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Determination of some toxic gaseous emissions at Ama Industrial Complex, Enugu, south eastern Nigeria

Alfreda Ogochukwu Nwadinigwe

Department of Plant Science and Biotechnology, University of Nigeria, Nsukka.

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A study of some gases emitted from three industries at Ama industrial complex, Nigeria, was carried out using Crowcon Gasman, single gas monitors. Results showed that HCN (0.94 ± 0.16 ppm) and CO (3.17 ± 0.89 ppm) emissions from Brewery were significantly (P < 0.05) higher than those of Bottling Company A (0.46 ± 0.12 and 0.65 ± 0.10 ppm, respectively). NH_3, SO_2 and NO_2 emissions were the same. Cl_2 emissions from Bottling Company A and Bottling Company B were the same, but each was significantly (P < 0.05) higher than that of Brewery. H_2S emission from Bottling Company A (21.24 ± 0.97 ppm) was significantly (P < 0. 05) higher than that from Brewery (17.71 ± 0.94 ppm), which was significantly higher than that of Bottling Company B (12.57 ± 0.32 ppm). Apart from CO and NH_3, the concentrations of other gaseous emissions exceeded the Nigerian and United States national ambient air quality standards. Therefore, it is recommended that these companies should determine appropriate control measures to reduce these toxic emissions.

Key words: Toxic gaseous emissions, type, concentrations, Ama Industrial Complex, Nigeria.

INTRODUCTION

Air pollutants such as carbon dioxide (CO_2), carbon monoxide (CO), ozone (O_3), oxides of nitrogen (NO_x) oxides of sulphur (SO_x), methane (CH_4), hydrogen cyanide (HCN), hydrogen sulphide (H_2S), particulate matter (PM), chlorofluorocarbons (CFCs) and other halogenated substances when released into the atmosphere in large amounts that exceed the self-cleansing properties of the ambient air, can cause harmful effects on human health and the environment. Directly emitted pollutants, called primary pollutants, have direct negative effects on the environment. However, generated complex pollutants, called secondary pollutants, as a result of reaction or interaction of primary pollutants generally have prolonged effects on human health and environment and are responsible for greater damages (Santosh, 2010).

Air pollution offers global environmental challenges such as ozone depletion, global warming, climate change (IPCC, 2013), acid rain that can destroy vegetation, aquatic life, wild life, induce diseases in humans and damage buildings, structures, monuments, etc. About three million people die each year as a result of air pollution (WHO, 1999) and Patel (2014) reported that air pollution caused one in eight deaths worldwide in 2012.

E-mail: alfreda.nwadinigwe@unn.edu.ng, Tel: 08036867051.

To reduce the greenhouse gas (GHG) emissions, ozone depletion and global warming to appreciable levels by the year 2020, the world had been organizing conferences and treaties. However, the economic development and growth in many developing countries militate against implementation of these environmental treaties (Santosh, 2010). The European Commission (EC) has set out the EU's vision for a new legal protocol that will, through collective commitments based on scientific evidence, put the world on track to reduce global emissions by at least 60% below 2010 levels by 2050. Among other intentions, the EU intends to create a common legal framework that will put all countries on track to keep global warming below 2^0C relative to the pre-industrial temperature level. Also, the EU will hold all countries accountable to each other and to the public for their targets (EC, 2015).

In Nigeria, there is problem of air pollution caused mainly by gas-flaring, exhausts of automobiles and diesel power generators. Okhimamhe and Okelola (2013) recorded a high CO_2 emission value of 3236 ppm at Suleja, 3043.5 ppm at Minna and 3036 ppm at Bida using Crowcon Gasman CO_2 gas meter. Tawari and Abowei (2012) reported emissions of 233 ppm of CO, 2.9 ppm of SO_2, 1.5 ppm of NO_2 and 852 ppm of total particulates in Lagos. In Ibadan, the highest vehicular emission levels obtained were 271 ppm for CO, 1.44 ppm for SO_2 and 1.0 ppm for NO_2. In Ado-Ekiti, the highest vehicular emission levels obtained were 317 ppm for CO, 0.6 ppm for NO_2 and 0.8 ppm for SO_2. These results were higher than FEPA (1991) limits for these gases. Nwachukwu et al. (2012) reported that the ambient air quality of Rivers State (Pb = 0.1115 ppm/year, PM = 10 ppm/year, NO_x = 2.55 ppm/year, SO_2 = 1 ppm/year, VOC = 82.78 ppm/year) is worse than the WHO air quality standard and this has direct impact on people's health.

