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Characterization of Atmospheric Gaseous Components in Abattoir Operation Site in Ogbor-Hill Aba, Abia State, Nigeria

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Abstract

Ambient air pollutant has become a major problem in most town in Nigeria. The study aimed at assessing the spatiotemporal variation of abattoir operation on the ambient air quality in Ogbor-hill Aba. The study was carried out within 3 months with emphasis on seven pollutant that originated from abattoir operation at graded distance. From the result, three of the criteria pollutants monitored, SO_2, NO_2 and PM_{10} recorded the mean values of 613.25 µg/m³. 699.05 µg/m³ and 1966.67 µg/m³. these exceeded the national ambient air quality standard (NAAQS) by 13%, 14.31% and 76.27% respectively. With a statistical model, the PSI value for the pollutants were found to be SO_2 (588.81 µg/m³), NO_2 (878.62 µg/m³) and PM_{10} (585.91 µg/m³) which signifies elevated concentration of pollutant. Further comparisons were made using WHO and FMENV, the result of the pollutants exceeded their approved standards. On subjection to ANOVA, SO_2 and NO_2 exerted a significant effect at $p \leq 0.01$ and PM_{10} proved significant at $p \leq 0.05$. the entire result indicated a very serious health implication on the public especially those with existing health challenges. The high concentration of these pollutants on the ambient air triggers health alters and every one may experience more serious health effect on continuous exposure. To mitigate this emission, the abattoir operators must adopt a hygienic and modern treatment of effluent before disposal. Excess waste can be used for agricultural purposes. Further abatement measures may require the relocation of the abattoir far from residential areas.

Keywords: Ambient air quality; Abattoir; PSI; Pollutant

Introduction

Air pollution is the introduction of substances into the atmosphere that harm or cause discomfort to human and other living and non-living things. Ambient air pollution has constituted serious threat to man and his environment during production processes that emits obnoxious gases into the atmosphere. Globally abattoirs are recognized as a major source of air pollutant [1]. The impact in the ambient air varies from relatively minor, if mitigating measures are applied to extreme where emission results to public menace [2]. In an abattoir operational system where incinerators are used to burn waste and carcasses, a range of air pollutants are released into the atmosphere. Such pollutants include Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), particulate matter (PM_{10}), Carbon monoxide (CO), Carbon dioxide (CO_2) and other volatile organic compounds VOCs [3]. On the other hand, the smoke emitted from the incinerator may also constitute a serious nuisance on the atmosphere. These odoriferous compounds produced because of abattoir operation affects the characteristics of the ambient air quality rendering it unsuitable for human inhalation [4].

A serious odour problem was reported from poorly managed pond at a chicken abattoir in North America [5]. Vehicle transporting livestock to and from abattoir sites may cause a serious odour problem as they pass through residential areas and during offloading at the abattoir sites. All these activities put together emits a great portion of air pollutants into the surrounding ambient air thereby altering its quality. Despite these environmental problems, the construction of abattoirs is on the increase, a recent study contended that abattoir operation contributes so much on air pollution problem in Nigeria. Abattoir emission also contributes to global problem caused by greenhouse gas emission. Emissions are variable in space and time and in how they interact within the various processes and media affected [6]. Abattoir also consumes fuel for energy production thereby emitting CO_2, NOx, SO_2 and particulates.

Till date, the extent of detrimental impact of abattoir operation on the ambient air quality are yet an unknown issue in Nigeria. The nature of emission produced from an abattoir operation introduces so much odoriferous compounds into the atmosphere and this in turn affects the air quality making it unbearable for man. Most respiratory track infections experienced by people in the urban areas especially those closer to abattoir sites attributes to ambient air pollution. The most alarming case is the high incidence of chronic lung infection among abattoir operators [7]. Abattoir are one of industries that releases appreciable amount of organic and inorganic air pollutants such as hydrogen sulphide (H_2S), Methanethiol, Ammonia, Di methyl sulphide etc. during the heating of animal tissues. These pollutants with high concentration can be objectionable and pose health effect such as headache, nausea, eye irritation paralysis and even death, therefore it must be controlled [7]. Volatile organic compounds such as SO_2, NO_2 and PM_{10} can cause irritation in the eye, nose and throat, in several cases leads to headache, nausea and loss of coordination. In long run, some of these are suspected to cause damage to the liver and other parts of the body which may even lead to death. Children and aged adults are most vulnerable to these organic pollutants.

