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Air Quality in Private and Public Offices in Abakaliki, Southeastern Nigeria

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Abstract: At Ebonyi State University, Abakaliki, we decided to contribute a little to awareness of air quality in private and public offices by selecting two offices namely: Citi Exotic Fast Food Center, Christ Embassy Church as two private offices and Federal Teaching Hospital and Central Police Station as public offices, with a village house at Ogbaga Onyikwa as control, all in Abakaliki, Southeastern Nigeria. The carbon monoxide (CO) indoor air concentration varied between 0.04 – 0.48 mg L^{-1} at statistical (P = 0.05) significant levels amongst offices. The indoor ammonia (NH_3) air concentration varied between 0.008 – 0.009 mg L^{-1}; while indoor hydrogen sulphide (H_2S) air concentration varied between 0.003 – 0.004 mg L^{-1} and nitrogen dioxide (NO_2) at 0.007 – 0.017 mg L^{-1} at no statistical significant levels. All the offices passed the permissible limits set by World Health Organisation (WHO) and Nigeria Environmental Protection Council (NEPC) for indoor gas concentrations. The workers and customers temporal health was declared safe.

Key words: Air quality · Private and public offices · Gaseous concentrations · Permissible limits · international standards · Human health

INTRODUCTION

The world citizens are estimated at over 6 billion and projected to hit 10 billion by the year 2050 [1-6]. The world total homes are also assumed to be over 6 billion. All over the world it is assumed that private offices, housing individual and corporate offices are over 6 billion; while public offices, virtually government, non-governmental and foundations/charities offices are over 7 billion. The public offices includes diplomatic missions, submarine, airforce, military outpost guiding nuclear warheads even in the Arctic and Antarctica regions that are sophisticatedly manned by dozens of personnel, robots and space satellites [1-5]. The number of world citizens in private and public offices is put at over 3 billion, with projected figures at over 6 billion by the year 2050 with greater majority in Sub Saharan Africa [1-5].

The average number of customers and citizens that world private and public offices receive daily is over 2 billion. The average working time for staff of these offices is 5 – 12 hours; while the average visit times for customers and citizens are 15 minutes to 2 hours. The break times in these offices are barely 30 minutes. The average air specifically oxygen (O_2) that each staff or customer or visitor breath in these offices is within 100 – 200 μl s^{-1}. The rate of inhalation of other gases like carbon dioxide (CO_2), carbon monoxide (CO), hydrogen sulphide (H_2S), ammonia (NH_3) and other dangerous gases is not included in this estimate because no one bargains for them. Here at Ebonyi State University, Abakaliki we have been assessing the environmental and human health of the air, water and soil we use on daily basis between 2001 to date. The findings for 2013 – 2015 on air quality of private and public offices in Abakaliki, Southeastern Nigeria is hereby presented.

MATERIALS AND METHODS

Geographical and Climatic Information: Abakaliki lies within Longitude 08° 06¹ E and Latitude 06° 19¹ N at an altitude of 128 meters above sea level. It lies within the derived savannah belt of South eastern Nigeria. The mean annual rainfall for 25 years (1977 – 2012) was 154.75 mm spread across April – November; while the mean annual minimum and maximum temperatures for same period were 23.58 and 32.40°C respectively; with higher and lower

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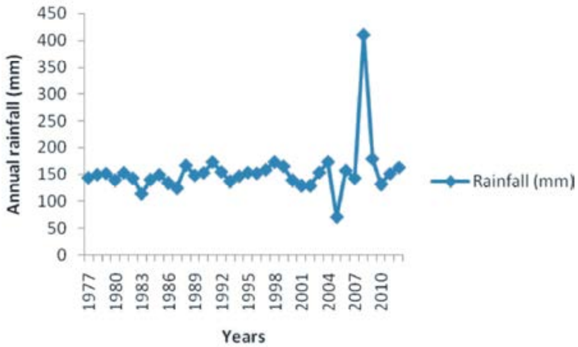

Fig. 1: Annual rainfall for Abakaliki (1977-2012).