In Nigeria, most of these air pollution studies are independently carried out by individuals and so far, not much work has been carried out on monitoring gaseous emissions from industries. This work was undertaken to help bridge this gap. The objectives of this study were: to determine the type of toxic gaseous emissions from three industries at Ama Industrial Complex in Enugu State, Nigeria; to determine the concentrations of these gaseous emissions and to compare the quantities emitted with Nigerian ambient air quality standards. This Industrial Complex is in a small fast growing city that is located about nine miles before Enugu, the capital of Enugu State, South Eastern Nigeria. Industries such as bottling companies, breweries, table water treatment companies, hospitals, vehicle mechanic workshops, arboretums, petrol stations, shops and markets are located there. It is often used as a stop-over town for heavy duty vehicles, tankers, trailers, buses and other vehicles that ply from the Northern part of Nigeria to the South. Consequently, gaseous and particulate matter emissions are often released from vehicle exhausts, refuse burning, industrial production processes such as brewing of beverage alcohols, manufacturing plants, use of chlorine for water treatment and effluent disinfection, use of diesel power generators, fossil fuel-dependent energy requirement for heating and lighting.

MATERIALS AND METHODS

The study sites are located at Ama Industrial Complex, 9th mile corner in Udi Local Government Area, Enugu State, South Eastern Nigeria. Within Ama Industrial Complex, the three industries monitored were, the Nigerian Breweries PLC (named Brewery), the 7up Bottling Company (named Bottling Company A), both of which are located at 6° 26^1N and 7° 23^1E and Coca Cola Bottling Company (named Bottling Company B), located at 6° 25^1N and 7° 24^1E. Generally, the area has two seasons: rainy season (April to October) and dry season (November to march). Dry season has an average maximum temperature of 33°C while rainy season has an average minimum of 27°C. Average monthly rainfall is 270 mm although the dry season months (January, February and December) have less than 12 mm of rainfall each. The lowest mean relative humidity (RH) is 55% in January while August has the highest RH of 85%.

The study was carried out in the month of May. At each industry, the type and quantity of gaseous emissions from 9 locations were monitored. The 9 locations were: locations 1 to 3 were production hall, chlorination tank area and water treatment area. Locations 4 to 6 were equalization tank area, utility area and effluent discharge area. Locations 7 to 9 were areas near the boundary wall, generator house area and exit area. At each location, each gas was monitored at 3 random places, 3 times a day, morning (9 to 11 am), afternoon (12.30 to 3 pm) and evening (4 to 6 pm). The monitoring was carried out using eight Crowcon Gasman, hand-held single gas monitors (Gasman 19 H series, England) to determine the type and concentration of gases emitted. The monitored gases were: hydrogen cyanide (HCN), carbon monoxide (CO), chlorine (Cl_2), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), hydrogen sulphide (H_2S), ammonia (NH_3) and methane (CH_4). One Crowcon gas monitor was used for one gas and each meter was made with a specific gas sensor for each specific gas. A hand-held Crowcon Gasman single gas monitor was used because of its high sensitivity to outdoor gas detection (Okhimamhe and Okelola, 2013). The Gasman gas monitors were fully calibrated with crowcon gas cylinders, following the calibration procedures of the manufacturers. Each has a large easy-to-read display of gas concentration with audible, vibrating alarm. Before each reading, the latitude and longitude positions of the sampling points were located using the Global Position System (GPS) instrument. The Walker Meter (distance measuring wheel) was used to measure the distance between one reading and the other. To take the gas reading, the switch was turned on to gas position, while the sensor end of the monitor was positioned in the air. When the displayed value became constant on the liquid crystal display (LCD) panel of the monitor, the reading was taken. Each reading was carried out in 3 replicates and the data collected were subjected to Analysis of Variance (ANOVA). Means were compared using Duncan's multiple range test at $P \leq 0.05$ (Edafiogho, 2006).