This objective of this research is to analyse the spatiotemporal variation of abattoir operation on ambient air quality in Ogbor hill aba, Abia state, also to characterize the ambient air quality in the abattoir at graded distance and finding a possible solution or mitigative measures for sustainable use of abattoir. Hence, this research covers the impact of

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abattoir operation on atmospheric chemistry within Ogbor Hill and its environs in Aba.

Materials and Methods

Environmental setting

The research was carried out in Ogbor hill Aba in Aba South Local Government Area of Abia State, Nigeria. The area lies between latitude 5°07'N and 7°23'E and longitude 5°117'N and 7°367'E with an estimated population of 1,020,900 as at 2004 population census. The indigenous people of Aba are the Ngwas and are mostly Christians. Aba is known for its craftsmen. There are several abattoir sites in Ogbor hill Aba, and they dispose their waste into the Aba river and its environ. The climatic condition of the area has its parameter as; temperature range of 21°C and 27°C, relative humidity ranges between 60 – 80%. The area lies within the sub-equatorial, sub-humid region with March to October as rainy season and November to February as dry season. Annual average rainfall is about 2200 mm.

Sampling design, collection and preparation

Samples were collected from five sampling points in Ogbor hill Aba. The points were designated as SP_1, SP_2, SP_3, SP_4, SP_5 with SP_5 serving as the control. Each sampling point were located at distance of 50 m from each other however the control was located at 200 m from the study area [6]. Data collection was done insitu in accordance with a fixed sampling schedule at an hourly interval in the prevailing wind direction but in the downwind direction for the control sample point. Multiple sampling points were required to ensure reasonable coverage of the area and replicate measurement made at each sampling point. Air sampling was conducted focusing mainly on three criteria pollutants, SO_2, NO_2 and PM_{10} since they constitute a large portion of emission from abattoir site [3]. Other pollutant measured includes CO, CO_2, VOCs and H_2S. measurement was carried out using a multi gas analyser (2002 model) with electrochemical measuring principles and complete conditioning system. Other monitoring equipment used includes Gasman Model 19773H for VOCs and H_2S and Multi REA plus (PCM 50) for CO, CO_2 and relative humidity temperature and wind speed were also measured. Data were collected within 8:30 am and 4:30 pm on 8-hourly with one hour interval on daily basis during the three-month period. Samples were collected on dry and wet days to help assess the influence of humidity and dry atmosphere on ground level concentration of the measured pollutants.

Descriptive statistics were used to present data in numerical and tabular forms. Data were analysed using mixed effect models with random subject effect for repeated measurement. In the first level of analysis, linear and logistic model were applied for the pollutant gas combined to know whether association exists. The test homogeneity in mean variance of the concentration levels of monitoring gases across the sampling station was conducted with analysis of variance (ANOVA). The pollutants standard (PSI) was calculated for an overall assessment of air quality using the procedure adopted by EPA [8]. The value of PSI helped to know whether air quality was improving or worsening in the area and the pollutant(s) exceeding National Ambient Air Quality Standard (NAAQS), WHO and FMENV. All statistical analysis was done using the statistical model approved by EPA [4] to calculate the PSI value of the main pollutants (Tables 1-5).

A statistical model was applied to calculate the PSI of each pollutant, using the formula in accordance to EPA [4].

$$Lp=[Lhi-Llo]\ (CP-Bplo)+Llo/BPhi-Bplo \quad (1)$$

S No	Index/value	Descriptor	SO_2	NO_2	PM_{10}
1	0-100	Good	0-80	0-80	0-200
2	100-200	Moderate	81-367	81-180	201-260
3	200-300	Poor	368-786	181-564	261-400
4	300-400	Very Poor	787-1572	565-1272	401-800
5	400-500	Severe	>1572	>1272	>800

Source: Goyal and Kumar

Table 1: Shows the break point for PSI (AQI) in μg/m³.

API	Air pollution level	Health implications
0-50	Low	None expected
51-100	Medium	None expected for general population
101-200	High	Acute health effect is not expected but chronic effects may be observed if one is persistently exposed to such level
201-300	Very high	People with existing heart or respiratory illness may notice mild aggravation of their health condition. Generally, healthy individuals may also notice some discomfort.
301-500 and above	Severe	People with existing heart or respiratory illness may experience significant aggravation of their symptoms. There may also be widespread symptoms in the healthy population e.g. Eye irritation, coughing, sore throat, etc.

Source: FEPA

Table 2: Shows the Value and description of standard pollutant index (PSI) currently referred to as air quality index (AQI) by the US EPA.