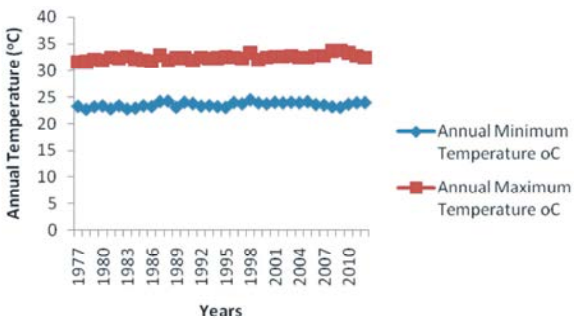

Fig. 2: Annual minimum and maximum temperature for Abakaliki (1977-2012).

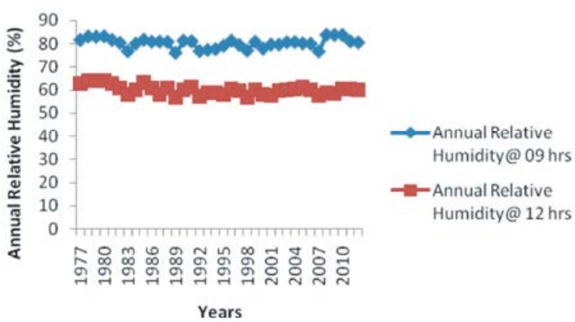

Fig. 3: Annual relative humidity@09/12 hrs at Abakaliki (1977-a2012).

temperatures during the dry and rainy seasons respectively. On the other hand, the average annual sunshine hours for same period was 5.13, while the mean annual relative humidity@09/15 hrs was 80.2 and 59.93%, respectively; with higher and lower relative humidity during rainy and dry season, respectively. The rainfall, temperature and relative humidity of the area are presented in Figs. 1, 2 and 3 [7]. The soil belongs to the order (Ultisol) classified as Typic Haplustult [8].

Identification of Private and Public Offices: In this study two private offices: Citi Exotic at Afikpo Road, Christ Embassy Church at Mile 50 and two public offices: Federal Teaching Hospital at Uga Street and Central Police Station along Abakaliki-Ogoja Highway; with a village house at Ogbaga Onyikwa as control were monitored for atmospheric gaseous concentrations i.e., CO, NH_3, H_2S and NO_2 between the hours of 07 – 11 am for 5 days a week, for 3 months and for 3 years (2013 – 2015). Each measurement was replicated four times, with each room serving as replicate.

Measurement Techniques: With the aid of potable hand held gas monitors (GASMAN Model) CO19256H; $CO_2$700IR; $NO_2$19835H; and $NH_3$19736H with detection limit of 0 – 50 ppm and alarm set at 3 ppm, atmospheric concentrations of the following gases were monitored: CO, CO_2, NO_2 and NH_3. The four monitors were hung on a wooden platform raised to a height of 1.5 meters. They were calibrated on each occasion of use due to regular weather changes. The Green Light Emitting Diode (LED) and the sounder operated once every three seconds. The Liquid Crystal Display (LCD) showed zeros. The flashing of red LED is an indicator that concentration of gases has passed alarm range. Hourly timing was done with the aid of stop watch. All readings were noted at hourly stability. All protocols for air monitoring were based on World Health Organisation and Nigerian Standards.

Statistical Analysis of Data: For analysis exercise daily values were pooled on fortnightly basis and subjected to analysis of variance (ANOVA) for randomized complete block design (RCBD). The values were captured in parts per million (where 1 parts per million (ppm) is equivalent to 1 mg kg^{-1} or 1 mg l^{-1}) [9]. Further mean separation and differentiation were done with Fishers Least Significant Difference (FLSD) at 1% and 5% probability levels or 99% and 95% confidence intervals [10, 11].