RESULTS

Brewery

Results showed that mean concentrations of HCN

Table 1. Mean concentrations (ppm) of gaseous emissions detected at different locations around Brewery.

Gases	Locations 1 to 3	Locations 4 to 6	Locations 7 to 9
HCN	1.17 ± 0.31^{a}	0.70 ± 0.16^{a}	0.95 ± 0.31^{a}
NH_3	$0.22 \pm 0.06^{a,b}$	0.25 ± 0.05^{a}	0.01 ± 0.01^{b}
CO	4.29 ± 1.91^{a}	2.95 ± 1.48^{b}	2.27 ± 1.16^{b}
SO_2	0.27 ± 0.06^{a}	0.33 ± 0.08^{a}	0.25 ± 0.06^{a}
CH_4	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
CL_2	0.75 ± 0.08^{a}	0.45 ± 0.05^{b}	0.27 ± 0.04^{b}
NO_2	0.88 ± 0.14^{a}	0.34 ± 0.06^{b}	$0.63 \pm 0.10^{a,b}$
H_2S	16.92 ± 1.46^{a}	18.93 ± 1.68^{a}	17.28 ± 1.76^{a}

Values represent means ± standard error. Means followed by the same letter(s) in the same row are not significantly different at P≤0.05.Locations 1 to 3 represent production hall, chlorination tank area and water treatment area. Locations 4 – 6 represent equalization tank area, utility area and effluent discharge area. Locations 7 to 9 represent areas near the boundary wall, generator house area and exit area. Global Position System: $6° 26^{1} 500^{11}$ to $6° 26^{1} 611^{11}$ N and $7° 23^{1} 90^{11}$ to $7° 23^{1} 361^{11}$ E. Elevations: 1105 to 1141 m.

Table 2. Mean concentrations (ppm) of gaseous emissions detected at different locations around Bottling Company A.

Gases	Locations 1 to 3	Locations 4 to 6	Locations 7 to 9
HCN	0.53 ± 0.19^{a}	0.59 ± 0.30^{a}	0.26 ± 0.05a
NH_3	0.37 ± 0.09^{a}	$0.33 \pm 0.08^{a,b}$	0.16 ± 0.03^{b}
CO	$0.78 \pm 0.16^{a,b}$	0.33 ± 0.05^{a}	0.84 ± 0.25^{b}
SO_2	0.44 ± 0.09^{a}	0.24 ± 0.04^{b}	0.21 ± 0.05^{b}
CH_4	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
CL_2	0.77 ± 0.07^{a}	0.70 ± 0.06^{a}	0.70 ± 0.06^{a}
NO_2	0.70 ± 0.11^{a}	0.70 ± 0.17^{a}	0.58 ± 0.10^{a}
H_2S	18.13 ± 1.3^{a}	23.33 ± 1.82^{b}	$22.25 \pm 1.83^{a,b}$

Values represent means ± standard error. Means followed by the same letter(s) in the same row are not significantly different at P≤0.05. Locations 1 to 3 represent production hall, chlorination tank area and water treatment area. Locations 4 to 6 represent equalization tank area, utility area and effluent discharge area. Locations 7 to 9 represent areas near the boundary wall, generator house area and exit area. Global Position System: $6° 26^{1} 639^{11}$ to $6° 26^{1} 766^{11}$ N and $7° 23^{1} 692^{11}$ to $7° 23^{1} 757^{11}$ E. Elevations: 1155 to 1227 m.

