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RESEARCH ARTICLE

Tricycles And Their Impacts on Air Pollution within Uyo urban South-eastern Nigeria

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Abstract

Globally, vehicular emissions contribute significant levels of contaminants into the air. Despite the contributions by tricycles to the contamination of the air, the contamination of air is mostly linked to vehicles. Hence, this work examined the contributions of tricycles to air pollution within Uyo Urban, Nigeria. Major tricycle parking bays at Akpandem and Itam Markets, Etuk Street Market, Udi Street by Ikot Ekpene Road, Ikpa Road by University of Uyo Gate, Urua Ekpa, Ekom Iman, and Shelter Afrique Junctions were designated for this research. Portable air quality monitors were used to quantify the concentrations of NO_2, SO_2, H_2S, CO, CO_2, and $PM_{2.5}$ at these locations. Results obtained showed the following mean concentrations 0.43±0.07 ppm, 0.55±0.09 ppm, 0.22±0.09 ppm, 7.25±2.37 ppm, 890.06± 300.26 ppm, and 208.72±250 μg/m^3, respectively. The mean concentrations of NO_2, SO_2, CO, and $PM_{2.5}$ were higher than their recommended safe limits by the Federal Environmental Protection Agency (FEPA), while H_2S and CO_2 were within their safe limits. The air quality index (AQI) analysis revealed that, NO_2 and $PM_{2.5}$ belong to the hazardous class, SO_2, H_2S, CO, and CO_2 belong the class unhealthy for the sensitive class. Principal component analysis (PCA) established that, emissions from tricycles were the principal source of air contaminants determined at the studied locations. The outcome of the study confirmed that, green plants can reduce air contaminants. The study substantiated those tricycles can release significant levels of obnoxious substances into the air.

Keywords: Tricycle; Uyo Urban; Air Pollution; Multivariate analysis; Nigeria

Introduction

Air pollution is an environmental issue that affects the developed, developing, and underdeveloped nations of the world. It has negative impacts on the urban, suburban, and rural areas in most countries [1]. Air pollution has significant negative impacts on human health irrespective of the age [2, 3]. Studies have shown that air pollution has the potential to impact negatively on the quality of rainwater harvested in an area [4-6]. Transportation is a major source of air pollution mostly in the underdeveloped and developing nations of the world [7]. Transportation by road is very popular in the developing countries like Nigeria due to its flexibility. However, it has been established that, transportation by road is the greatest source of air pollutants [8]. It has also been reported that, road transportation is one of the major contributors to the current climate change globally [9-11].

The use of tricycle as a means of transportation in Nigeria is becoming very popular due to its accessibility, affordability, and income [12]. Literature has shown that tricycles release high levels of pollutants into the atmosphere [13-16]. Most tricycles on Nigerian roads are aged and badly maintained since regulations on road transportation are either ignored or non-existent, this result in incomplete combustion of fuels. Consequently, harmful substances such as particulate matters (PM), nitrogen oxides (NOx), sulfur oxides (SO_x), and carbon oxides (CO_x) are discharged into the air environment [2, 17, 18]. Due to the unavailability of windows and doors on tricycles, the passengers are exposed to high levels of air contaminants [15]. The number of tricycles on the roads, duration spent, improper maintenance, age, and type of fuel used are the major factors influencing the level of contaminants released by tricycles into the air environment [16].

The emissions from exhausts of automobiles including tricycles mainly in congested roads can impact negatively on the economy, environment, and quality of life of the inhabitants in cities mostly in densely populated areas [19-21]. The emissions from tricycles can also impact negatively on edible plants cultivated by roadsides [22, 23]. The effects of vehicular emissions are noticed more during the dry season than in wet; thus, temperature can also influence the availability of air contaminants and other processes in life [24-26]. Persistent human exposure to toxic substances in the air may result in adverse health issues including cancer and death [27-29]. The air environment within the study area (Akwa Ibom State) in the oil producing region of Nigeria has been negatively impacted by gas flaring from crude oil activities in the region [30, 31]. Consequently, the uncontrolled emissions of obnoxious gases by tricycle into atmosphere will exacerbate the already bad status of the air environment in the area. The population of Uyo Metropolis is gradually increasing due to migration of people from rural areas to the city for improved standard of living [32]. The population of Uyo is approximately 3,920,208 with over 10,500 tricycles operating within the area [32, 33]. Hence, studies on the rate of emission of toxic substances into the air environment by road transportation should be intensified. However, studies on the levels and the sources of air contaminants/pollutants in Nigeria are mainly focused on vehicles and the industrial section.