RESULTS

Carbon Monoxide Indoor Air Concentrations: There was statistical (P = 0.05) significant differences in carbon dioxide (CO_2) air concentration amongst private and public offices with a private office known as Citi Exotic giving highest carbon monoxide (CO) indoor air concentration of 0.48 mg L^{-1}, followed by public office known as Federal Teaching hospital with 0.47 mg L^{-1}. Another private office known as Christ Embassy Church and a public office known as Central Police Station gave 0.29 and 0.26 mg L^{-1} respectively. The village house at Ogbaga Onyikwa that served as control gave the least CO indoor air concentration of 0.04 mg L^{-1}. On cumulative

Table 1: The gaseous concentrations of private and public offices in Abakaliki, Southeastern Nigeria (mg L^{-1})

Offices	CO	NH_3	H_2S	NO_2
Citi Exotic	0.48	0.009	0.004	0.012
Christ Embassy	0.29	0.008	0.003	0.009
Federal Hospital	0.47	0.009	0.003	0.017
Central Police	0.26	0.009	0.003	0.014
Control	0.04	0.008	0.004	0.007
FLSD(0.05)	0.06	Ns	Ns	Ns
WHO	30	0.28	0.07	0.12
NEPC	35	0.12	0.02	10

WHO, World Health Organisation and NEPC, Nigeria Environmental Protection Council Standards (ppm equivalent to mg L^{-1}).

Table 2: The cumulative gaseous concentrations of private and public offices in Abakaliki, Southeastern Nigeria (mg L^{-1}).

Gases	CO					NH_3					H_2S					NO_2				
Period	CE	CEC	FETHA	CPS	C	CE	CEC	FETHA	CPS	C	CE	CEC	FETHA	CPC	C	CE	CEC	FETHA	CPC	C
2	0.49	0.29	0.47	0.24	0.04	0.01	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.02	0.01	0.01
4	0.47	0.28	0.48	0.23	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.00	0.01	0.01	0.01	0.02	0.02	0.01
6	0.48	0.30	0.47	0.25	0.04	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.01
8	0.48	0.30	0.47	0.25	0.04	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.01
10	0.48	0.29	0.47	0.30	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01
12	0.49	0.30	0.45	0.30	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
FLSD	0.09	0.12	0.05	0.07	0.04	ns	ns	ns	ns	ns	ns	Ns	ns	ns	ns	Ns	ns	ns	ns	ns
WHO	30	30	30	30	30	0.28	0.28	0.28	0.28	0.28	0.07	0.07	0.07	0.07	0.07	0.12	0.12	0.12	0.12	0.12
NEPC	35	35	35	35	35	0.12	0.12	0.12	0.12	0.12	0.02	0.02	0.02	0.02	0.02	10	10	10	10	10

WHO, World Health Organisation; NEPC, Nigeria Environmental Protection Council Standards (ppm equivalent to mg L^{-1}). CE, Citi Exotic; CEC, Christ Embassy Church; FETHA, Federal Teaching Hospital; CPS, Central Police Station; Control; FLSD(0.05), Fishers Least Significant Difference at 95% Confidence Interval

periods Citi Exotic recorded highest CO indoor air concentration of 0.49 mg L^{-1} at 12 weeks; while Christ Embassy Church gave highest value of 0.30 mg L^{-1} at 6, 8 and 12 weeks cumulative period. The Federal Teaching hospital gave highest value of 0.48 mg L^{-1} at 4 weeks; the Central Police Station gave 0.30 mg L^{-1} at 10 and 12 weeks respectively; while the control gave 0.04 mg L^{-1} at all cumulative period except 12 weeks. The CO indoor air concentrations of all offices and control passed the World Health Organisation (WHO) and Nigeria Environmental Protection Council (NEPC) permissible limits of 30 and 35 ppm, equivalent to mg L^{-1} respectively [12, 13] as in Tables 1 and 2.

Ammonia Indoor Air Concentrations: No statistical difference was observed in NH_3 indoor air concentration amongst the offices. While Citi Exotic, Federal Teaching Hospital and Central Police Station gave 0.009 mg L^{-1} indoor NH_3 air concentration; others namely: Christ Embassy Church and Control gave 0.008 mg L^{-1} respectively. Across cumulative intervals, Citi Exotic gave highest value of 0.008 mg L^{-1} at 8 weeks; same value for Christ Embassy Church at 4 and 8 weeks; same value for Central Police Station and Control at 8 weeks. All the offices also passed the WHO and NEPC permissible limits of 0.28 and 0.12 ppm, equivalent to mg L^{-1} respectively.