detected from different locations around Brewery were not significantly different from each other (Table 1). The same applies to SO_2 and H_2S. Mean quantities of NH_3 detected in locations 4 to 6 (equalization tank area, utility area and effluent discharge area) were significantly ($P<0.05$) higher than those detected in locations 7 to 9 (the boundary wall, generator house area and exit area). CO and Cl_2 detected in locations 1 to 3 (production hall, chlorination tank area and water treatment area) were significantly ($P<0.05$) higher than those detected from locations 4 to 6 and 7 to 9. Concentrations of NO_2 detected around locations 1 to 3 were significantly ($P<0.05$) higher than those detected from locations 4 to 6. When diurnal gaseous emissions from Brewery were considered, result showed that emissions of NH_3, SO_2, and NO_2 were each, the same morning, afternoon and evening. On the other hand, concentrations of HCN detected in the morning were significantly ($P<0.05$) higher than those detected in the afternoon and evening. CO detected in the morning and evening was significantly ($P<0.05$) higher than that detected in the afternoon. H_2S emitted in the afternoon and evening was significantly ($P<0.05$) higher than that detected in the morning.

Bottling Company A

Mean concentrations of HCN detected from different locations around Bottling Company A were the same (Table 2). The same applies to Cl_2 and NO_2. Concentrations of NH_3 from locations 1 to 3 were significantly ($P<0.05$) higher than those detected around locations

Table 3. Mean concentrations (ppm) of gaseous emissions detected at different locations around Bottling Company B.

Gases	Locations 1 to 3	Locations 4 to 6	Locations 7 to 9
HCN	0.54 ± 0.19^{a}	0.39 ± 0.10^{a}	1.61 ± 0.47^{b}
NH_3	0.31 ± 0.07^{a}	0.31 ± 0.12^{a}	0.27 ± 0.07^{a}
CO	$0.91 \pm 0.21^{a,b}$	0.41 ± 0.08^{a}	1.03 ± 0.24^{b}
SO_2	0.28 ± 0.06^{a}	0.18 ± 0.06^{a}	0.23 ± 0.05^{a}
CH_4	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
CL_2	0.86 ± 0.10^{a}	0.78 ± 0.11^{a}	0.85 ± 0.10^{a}
NO_2	0.84 ± 0.13^{a}	0.50 ± 0.07^{b}	$0.77 \pm 0.13^{a,b}$
H_2S	11.31 ± 0.54^{a}	13.08 ± 0.38^{b}	13.31 ± 0.66^{b}

Values represent means ± standard error. Means followed by the same letter(s) in the same row are not significantly different at P≤0.05. Locations 1 to 3 represent production hall, chlorination tank area and water treatment area. Locations 4 to 6 represent equalization tank area, utility area and effluent discharge area. Locations 7 to 9 represent areas near the boundary wall, generator house and exit area. Global Position System: 6° 25^{1} 442^{11} to 6° 25^{1} 572^{11} N and 7° 24^{1} 081^{11} to 7° 24^{1} 304^{11} E. Elevations: 1114 to 1493 m.

7 to 9. CO from locations 7 to 9 was significantly (P<0.05) higher than that from locations 4 to 6. SO_2 from locations 1 to 3 was significantly (P<0.05) higher than those emitted from locations 4 to 6 and 7 to 9. H_2S detected from locations 4 to 6 was significantly (P<0.05) higher than that of locations 1 to 3. Daily gaseous emissions from Bottling Company A showed that NH_3, SO_2, Cl_2 and H_2S, were each, the same. However, HCN detected in the morning was significantly (P<0.05) higher than that detected in the afternoon and evening. CO detected in the morning and afternoon was significantly (P<0.05) higher than that detected in the evening. NO_2 detected in the morning was significantly (P<0.05) higher than that of the afternoon.