Despite the high number of tricycles operating within the study area and the population, there is no information on the level of air contamination and related risks associated with this means of transportation. Hence, this study was carried out to determine the levels of air contaminants released by tricycles operating within Uyo Urban. This research also aimed at investigating the environmental and human health problems associated with the levels of air contaminants released by tricycles operating in the area. Multivariate analyses will also be performed on the air contaminants to establish the source and relationships among the air contaminants examined.

Materials and Methods

Study Area

The research was conducted at tricycle parking bays located across Uyo Urban, Akwa Ibom State, Nigeria. The studied locations were Akpandem, Itam, and Etuk Street Markets, Udi Street by Ikot Ekpene Road, Ikpa Road by University of Uyo Gate, Urua Ekpa, Ekom Iman, and Shelter Afrique Junctions. The study area covered between latitude 05° 00’ 27.77” and longitude 07° 51’ 18.98” within Akwa Ibom State, Nigeria. Uyo is the capital of Akwa Ibom State and due to urban drift, the population within the area is very high. Uyo is located within the South-eastern section of Nigeria commonly called Niger Delta Region. The region has two prominent seasons namely: dry and wet. This work was carried out during the dry season of the study area to evade the washing down of air contaminants investigated [34]. Uyo urban is within the tropics with abundant rainfall and high temperature. The annual rainfall varies between 2,000 and 3,000 mm, while the temperature of the area may range from 25 to 29 ℃. The number of tricycles operating within the study area is over ten thousand. Consequently, very high levels of toxic substances may be released into the air environment regularly. As a state in the Niger Delta Sector of Nigeria, the area has been impacted negatively by the activities by Oil Companies. Hence, emissions from the exhaust of tricycles can exacerbate the air pollution status of the study area. The studied locations (point sources), their symbols, coordinates, and elevation are shown in **Table 1**.

Table 1. Point sources, related Symbols, their coordinates, and their elevations

Tricycle parking Bay	Symbol Used	Latitude (^{0}N)	Longitude (^{0}E)	Elevation (Ft)
Akpandem Market	AKM	05º 01' 15.88"	07 º 55' 35.24"	223
Etuk Street Market	ESM	05º 01' 55.85"	07 º 55' 37.32"	197
Udi Street by Ikot Ekpene Road	UIK	05º 02' 10.77"	07 º 55' 37.22"	230
Ikpa Road by University of Uyo Gate	1UU	05º 02' 13.29"	07 º 55' 25.14"	233
Itam Market	ITM	05º 02' 49.68"	07 º 53' 54.20"	226
Urua Ekpa Junction	UEJ	05º 03' 45.66"	07 º 55' 11.96"	243
Ekom Iman Junction	EIJ	05º 00' 27.77"	07 º 51' 18.98"	184
Shelter Afrique Junction	SAJ	04º 59' 27.56"	07 º 57' 57.30"	197

Analytical Procedures

Gasman portable digital air quality monitors were used for the quantification of NO_2, SO_2, H_2S, CO, CO_2 and $PM_{2.5}$ at the different tricycle parking bays in Uyo urban (Point sources). At each of the studied locations, the monitor was positioned in an open space, adjusted to TEST point and kept for two minutes. The equipment was then regulated to GAS point and readings displayed on the stable LCD were recorded in triplicates. The monitor used for the determination of each of the air parameters is shown in **Table 2** below. Regular maintenance and calibration of the monitors ensure the accuracy and reliability of data obtain from the field. Gasman portable digital air quality monitors are always calibrated by sending them to the calibration laboratory at the time specified by the manufacturer. These monitors are maintained by replacing the battery when the indicator alerts it is low. Troubleshoot of the portable monitors was also carried regularly to maintain them for optimal performance. The sensors are cleaned regular, and the bad ones are replaced. The monitors are also maintained by not exposing them to extreme high or low weathers. They are also maintained through regular cleaning of the components and preserving them in clean and dry environment.