Hydrogen Sulphide Indoor Air Concentrations: There was no statistical variation in indoor H_2S air concentrations across offices. The Citi Exotic and Control gave highest indoor H_2S air concentration of 0.004 mg L^{-1}; while others gave 0.003 mg L^{-1}. Across monitoring intervals, Citi Exotic gave highest indoor H_2S air concentration of 0.008 mg L^{-1} at 10 weeks; Christ Embassy Church gave 0.013 mg L^{-1} at same period; while Federal Teaching Hospital, Central Police Station and Control gave 0.02, 0.018 and 0.013 mg L^{-1} at 4, 10 weeks respectively. All the values were below the limits of 0.07 and 0.02 ppm, equivalent of mg L^{-1} set by WHO and NEPC respectively (Tables 1 and 2).

Nitrogen Dioxide (NO_2) Indoor Air Concentrations: There were no statistical differences between offices in indoor NO_2 air concentrations. The Citi Exotic, Christ Embassy Church; Federal Teaching Hospital, Central Police Station and Control recorded 0.012, 0.009, 0.017, 0.014 and 0.007 mg L^{-1} respectively. Across cumulative periods, Citi Exotic gave 0.025 mg L^{-1} at 2 weeks; Christ Embassy Church gave 0.001 mg L^{-1} across all periods, the Federal Teaching Hospital gave 0.02 mg L^{-1} across all periods except at 10 and 12 weeks; while the Central Police Station and Control gave 0.02 mg L^{-1} at 4/8 weeks and 0.01 at all periods respectively. The offices also passed the test of indoor NO_2 air concentration of 0.12 and 10 ppm, equivalent of mg L^{-1} set by WHO and NEPC (Tables 1 and 2).

DISCUSSIONS

Carbon Monoxide (CO) Indoor Air Concentrations: The Citi Exotic that recorded 0.48 mg L^{-1} indoor CO air concentration is a fast food kitchen that uses gas cooker, kerosene stoves for their services. Even though the kitchens were fairly ventilated, there is bound to be some indoor circulation of the gas within the service areas as observed in this work. The kitchens CO air concentrations were not measured. The focal areas were the rooms where staff and customers are served. That of Federal Teaching Hospital that recorded 0.47 mg L^{-1} are 24 hrs glued to lister power generating sets in view of the epileptic power nature of the place. The Christ Embassy Church and Central Police Station were more descent places with power generating sets set outside the rooms and used occasionally during power failure. Hence, the 0.29 and 0.26 mg L^{-1} indoor air concentration. The Ogbaga Onyikwa Control is a village house with no power generating sets. They, however use biomass stove, coal stove, kerosene stove, charcoal and firewood which release gases including CO. Yet, the level in this place is still less than others.

Ammonia (NH_3) Indoor Air Concentrations: The levels of NH_3 were nearly the same in all offices monitored including control (0.008 – 0.009 mg L^{-1}). This has gone clearly to show that NH_3 is not fossil fuel combustion fired. It is also not coming basically from the kitchen of Citi Exotic, nor from the lister generating sets within the Federal Teaching Hospital. It is likely the traces may be from other sources like drains, septic tanks, or municipal wastes.

Hydrogen Sulphide (H_2S) Indoor Air Concentrations: Like NH_3, the H_2S indoor air concentrations were also nearly the same including control (0.003 – 0.004 mg L^{-1}). The fact that control exceeded the levels of offices in urban area show that NH_3 and H_2S is not fossil fuel related to more than 90%. They are likely to be coming from drains, sewage (septic tanks) or municipal wastes. The type of septic tanks practices in the urban offices is concrete system; while that of control is the open latrine septic system, which lie adjacent to residential houses. There is no central collecting system for sewage in the study area; apart from the ones described in these discussions.

Nitrogen Dioxide (NO_2) Indoor Air Concentrations: There is a different picture in the NO_2 indoor air concentrations. While the Federal Teaching Hospital is leading with 0.017 mg L^{-1}; the Central Police Station followed with 0.014 mg L^{-1}, then Christ Embassy Church with 0.009 mg L^{-1}. The least in Control with 0.007 mg L^{-1}. The lister power generating set that are continuously turned on to keep hospital services when there is power failure and burning of gas cookers and kerosene stove in Citi Exotic fast food kitchens confirms fossil fuel as major source of nitrogen dioxide emissions. The levels of NO_2 from Christ Embassy Church and Central Police Station may be coming from automobile of worshippers and clients respectively. These automobiles emissions may also have affected all other areas including control in view of the roads that connect them.