Bottling Company B

Mean concentrations of NH_3 detected from different locations around Bottling Company B were the same (Table 3). The same applies to SO_2 and Cl_2. Concentrations of HCN detected from locations 7 to 9 were significantly (P<0.05) higher than the quantities detected from locations 1 to 3 and 4 to 6. Concentrations of CO detected from locations 7 to 9 were also significantly (P<0.05) higher than concentrations emitted from locations 4 to 6. NO_2 detected from locations 1 to 3 was significantly (P<0.05) higher than that detected from locations 4 to 6. H_2S detected from locations 4 to 6 and 7 to 9 was significantly (P<0.05) higher than that emitted from locations 1 to 3. Daily readings indicated that H_2S detected in the afternoon and evening was significantly (P<0.05) higher than that detected in the morning. HCN detected in the morning and evening was significantly (P<0.05) higher than that detected in the afternoon. Apart from HCN and H_2S, all the other gases had the same concentration of daily emissions, individually.

In comparing the concentrations of gaseous emissions detected from the three companies, HCN detected from Brewery was significantly (P<0.05) higher than that detected from Bottling Company A (Table 4). CO detected from Brewery was significantly (P<0.05) higher than those from Bottling Companies A and B, respectively. Cl_2 detected from Bottling Companies A and B was significantly (P<0.05) higher than that detected from Brewery. For NH_3, SO_2, and NO_2, their emission concentrations were the same for the three industries. Bottling Company A emitted significantly (P<0.05) the highest quantity of H_2S, followed by the Brewery, while the lowest was from Bottling Company B. For the three companies, CH_4 gave zero emission all through the experiment.

DISCUSSION

H_2S was detected in comparatively higher concentrations in locations 4 to 6 and 7 to 9 than in locations 1 to 3 for the three industries. Waste ponds of these companies are located adjacent to the exit area and gate, while solid wastes are burnt in incinerators kept near the boundary wall. These might have contributed to the high concentration of H_2S in those locations. This is in agreement with the report of WHO (2000) which stated that H_2S is often emitted at a hazardous level from waste water or sewage treatment facilities. Also, the National Pollution Inventory (NPI) (2014) reported that H_2S is emitted from electric power plants, burning of coal or fuel oil containing sulphur, from coke ovens, geothermal power plants, breweries, car exhausts, and septic tanks, among others. Adeyemi (2009) reported that the Nigerian Breweries PLC (NBPLC) uses diesel, low pour fuel oil (LPFO) and

Table 4. Average concentrations (ppm) of gaseous emissions from Brewery, Bottling Company A and Bottling Company B.

Gases	Brewery (ppm)	Bottling Company A (ppm)	Bottling Company B (ppm)
HCN	0.94 ± 0.16^{a}	0.46 ± 0.12^{b}	$0.85 \pm 0.18^{a,b}$
NH_3	0.19 ± 0.03^{a}	0.29 ± 0.04^{a}	0.30 ± 0.05^{a}
CO	3.17 ± 0.89^{a}	0.65 ± 0.10^{b}	0.78 ± 0.11^{b}
SO_2	0.28 ± 0.04^{a}	0.30 ± 0.04^{a}	0.23 ± 0.03^{a}
CH_4	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
CL_2	0.49 ± 0.04^{a}	0.72 ± 0.04^{b}	0.83 ± 0.06^{b}
NO_2	0.62 ± 0.04^{a}	0.66 ± 0.08^{a}	0.70 ± 0.07^{a}
H_2S	17.71 ± 0.94^{a}	21.24 ± 0.97^{b}	12.57 ± 0.32^{c}

Values represent means ± standard error. Means followed by the same letter(s) in the same row are not significantly different at $P \leq 0.05$.

natural gas for the generation of thermal energy, while diesel and liquefied petroleum gas (LPG) are used for some logistic operations and by the canteen. H_2S concentrations detected in the afternoons and evenings were significantly higher than the concentrations detected in the morning hours. Possibly afternoons and evenings were the times when wastes are treated and much fossil fuel energy used. Enough wastes might not have been released in the morning hours. Also burning and use of fossil fuel energy might not be maximal in the morning. H_2S detected in these 3 companies ranged from 12.57± 0.32 to 21.24 ± 0.97 ppm. This value is higher than the Nigerian ambient air quality standard (NAAQS) of 0.008 ppm (daily average of hourly value) (FEPA, 1991). WHO (2000) had stated that H_2S should not be allowed to exceed 7 µg/m^3 with a 30 minute averaging period. The report further stated that low concentrations of H_2S (5 to 50 ppm) may cause various human aliments, toxicity to animals and aquatic life, especially for repeated exposures. Therefore these companies are advised to reduce their emission of H_2S.