Table 2. Equipment and procedures employed for the detection and quantification of Air Contaminants

Parameters	Equipment's model	Range (ppm)	Alarm level (ppm)
Nitrogen (IV) oxide (NO_2)	NO_2: Crowcon Gasman S/N: 19831N	0-10	3
Sulphur (IV) oxide (SO_2)	SO_2: Crowcon Gasman S/N: 19648H	0-10	2
Hydrogen sulfide (H_2S)	H_2S: Crowcon Gasman S/N: 19502H	0-50	50
Carbon (II) oxide (CO)	CO: Crowcon Gasman S/N: 19252H	0-500	50
Carbon (IV) oxide (CO_2)	CO_2: gas monitor Gasman model JSM-131SC	0 – 50000	1000
Suspended Particulate matter ($SPM_{2.5}$)	$PM_{2.5}$: gas monitor Gasman Model Air Ae Steward air quality monitor	0-500 μg/m³	200-500μg/m³

Air Quality Index (AQI) of Air Contaminants

The air quality index of the parameters assessed at the various point sources was estimated using Equation (1) as reported by USEPA [35].

$$AQI = \frac{\text{Level of Air Contaminant}}{Recommended\ Safe\ Limt} \text{ x } 100 - - - (1)$$

AQI is the air quality index of the air contaminants determined, Level of air contaminant indicates the concentrations of the air parameters assessed, and recommended safe limit signifies the highest concentration recommended for each parameter by Federal Environmental Protection Agency (FEPA, 1991). Air quality index of the parameters signifies the health consequences related to constant exposure to these contaminants. The main categories of AQI and health problems associated with each of the contaminants according to Longinus *et al.* [36] are indicated in Table 4 below.

Statistical handling of Data

The results obtained were treated statistically using IBM SPSS Statistic version

29.0.2.0 (20) Software. The minimum, maximum, mean, and standard deviation values were acquired directly from the software. Multivariate analyses (Correlation, principal component, and cluster analyses) were done with Varimax Factor analysis on the six air parameters determined. Values ranging from 0.507 and above were considered significant and used for discussion. Cluster analysis was carried out using Dendrograms with linkages.

Results and Discussion

The results of air contaminants obtained at the studied locations are shown in Table 3. The levels of nitrogen (IV) oxide (NO_2) ranged from 0.30 to 0.51 ppm with a mean value of 0.43±0.07 ppm. The mean concentration of NO_2 obtained is higher than the 0.216 ppm reported by Odoemelan and Jonah [37]. Consequently, the sources that released NO_2 into the studied environment, discharged higher levels of the pollutant than the sources investigated by Odoemelan and Jonah [37]. The range and mean levels of Sulphur (IV) oxide (SO_2) were 0.40-0.70 ppm and 0.55±0.09 ppm. The average value of SO_2 reported is lower than 16.183 ppm reported by Zajusz-Zubek and Korban [38]. Hence, the levels of SO_2 at the environment studied by Zajusz-Zubek and Korban [38] were much higher than what was discharged by tricycles in Uyo Urban. The negative effects on those exposed to the toxic gas might be more severe in studied environment within Poland than in Uyo Urban over time. Levels of hydrogen sulfide (H_2S) ranged between 0.10 and 0.31 ppm with an average value of 0.22±0.09 ppm. The mean value reported is lower than 1.87 ppm obtained by Antai *et al.* [39]. Thus, the activities at Eleme, Rivers State, Nigeria might have discharged higher concentrations of H_2S than tricycles in Uyo Urban. Levels of carbon (II) oxide (CO) varied from 4.00 to 10.98 ppm with 7.25±2.37 ppm as the average value.

Table 3. Levels of Air contaminants and their air quality indices

Analyses	NO_2 (ppm)	SO_2 (ppm)	H_2S (ppm)	CO (ppm)	CO_2 (ppm)	$PM_{2.5}$ (ppm)
AKM	0.40	0.50	0.31	5.02	1512.0	0.821
ESM	0.41	0.60	0.11	6.99	865.0	0.115
UIK	0.51	0.60	0.31	10.02	884.75	0.130
IUU	0.41	0.51	0.20	8.00	871.0	0.119
ITM	0.51	0.70	0.30	10.98	876.0	0.210
UEJ	0.40	0.40	0.20	6.00	843.0	0.980
EIJ	0.50	0.60	0.20	7.00	869.0	0.105
SAJ	0.30	0.50	0.10	4.00	399.75	0.720
Min	0.30	0.40	0.10	4.00	399.75	0.105
Max	0.51	0.70	0.31	10.98	1512	0.980
Mean	0.43	0.55	0.22	7.25	890.06	0.400
SD	0.07	0.09	0.09	2.37	300.26	0.373
AQI	300-510	80-140	50-155	80-220	40-151	46.0-392.0