Indoor Air Pollution: In Baird's [14] indoor air pollutant concentrations vary significantly from building to building. According to the author, the levels of some common air pollutants are often greater indoors than outdoors. Coupled with the fact that most people spend more time indoors than outdoors, which makes exposure to indoor air pollutants a serious environmental problem. In addition, the worker laments on the inadequate ventilation practices of developing countries that burn coal, wood, crop residues and other unprocessed biomass fuels, to have advanced smoke and carbon monoxide pollution. All of them lead to respiratory problems and ill health among huge numbers of people in these countries, particularly women and young children.

For RSC [15] pollution with indoor sources can be built up to appreciable levels because of the slowness of air exchange. Typical examples are oxides of nitrogen from gas cookers and flueless gas and kerosene heaters which can readily exceed outdoor concentrations. According to these scientists, kerosene heaters can be an important source of CO and SO_2. Similarly, according to the workers, building materials and furnishings can also release a wide range of pollutants, such as formaldehyde from chipboard and hydrocarbons from paints, cleaners, adhesives, timber and furnishings. The tendency towards lower ventilation levels (energy efficient houses) has tended to worsen this problem. For these experts, pollutants with a predominantly outdoor source may be reduced to rather low levels indoors due to the high surface area/volume ratios indoors, leading to extremely efficient dry deposition of pollutants such as ozone and sulphur dioxide.

Table 3: Some gases emitted naturally into the atmosphere from natural sources.

Symbol	Name	Important Natural Source
CH_4	Methane	Anaerobic Biological Decay
NH_3	Ammonia	Anaerobic Biological Decay
H_2S	Hydrogen Sulphide	Anaerobic Biological Decay
HCl	Hydrogen Chloride	Anaerobic Biological Decay, Volcanoes
CH_3Cl	Methyl Chloride	Oceans
CH_3Br	Methyl Bromide	Oceans
CH_3I	Methyl Iodide	Oceans
CO	Carbon Monoxide	Atmospheric Methane, Fires
SO_2	Sulphur Dioxide	Volcanoes
NO	Nitric Oxide	Lightning

Source: Baird [14].

Baird [14] also included the gas formaldehyde as the most controversial indoor air pollutant. According to the author, it is a widespread trace constituent of the atmosphere since it occurs as a stable intermediate in the oxidation of methane and other volatile organic compounds. This substance was not investigated in current research.

NO_2 and CO, according to Baird [14] are released as a result of combustion processes, including those that take place in homes and offices when fossil fuels are burned. According to the worker, indoor concentrations of NO_2 exceed outdoors values in homes that contain stoves, space heaters and water heaters that are fuelled by gas. The author attribute the flame temperature in these appliances to be sufficiently high to trigger the combination of nitrogen and oxygen in the air to form nitrogen oxide; which eventually is oxidized to NO_2. He supported the fact with studies that revealed NO_2 levels in homes that use gas for cooking or that have kerosene stove to average 24 ppb, compared to 9 ppb for homes that have neither. The peak concentration near gas cooking stoves often exceeds 300 ppb.

The author adds the solubility of NO_2 in biological tissue and as an oxidant. Hence, its effect on health is on the respiratory system. The worker describes CO as a colourless, odourless gas whose concentration indoors can be greatly increased by the incomplete combustion of carbon containing fuels such as wood, gasoline, kerosene or gas. High indoor concentrations usually as a result of malfunctioning of combustion appliance, such as kerosene heater. Similarly, according to Baird [14] CO poisoning is a serious hazard in developing countries, when biomass fuels are used to heat poorly ventilated rooms in which people sleep. Average indoor and outdoor CO concentrations, according to the worker usually amount to a few parts per million, though elevated values in the 10 – 20 ppm range are common in parking garages due to the CO emitted by motor vehicles. The major danger from CO, according to this worker arises from its ability, when inhaled, to complex strongly with the haemoglobin in blood and thus to impair its ability to transport oxygen to cells. On average, non-smokers have about 1% of their haemoglobin tied up as a complex with CO (called carboxyhemoglobin); while the value for smokers is double this value or more because of the CO that they inhale during smoking and which arises from the incomplete combustion of the cigarettes. The worker reports increased mortality from heart disease which can occur even if only several percent of haemoglobin is chronically tied up as the CO complex. Exposure to very high concentrations of CO results in headache, fatigue, unconsciousness and eventually death (if such exposure is sustained for long periods). The worker even recommended low priced, easily installed carbon monoxide detectors that are suitable to warn residents in homes and offices, when high CO levels occur, to be available everywhere in the market.