Parameter	*In Situ*	0-50 m	50-100 m	100-150 m	150-200 m
SO_2 (μg/m³)	853.33	826.34	480.00	253.34	80.00
NO_2 (μg/m³)	893.30	840.00	542.86	520.00	173.34
PM_{10} (μg/m³)	2733.34	2333.34	1733.34	1066.67	160.00
H_2S (μg/m³)	1306.67	893.34	273.34	333.33	93.34
CO (μg/m³)	64186.67	81360.00	85920.00	26186.67	24613.34
CO_2 (μg/m³)	273600.00	271600.00	165040.00	141493.34	121373.33
VOCs (μg/m³)	121467.00	1293.34	1053.34	600.00	373.33
TEMP (°C)	30.85	30.20	24.00	24.00	25.00
RH (%)	20.50	21.00	23.50	28.50	29.00
W/S (m/s)	0.40	0.35	0.90	1.00	1.05

Where, TEMP is Temperature in °C, RH is relative humidity in % and W/S is Wind speed in m/s.

Table 3: The mean distribution of all the pollutants monitored.

where: Lp=The PSI for the polluted P; Cp=The actual ambient concentration of P; BPhi=The breakpoint in Table 1 greater than or equal to Cp; BPlo=The breakpoint in Table 1 less than or equal to Cp; Lhi=The sub index values corresponding to BPhi; Llo=The sub index values corresponding to BPlo.

Results

The PSI of SO_2 in the study area is high, confirming that members of the sensitive group may experience more serious health effects. NO_2 and PM_{10} recorded very high PSI which triggers health challenges. This is consistent with Goyal and Anikender report on mathematical modelling of air pollutants [9].

Discussion

The various activities of abattoir operators in Ogbor hill Aba have led to the emission of obnoxious gases which alters he atmospheric composition in the study area. The criteria pollutants considered in this study showed elevated concentration likewise other gases monitored such as H_2S, CO, CO_2, HCl, and VOCs. Thus, the more concentration

S No	Air Pollutant	Psi	WHO Standard	FMENV Standard	NAAQS Standard	Description
1	SO_2 (µg/m³)	588.81	20	83	80	High
2	NO_2 (µg/m³)	878.62	40	50	100	Very High
3	PM_{10} (µg/m³)	585.91	20	50	150	Very High

Table 4: The pollutant standard index (PSI) of the criteria pollutants.

S No	Air Pollutant	Mean	S^2	S	CV
1	SO_2 (µg/m³)	613.25	74381.25	272.23	44.47
2	NO_2 (µg/m³)	699.05	38023.24	195.00	28.32
3	PM_{10} (µg/m³)	1966.67	528890.89	727.28	37.00

Table 5: The mean, standard deviation and coefficient of variance of the criteria pollutants.

of gases in the atmosphere can as well affect the health of the abattoir operators as well as public. Erratically, the atmospheric environment is altered thus increasing the concentration levels of photochemical oxidants.

The mean concentration of SO_2 is 858.33 µg/m³ and it exceeds the recommended standards by NAAQS. This signifies that continuous emission of SO_2 in Ogbor hill Aba will aggravate the health status of the people with existing heart or respiratory illness, other healthy individuals may experience discomfort. Comparing this value to WHO and FMENV guidelines which are given as 20 µg/m³ and 83 µg/m³ respectively, the elevated mean of SO_2 to the rate of 613.25 µg/m³ far exceed these standards and immediate attention is required. According to WHO [10], high concentration of SO_2 in the ambient air irritates the skin and mucous membrane of the eye, nose, throat and lungs. An increase in the rate of exposure increases the risk of inflammation and irritation of the respiratory system, especially during heavy physical activities. High concentration of SO_2 can affect lungs function, worsen asthmatic attacks and aggravate existing heart diseases in the sensitive group.

Emission that leads to high concentration of SO_2 generally also leads to the formation of other SOx. Control measures that reduces SO_2 can generally be expected to reduce people's exposure to other gaseous SOx. This may have the important co-benefit of reducing the formation of fine sulphate particles which pose significant public health issue. The indiscriminate discharge of untreated abattoir effluent into the Aba river and the poor management of animal waste caused by the emission of NO_2 at an alarming rate. the mean value of NO_2 is 699.05 µg/m³ is high, the PSI value is 878.62 µg/m³ which is elevated and can pose serious health threat to the public on constant exposure. This conform with Aneja et al. [11] which states that an increasing evidence show that greater size and intensity of abattoir and concentrated animal feeding operations increases the emission of odorous compounds such as NO_2 and SO_2. Currently, scientific evidence by the US EPA [12] links short term NO_2 exposure ranging from 30 minutes to 24 hours with adverse respiratory effects including air way respiratory symptoms in individuals with asthma.