Min = Minimux, Max = Maximum, $\bar{x}$ = Mean, SD = Standard Deviation, AQI = Air Quality Index

The average value of CO recorded in this study is lower than 39.62 ppm obtained by Nwokocha *et al.* [40] in related research. Accordingly, the commercial and industrial activities at Port Harcourt, Nigeria released higher levels of CO than the tricycles examined in Uyo Urban. The range and mean value recorded for carbon (IV) oxide (CO_2) were 399.75-1512.0 ppm and 890.06±300.26 ppm, respectively. The mean value is higher than the 531.09 recorded for CO_2 by Awosusi *et al.* [41]. Hence, the tricycles and other commercial activities in Uyo Urban discharged more CO_2 than at the forest and non-forested Domains in Oyo, State, Nigeria. The levels of suspended particulate matter ($SPM_{2.5}$) recorded at the point sources examined varied between 0.105 and 0.980 ppm with an average value of 0.400±0.373 ppm. Generally, the results obtained indicated that, the mean values of NO_2, SO_2, CO, and $PM_{2.5}$ were higher than their recommended limits of 0.1 ppm, 0.05-0.5 ppm, 1.0-5.0 ppm, and 0.25 ppm, respectively by FEPA [42]. However, levels of H_2S and CO_2 recorded were within their safe limits of 0.15-0.20 and 1000.0 ppm, respectively [42]. Consequently, persistent exposure to the levels of air contaminants reported may result in adverse human health problems. These problems include respiratory, irritation of the eye, nose, lungs, and throat, sneezing, and coughing. It may also dizziness, wheezing; affect the brain, heart, and even death [43-46]. The overall results also indicated that, all the contaminants recorded their lowest concentrations at Shelter Afrique and Urua Ekpa Junctions. This could be attributed to the high population of green plants available at these locations [47, 48]. The highest levels of the contaminants were obtained at the locations with low vegetation and high vehicular emissions [21, 49].

Table 4. Grade of Air quality Index and associated health consequences [36].

Range	Class	Status	Health problems
0 - 50	A	Good	Minor or no health risk
51 – 100	B	Moderate	Good for all categories of people except the ones sensitive to ozone might have respiratory problems
101 – 150	C	Unhealthy for sensitive group	Can have negative effects on sensitive people, but those in the non-sensitive class might not be affected.
151 – 200	D	Unhealthy	The sensitive class may have adverse health problems.
201 – 300	E	Very unhealthy	Can impact negatively on both the sensitive and non-sensitive classes.
>300	F	Hazardous	Can have severe health consequences on those in both the sensitive and non-sensitive classes.

The results of air quality index (AQI) analysis of the air contaminants are indicated Table 3. The AQI values for NO_2 ranged between 300 and 510 thus, it belongs to the F (Hazardous) class according to Longinus *et al.* [36] classifications. Hence, constant exposure to the pollutant may result in serious health consequences to both the sensitive and non-sensitive classes. AQI values for SO_2 varied between 80 and 140, hence the air contaminant ranged between moderate (B) and Unhealthy for sensitive groups (C) classes (**Table 4**). Consequently, prolonged exposure to the air contaminant may be dangerous to those sensitive to ozone and those in the sensitive group. The AQI values of H_2S ranged between 50 and 155 thus; it varied between groups A (Good) and D (Unhealthy) groups (**Table 4**). The AQI values obtained at ESM and SAJ were within the group A; hence, exposure to the air contaminant at these locations may pose slight or no health risks. However, based on the AQI results, constant exposure to the levels of H_2S recorded at the other studied locations may result in severe health problems. The AQI values reported for CO ranged from 80 to 220 (Class B to E) (Table 4). Accordingly, persistent exposure to the gas at the studied locations may affect people in both the sensitive and non-sensitive groups [3, 36]. An AQI range of 40-151 was recorded for CO_2 in this study indicating that, the health consequences that may result from the exposure to the contaminant varied between good (A) and unhealthy (D) groups (**Table 4**). The AQI values for CO_2 for all the studied locations belong to the unhealthy class except at SAJ (Table 4). Because of this, constant exposure to CO_2 at the studied locations might cause serious health problems except at SAJ. The low AQI value of CO_2 at SAJ could be attributed to the high population of green plants available at the location [48]. The AQI values for $PM_{2.5}$ ranged from 46.0 to 392.0, accordingly, the air particulate varied between classes A (Good) and F (Hazardous) (**Table 4**). Hence, constant exposure to the levels of $PM_{2.5}$ reported at the studied locations could cause serious health problems to both the sensitive and non-sensitive groups [46].