Trace Gases in Clean Air: Baird [14], Jackson and Jackson [16] and Briggs *et al*. [17] list biological and volcanic sources as the main input of atmospheric CO, SO_2 and several gases namely: H_2S, NH_3. The most important of these natural substances are listed in Table 3. Although most of these gases, according to the author, are gradually oxidized in air, none of them reacts directly with diatomic oxygen. Rather, their reactions begin when they are attacked by the hydroxyl radical (OH), even though the concentration of this species in air is exceedingly small. The worker reports that during the atmospheric oxidation of any of the hydrides (simple hydrogen containing molecules such as CH_4, H_2S and NH_3), one or more stable species are encountered along the reaction sequence before the totally oxidized product is formed. These intermediates are also formed independently by various pollution processes. In the order of sequence for hydrides and partially oxidized materials, from the viewpoint of stable species, the net result is the OH induced oxidation of the reduced and partially oxidized gases emitted into the air from both natural and pollution sources. In a few cases, according to Baird [14] as in methane and methyl chloride, the initiation reaction is sufficiently slow that a few percent of these gases survive long enough to penetrate to the stratosphere on account of the upward diffusion of tropospheric air. Much hydrocarbons, according to the worker, react much more quickly than does methane, since their C-H bonds are weaker, or fast reactions with OH other than by hydrogen abstraction are possible and are often classified as non-methane hydrocarbons (NMHC) to emphasize this distinction.

CONCLUSIONS

Clean air is an essential ingredient of a good quality of life. According to DEFRA [14] and RSC [15] people have a right to expect that the air they breathe will not harm them. Jackson and Jackson [16], Baird [14] and DEFRA [14] collaborates the duty of every nation to protect people's health and the environment without unacceptable economic and social costs. These, according to them form an essential part of strategies for sustainable development with four main aims: social progress which meets the needs of everyone; effective protection of the environment; prudent use of natural resources and maintenance of high and stable levels of economic growth and employment. The main air pollutants of concern in many countries, according to RSC [15] are: CO, SO_2, NO_2, ozone, lead, particulate matter, benzene and 1,3-butadiene. Under local air quality management, according to DEFRA [14] and RSC [15], local authorities are expected to work towards achieving the objectives prescribed by regulations for the seven pollutants, but not that for ozone, since this is affected by pollutants produced outside a given country. Projections suggest that some of the objectives can be achieved through tighter control of vehicle emission and regulation of industry [14].

International standards and agreements are most important as air pollutants do not respect territorial boundaries [14, 15, 16]. Their combined action, according to these scientists are very important to reduce air pollution, especially government roles on clear and simple policy framework, realistic but challenging objectives; regulation and financial incentives to help achieve objectives; analysis of costs and benefits; monitoring and research to increase our understanding and information to increase public awareness. Industry is a significant source of some of the pollutants. Regulators normally require industry to go extra miles on best available technologies without entailing excessive cost in order to achieve National Objectives. Similarly, since Road traffic emissions make a significant contribution to levels of air pollution, particularly in towns and cities, integrated transport system to cut congestion and pollution are advocated. Other remedied include local authorities air quality strategies, smoke control and local traffic powers; and land use planning. For DEFRA [14] and RSC [15] people need to be aware that they too can help improve the air they breathe. People's everyday behaviour like walking, cycling and public transport adds up to overall air quality.

In Abakaliki, we have several private and public offices housing numerous workers. Their air health is very imperative. Air pollution in these offices is subject to vagaries of several factors: degree of ventilation, access to power generating sets; effects of traffic emissions and pollution from municipal wastes, sewages and drainage systems. The level of industrialisation and their contributions to air pollution are minimal in Abakaliki in view of their little number.

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