Concentrations of HCN detected from different locations in the respective companies were the same, except for the concentrations emitted from Bottling Company B, which were highest at locations 7 to 9. These locations were areas near the boundary wall, generator house and exit area. Solid wastes from these companies are burnt in incinerators kept near the boundary wall, while waste ponds are located adjacent to the exit area and gate. IPCS (2004) reported that HCN can be released from fossil fuel combustion, including generators; vehicle exhausts emissions, production of coke or other coke carbonization procedures, waste ponds, biomass burning and solid waste incinerators. HCN concentrations emitted in the morning hours were significantly higher than those released in the afternoon and evening hours, for the three companies. Also concentrations of HCN detected around the Brewery were more than the quantities detected from Bottling Company A. Breweries normally use large quantities of cereals like sorghum, wheat, rice, barley, maize in brewery processing (WBG, 2007) and these are stored in grain silos and preserved using HCN as a fumigant. The release of this fumigant into the atmosphere may go on throughout the night, and in the morning comparatively higher quantities of HCN may be detected. IPCS (2004) reported that HCN is released into the air from HCN used as a fumigant in grain silos, in seed vacuum chambers, as well as directly from the seeds, higher plants like sorghum, corn, cassava, fruits, vegetables, and lower plants like bacteria and fungi. Concentrations of HCN detected in the three companies ranged from 0.46 ± 0.12 to 0.94 ± 0.16 ppm. This is higher than the NAAQS of 0.01 ppm for an average time of 24 h (FEPA, 1991). On the other hand, this range is much lower than the report of Okafor and Maduagwu (2000) who detected cyanide at levels of 20 to 46 mg/m^3 in the air, near large – scale cassava processing facilities in Nigeria. HCN adversely affects the cardiovascular, respiratory, central nervous and endocrine systems. In humans, minor effects may occur at exposure of 20 to 60 mg/m^3, but above 120 mg/m^3, death may occur (IPCS, 2004).

Concentrations of NH_3 detected in locations 1 to 3 and 4 to 6 were comparatively higher than the concentrations detected around locations 7 to 9, especially for Brewery and Bottling Company A. These industries use NH_3 as a refrigerant in order to cool their products located in the production hall and utility areas. This agrees with the report of USEPA (2004) which stated that NH_3 is emitted from industrial waste water treatment and industrial refrigeration, among others. The report further elaborated that food and beverage industries operate with NH_3 as a refrigerant because it provides cooling efficiencies that are approximately 4 times greater than chlorofluorocarbon (CFC) and hydro chlorofluorocarbon (HCFC) refrigerants. NH_3 can be easily liquefied to ammonium hydroxide by compression or cooling and when it is returned to its gaseous state, it absorbs large amounts of heat from its

surroundings. For soft drinks, Hirsheimer (2012) added that for carbonation (absorption of CO_2) to occur, soft drinks are cooled using large, ammonia-based refrigeration systems. This is what gives carbonated products their effervescence and texture. Concentrations of NH_3 detected from the three companies ranged from 0.19 ± 0.03 to 0.30 ± 0.05 ppm. This is within the NAAQS of 0.2 ppm (FEPA, 1991). Recommended NH_3 emission from industrial refrigeration is 30 lb/scc unit yearly (USEPA, 2004).