Multivariate Analyses

Correlation analysis

The results of correlation analysis (CA) of the air contaminants performed at 95, 90, and 80 % confidence are shown in Table 5. The results of CA indicated that, NO_2 correlated positively and significantly with SO_2 and H_2S at 80 % confidence with r values of 0.678 and 0.655, respectively. NO_2 also correlated with CO positively and significantly but at a 99 % confidence (r = 0.842). Hence, an increase in the concentration of NO_2 at the point sources may also result in a corresponding increase in the levels of SO_2, H_2S, and CO [50]. However, NO_2

corrected significantly but negatively with $PM_{2.5}$ at 80 % confidence with r values of -0.619. Consequently, high concentrations of NO_2 at the studied locations may result in the reduction of $PM_{2.5}$ and vice versa.

Table 5. Correlation matrix of Air Contaminants.

Contaminants	NO_2	SO_2	H_2S	CO	CO_2	$PM_{2.5}$
NO_2	1.000					
SO_2	0.678^c	1.000				
H_2S	0.655^c	0.282	1.000			
CO	0.842^a	0.724^b	0.555c	1.000		
CO_2	0.289	-0.018	0.661c	0.039	1.000	
$PM_{2.5}$	-0.619^c	-0.767^b	0.040	-0.683^c	0.128	1.000

a = Significant at $p < 0.01$; b = Significant at $P < 0.10$; c = Significant at $p < 0.20$

Sulphur (IV) oxide (SO_2) showed a strong and positive correlation with CO at 90 % confidence (r = 0.724).SO_2 correlated significantly but negatively with $PM_{2.5}$ at 90 % with r value of -0.767. Hydrogen sulfide (H_2S) correlated significantly and positively with CO and CO_2 at 80 % confidence with r values of 0.555 and 0.661, respectively. Carbon (II) oxide (CO) correlated negatively and significantly with $PM_{2.5}$ at 80 % confidence with r value of -0.683. Accordingly, all the air contaminants with significant positive correlations might have been directly proportional to the concentration of one another and vice versa. Hence, a source for any of the contaminants in a positive and significant relationship with another may also elevate the level of the other one [51, 52].

Principal component analysis

The results of principal components analysis (PCA) of air contaminants at the point sources examined are shown in Table 6. Results obtained revealed that, two factors were responsible for the buildup of these contaminants at the studied locations. These factors have 85.3 as the cumulative percentage of variance. Factor one (PC1) had Eigen value of 3.46 and contributed 57.6 % of the entire variance. As indicated in **Table 6**, PC1 has strong positive loadings on NO_2, SO_2, H_2S, and CO.

Table 6. Results of PCA of air contaminants in the studied point sources

Air contaminants	PC1	PC2
NO_2	0.936	0.112
SO_2	0.836	-0.332
H_2S	0.634	0.711
CO	0.923	-0.111
CO_2	0.251	0.865
$PM_{2.5}$	-0.751	0.521
Eigen value	3.46	1.66
% total variance	57.6	27.7
Cumulative %	57.6	85.3

It also had a moderate positive loading on CO_2 which is like the results obtained from the correlation analysis. This could be attributed to the negative effects of burning of petroleum products by vehicles [53, 54]. The second factor (PC2) with Eigen value of 1.66, added 27.7 % of the total variance. PC2 had significant positive loadings on H_2S, CO_2, and $PM_{2.5}$ (Table 6). This could be the impacts of vehicular emissions, construction activities, and decay of biodegradable wastes [55, 56].

Cluster analysis

Cluster analysis was employed to determine the relationships among the various point sources investigated [23, 51]. Results of the Hierarchical cluster analysis (HCA) of the air contaminants are demonstrated in **Fig. 1**.