The NAAQS rated the respiratory quantity of NO_2 as 100 µg/m³, whereas WHO and FMENV have their guidelines as 40 µg/m³ and 50 µg/m³ respectively, these range cannot be a proximity of the result obtained from the study area of 893.34 µg/m³, nor compared to the mean value of 699.05 µg/m³. A recent study by WHO show a connection between breathing elevated short term NO_2 concentration and increased visits to emergency department and hospital admission for respiratory issues especially asthma. The sum of nitric oxides and NO_2 in the atmosphere is commonly called nitrogen oxide or NOx. Other oxides of nitrogen including nitrous acid and nitric acid are part of the nitrogen oxide family. While EPA's NAAQS covers these entire family, NO_2 is the component of greatest interest and indicator of the large group of nitrogen oxides.

The main source of PM_{10} from the abattoir operation is the high rate of carcass combustion and the process of dehairing. A close physical observation of the study area shows a cloudy weather during major activities at the abattoir and smoke is readily emitted simultaneously. These particulates do not only emit from the carcass burning or meat processing but also the wood used in dehairing, cooking and drying of meat.

The estimated mean from the result of 1966.67 µg/m³ for PM_{10} exceeds the set-out standard by NAAQS (150 µg/m³), WHO (20 µg/m³) and FMENV (50 µg/m³), this constitute a serious risk factor for public health. In line with report by FEPA [8], the size of the particles is directly linked to their potentials for causing health problems. Small particles less than 10 micrometres in diameter pose the greatest problem because they can get deep into the human lungs and some may eventually get into the blood stream, therefore exposure to such particles can affect the lungs and heart.

Further analysis of the result was done using the ANOVA, after being subjected to the statistical test, several air pollutants exerted significant influence on the ambient air quality. Considering the criteria pollutants at $P \leq 0.01$ SO_2 and NO_2 exerted a significant effect on the composition of the ambient air quality in the study area. PM_{10} though recorded the highest values have no significant effect at $P \leq 0.01$. Further verification at $P \leq 0.05$, it has a significant effect on the ambient air quality. Therefore, SO_2 and NO_2 proved significant at ($P \leq 0.01$) on the ambient air around the study area where PM_{10} was found to be significant at $P \leq 0.05$, this proved that there is significance effect of abattoir operation on the ambient air quality in Ogbor hill Aba.

A critical look at the result, climate variables such as temperature, relative humidity and wind speed have crucial impact on the ambient concentration level of these pollutants. At a high temperature, the pollutant gain more kinetic energy and can travel (disperse) faster at a higher velocity and wind speed. An increase in relative humidity tends to increase their molecular mass and reduces their concentration at the ground level (ambient). The wind speed helps in spreading the gases far and near depending on their molecular weight and velocity of the prevailing wind. Due to the nature of the landscape in the area, the pollutants cannot disperse or be carried far away from the abattoir because the whole region is on a valley. The higher the temperature, the higher the concertation of the pollutants, the higher the relative humidity, the lower the concentration and vice versa, whereas wind speed facilitates their dispersal.

Conclusion

The result obtained from this study revealed that air quality was altered by various activities in the abattoir such as indiscriminate disposal of animal waste and untreated effluent discharge on the Aba river, meat processing, dehairing, burning of carcass etc. the criteria

pollutants are responsible for the unpleasant odour and health risk of the public around the study area. Most of the gaseous pollutant monitored exceeded their established standards by WHO, NAAQS and FMENV respectively. Results also showed a strong elevation among the identified gaseous pollutants, three of these are namely SO_2, NO_2 and PM_{10} were mostly predominant as they recorded the highest level of exceedances during the monitoring period. The result was further subjected to ANOVA and it was found that SO_2 and NO_2 exerted significant effect at $P \leq 0.01$, whereas PM_{10} show a significant effect at $P \leq 0.05$. However, the overall assessment of the ambient air quality in the study area indicates a result that would be described as unhealthy by various health standard. Climatic variables such as temperature, relative humidity and wind speed also contributes to an extent to this variability of the level of measured pollutant.

This study recommends that agricultural industries should develop and utilize the various waste products generated from abattoir operation. Relocation of the abattoir to a government designated area would help reduce dispersion of pollutants to residential area. There is need for further epidemiological research in the study area to ascertain the level of impact of a long-term exposure from the abattoir emission on the local residence.

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