CO detected from Brewery was significantly higher than concentrations detected from the two Bottling Companies. CO was detected more around the production hall, chlorination tank area, water treatment area, equalization tank area, utility and effluent discharge areas than in areas near the boundary wall, generator house and exit area. Hirsheimer (2012) reported that CO is released from production processes such as brewing of beverage alcohols and the use of internal combustion engines especially old diesel power generators. Also gas or liquid petroleum (LP) fork-lift engines generate CO as a by-product of combustion. Adeyemi (2009) had earlier reported that Nigerian Breweries PLC has been using natural gas to replace diesel in her internal forklift truck transportation system. He further stated that Ama brewery uses combined heat power generating system in order to conserve energy. In this case the energy that could have been wasted from electricity generating sets is converted to heat energy for use in their processes. This pre-empts the generation of more heat energy by other means that could have increased fossil fuel consumption and thus carbon emission. In addition, there is the recovery of heat energy from spent grains, which reduces industrial solid waste. The report further stated that Lagos and Aba breweries in Nigeria are using natural gas in the generation of heat energy from boilers, resulting in a significant reduction in the emission of CO and NO_x. Indeed all these measures actually reduced the emission of CO because concentration of CO detected from the companies ranged from 0.65 ± 0.10 to 3.17 ± 0.89 ppm. This is much less than NAAQS and tolerance limit of between 10 ppm to 20 ppm (daily average of hourly value) (FEPA, 1991). This small quantity of CO emission from these three companies may not poison human beings in a well ventilated environment, since the natural self – cleansing properties of the ambient air can take care of these little emissions. This is in contrast with the report of John and Feyisayo (2013) who stated that many families including children, pregnant women, babies and individuals lost their lives in Lagos, Nigeria due to inefficient control of air pollution caused by this deadly CO. Although the authors did not quantify the amount of CO that might have poisoned the people, it is a well-known fact that people should not sleep in a poorly ventilated room where generator exhausts emit toxic fumes.

Concentrations of SO_2 detected from different locations in the respective companies were significantly the same, except in Bottling Company A where quantities of SO_2 emitted from the production hall, chlorination tank area and water treatment area were significantly higher than those released from the other locations. These companies use power plants for the generation of energy and burn fossil fuels, coal and gas in the process of production and transportation and these activities release SO_2. This agrees with the report given by WHO (1999) which stated that SO_2 and NO_2 are released from burning of coal, gas and oil by factories, vehicles and power plants. These gases react with water vapour in the air to form acid rain (Anderson, 2005), which damages many buildings, bridges, statues, kills plants, animals, causes diseases to human beings and harm to the environment. For the three companies, range of SO_2 emissions was from 0.23 ± 0.03 to 0.30 ± 0.04 ppm. This is a little higher than the NAAQS of 0.01 to 0.1 ppm (FEPA, 1991). This range is somewhat lower than the results given by Mohammed et al. (2013), who worked on vehicular emissions in Kaduna (Nigeria) metropolis. They reported that the average SO_2 concentration range was 0.16 – 0.75 ppm with the highest value of 0.75 ppm at highly industrialized area and 0.70 ppm at high traffic area while 0.16 ppm was detected in areas with low traffic. They concluded that the higher the number of automobiles in an area, the higher the SO_2 concentrations.

Cl_2 concentrations emitted from the various locations in the respective companies were significantly the same, except in Brewery, where the quantities released in the production hall, chlorination tank and water treatment areas were significantly higher than those emitted from other locations within the company. In these companies Cl_2 is stored in chlorination tanks for water treatment. This agrees with the report of Hirsheimer (2012) who stated that chlorine is often purchased and stored in pressurized metal containers by beverage industries that usually use it for water treatment since they require pure water in their production processes. Chlorine is extremely hazardous and leakages can occur when there is a change from one container to another or from a leaking or defective valve. Concentrations of Cl_2 emitted from Bottling Companies A and B were significantly higher than that released from Brewery. This may perhaps mean that the Bottling companies require purer water than Brewery and they even market bottled drinking water. Therefore, the leakages of Cl_2 into the air from Bottling Companies were expected to be more than that of Brewery. Burning of chlorinated organic solid wastes by these industries may also release hydrogen chloride and chlorine gases into the atmosphere. This agrees with the report given by USEPA (2014b) which stated that hydrogen chloride and chlorine gases form when chlorinated organic compounds in hazardous wastes are burned. If uncontrolled, this Cl_2 can become a human

health risk and is a large component in the formation of acid rain. Range of Cl_2 concentrations detected was from 0.49 ± 0.04 to 0.83 ± 0.06 ppm. The current limit of total emission of chlorine allowed for a new incinerator should not exceed 21 ppmv (parts per million by volume). By achieving the regulatory emission limit of chlorine, both hydrogen chloride and Cl_2 gas emissions will be reduced (USEPA, 2014b).