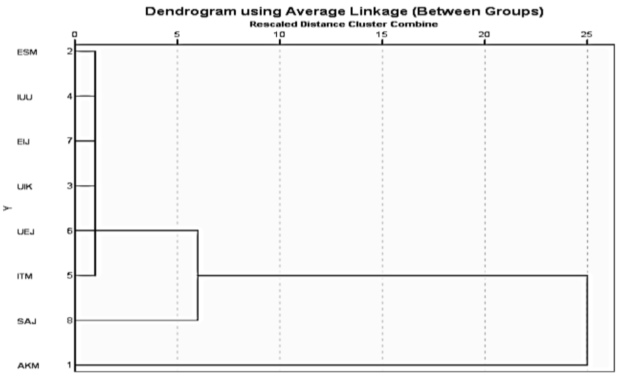

Fig. 1. Hierarchical clusters analysis of the point sources examined.

The results revealed three major clusters, the first one showed a strong relationship among locations ESM, IUU, EIJ, UIK, and ITM. The second cluster connects SAJ alone, while the third one links AKM only. Consequently, members of the first cluster may have experienced similar levels of common air contaminants, while the second and third clusters have contaminants different from each other and different from the ones in cluster one. The results of Hierarchical cluster analysis (HCA) of air contaminants at the studied locations are shown in **Fig. 2**.

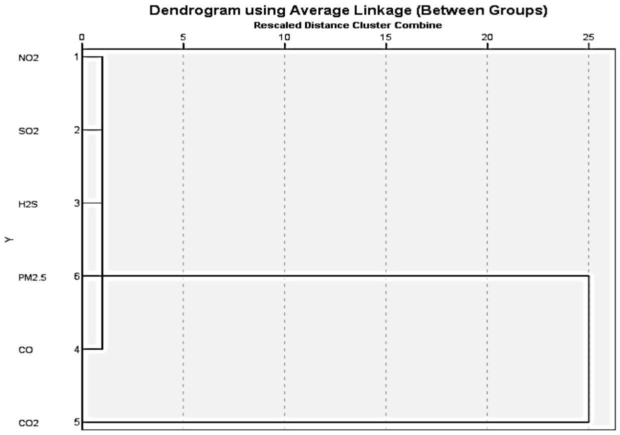

Fig. 2. Hierarchical clusters analysis of the point sources examined.

The HCA results indicated two major clusters. The first cluster showed strong relationships among NO_2, SO_2, H_2S, $PM_{2.5}$, and CO at the studied locations. This corroborates the results of both correlation and principal component analyses. The second cluster connects carbon (IV) oxide (CO_2) alone. This HCA corroborates the common relationships among NO_2, SO_2, H_2S, $PM_{2.5}$, and CO as indicated by PC1 in PCA. Thus, these air contaminants could have originated from common sources at the locations investigated [57, 58].

Conclusions

The study on the impacts of tricycles on the air pollution status of Uyo urban revealed that, this means of road transportation can contribute significant air contaminants into the environment. The results also revealed that, the mean concentrations of NO_2, SO_2, H_2S, CO, and $PM_{2.5}$ were higher than their recommended safe limits; hence, can impact negatively on those exposed to them over time. The mean concentration of CO_2 was within the acceptable limit; however, the level obtained at Akpanandem Market (AKM) was higher than the safe limit. Consequently, prolonged exposure to the reported level of CO_2 at the market by human might be risky. The outcome of the study revealed that, green plants have the potentials of reducing high loads of contaminants in the air environment effectively. Air quality index analysis of the parameters indicated that, most of the air contaminants determined could be harmful to human health. Principal component analysis confirmed the significant contributions of tricycle to air pollution status of Uyo urban. Consequently, the contributions of tricycles to the pollution status of the environment should be closely monitored. The study has revealed that, tricycles that are poorly maintained should be eliminated from the roads to reduce the level of contaminant in the air. The cultivation of green plants adjacent to roadsides is highly encouraged to reduce the rate of air pollution. Investigating the other sources of these air pollutants if any within the study area is subsequent study is highly recommended.

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Author's Contribution Statement

G. A. Ebong: Conceptualization, Sample collection, Data interpretation and analysis, writing: original draft and reviewing; **H. S. Etuk**: Resources, Supervision, Writing: reviewing and editing; **I. S. Ambrose:** Data collection, Data interpretation, analysis, and Writing: editing.

Conflict of Interest

The authors do not have any conflict of interest throughout this research work.

Data Availability Statement

The data supporting this study's findings are available from the corresponding authors upon reasonable request.

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