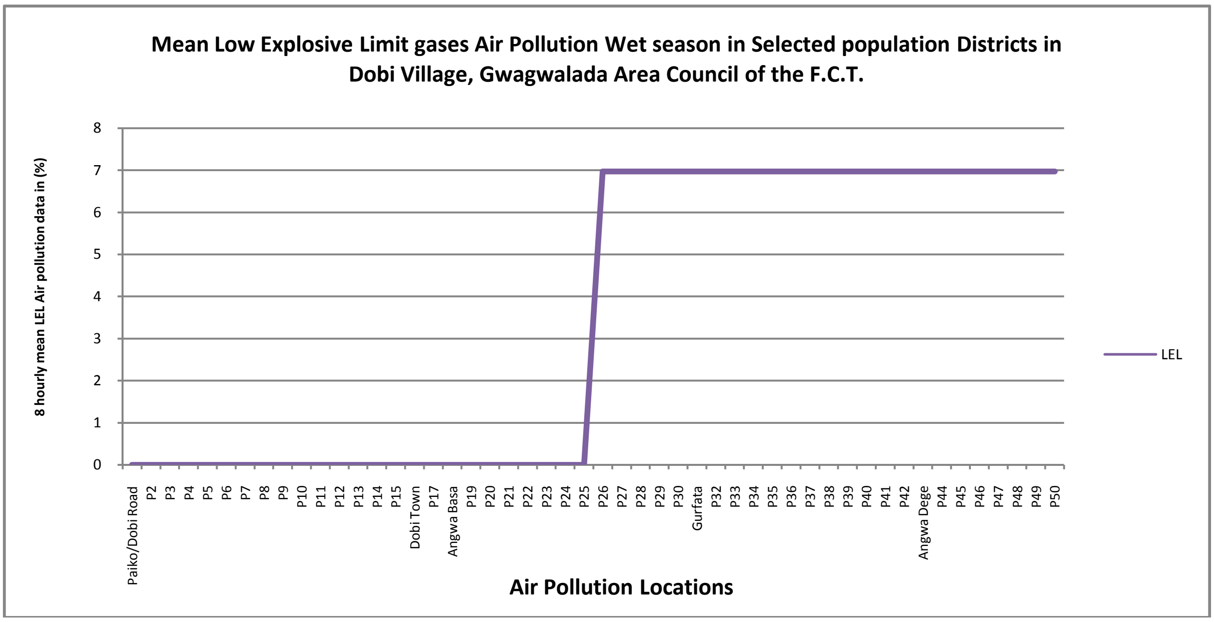

Fig.5: Graph showing LEL gases obtained in Dobi Village, Gwagwalada Area Council F.C.T during Wet Season

The dry season mean value results for Low Explosive Limit (LEL) gases obtained in Dobi village as presented in figure 6 showed that there was no emission of LEL gases during dry season.

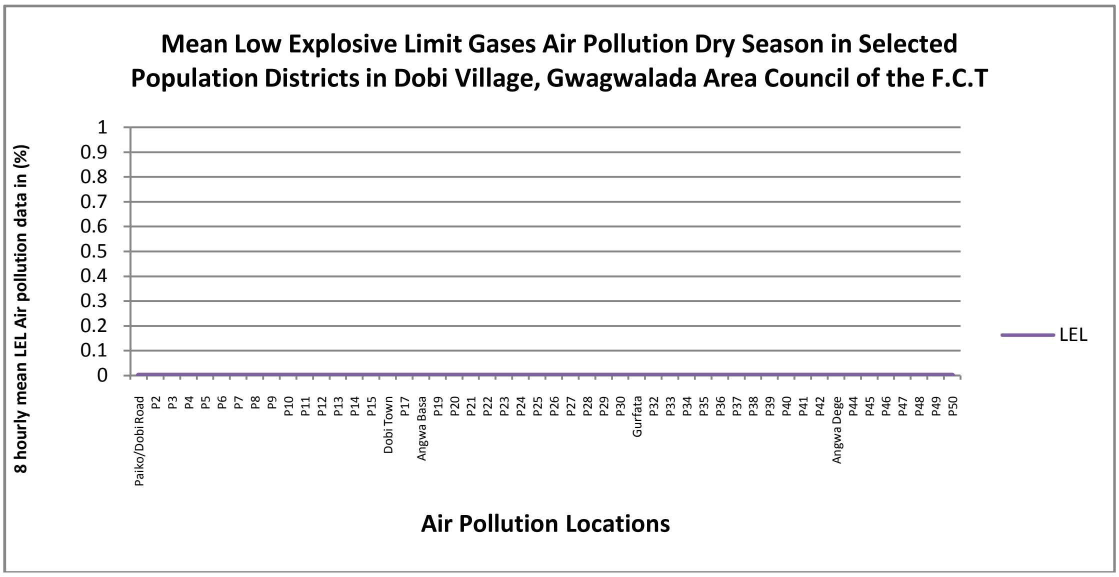

Fig. 6: Graph showing LEL gases obtained in Dobi Village, Gwagwalada Area Council F.C.T during Dry Season

CONCLUSION

Globally, there is environmental awareness on air pollution but it is obvious that there has not been proper dissemination of information on its effect in the continent of Africa and its regions. The increasing world population and especially those of developing countries are alarming. The asphyxiant effects of methane may enhance cardiac sensitization. Methane displaces oxygen to 18% in air when present at 14% (140000 ppm). It is of utmost importance that with the expansion of the FCC Abuja, standard control measures and proper waste disposal methods be quickly put in place to avoid continuous emission that may lead to high concentration of methane and other gases such as n-butane, acetylene, toluene, cyclohexane, Carbon Disulfide, styrene, ethane, Arsine, propane, etc., which are VOC within the low explosive limit 6% as shown in figures 2 and 5. It is recommended that extensive awareness campaigns be carried out and further study to ascertain and proffer mitigation on its effects on humans.

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