NO_2 concentrations emitted from the production halls, chlorination tank and water treatment areas were significantly higher than the quantities detected from equalization tank area, effluent discharge and utility areas for Brewery and Bottling Company B. NO_2 is released into the atmosphere from power plant emissions, vehicle exhausts and leakages from damaged cylinders or pipelines in the production halls of these industries. This agrees with the report given by WBG (2007) which stated that brewery activities involve the use of pressurized gases such as CO_2, nitrogen refrigerants and compressed air. Some beers may be served with a nitrogen/ carbon dioxide mixture. Nitrogen produces fine bubbles, resulting in a 'dense head and a creamy mouth-feel'. Uncontrolled release of these gases or inadequate ventilation, particularly in confined or enclosed spaces such as fermentation and maturation rooms can result in accumulation of sufficient concentration to present asphyxiation risk especially for workers. The average quantities of NO_2 detected from the three companies were the same and ranged from 0.62 ± 0.04 to 0.70 ± 0.07 ppm. This was higher than the NAAQS of 0.04 to 0.06 ppm hourly (FEPA, 1991).

SO_2 and NO_2 emissions were higher than United States national ambient air quality standards, while CO emission was lower (USEPA, 2014a). Apart from gaseous emissions released directly from the companies, air pollutants can be released from burning of solid wastes, gas flaring activities of the petroleum sectors and vehicle exhausts. The atmosphere may be inundated with CO_x, SO_x, NO_x, volatile organic compounds, polyclic aromatic hydrocarbons, dioxins, polychloro biphenyls (PCBs) and heavy metals such as lead, nickel and mercury (Tawari and Abowei, 2012) and these travel far from one part of the atmosphere to the other. USEPA (2013, 2014a) has set National ambient air quality standards for 6 principal pollutants which are called "criteria pollutants". These are CO, NO_2, Pb, O_3 (or smog), PM and SO_2. If the levels of these pollutants are higher than what is considered acceptable by Environmental Protection Agency (EPA), the area in which the level is too high is called a non attainment area. The air quality index (AQI) is a scale ranging from 1 to 10_x, with different colours which are used to communicate to the public the relative risk of outdoor activity. The air quality health index (AQHI) indicates the level of health risk associated with air quality and it provides associated health advice for the public (Wikipedia, 2015). In Nigeria, the challenges facing air quality studies include lack of equipment, inadequate expertise, lack of infrastructure and weak policy framework and enforcement. Also the existing network of meterological stations in Nigeria is too coarse to provide data covering the whole nation (Tawari and Abowei, 2012).

CH_4 was not detected from the three companies. CH_4 is generated in waste deposition in landfills (Wikipedia, 2011) and in animal rearing and so may not be expected to be detected in the three companies. This study was carried out in the rainy season while the dry season gaseous emission in the industries is on-going.

Conclusion

Apart from CO and NH_3 the concentrations of other gaseous emissions were higher than the Nigerian and United States National ambient air quality standards. Therefore, it can be recommended that these companies should determine best control measures to reduce these toxic gaseous emissions. Government should be more involved in systematic and consistent air quality assessment programmes so as to come up with a definite well-publicized air quality index with which to communicate to the public the risks that are involved in inhaling these gaseous pollutants. All these will help improve the health of humans, secure the lives of plants and animals and conserve the ecosystem and biodiversity.

Conflict of Interests

The author have not declared any conflict of interests.

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