Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454

Vol. 20 | No. 5 (Suppl) | pp. 1903-1913 | 2021

Original Research Paper

https://doi.org/10.46488/NEPT.2021.v20i05.006

Open Access Journal

Characterization and Assessment of Stormwater Runoff Quality from Automobile Workshops in Nigeria Using Multivariate Linear Regression

C.O. Ataguba† and I. C. Brink
Department of Civil Engineering, Stellenbosch University, Stellenbosch, South Africa
†Corresponding author. C.O. Ataguba; clematrix2008@gmail.com

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 18-02-2021
Revised: 25-04-2021
Accepted: 03-05-2021

Key Words:
Automobile workshop
Electrical conductivity
Heavy metals
Multivariate regression
Stormwater runoff

ABSTRACT

An investigation into the pollution of stormwater runoff from automobile workshops in Nigeria was performed. Also, multivariate regression was used to predict the pH, oil, and grease (O&G) as well as the electrical conductivity (EC) in relation to the characteristics of the solids and metals pollutants of the untreated automobile workshop stormwater. The results indicated that automobile workshops contributed notable amounts of pollutants to stormwater runoff. Results were compared with Nigerian and USEPA standards. It was found that most of the parameters had mean value ranges far greater than standard limits. The multivariate regression showed variations in the results obtained from different automobile workshops. These variations could be due to the influence of factors such as the volume of automobile servicing activities and the waste generated from these activities that flow in the stormwater runoff. However, the bulk of the EC and pH of the stormwater were associated with the concentrations of the total dissolved solids and copper while the bulk of the O&G concentration was associated with the concentrations of lead and cadmium. It is recommended to treat automobile workshop stormwater to prevent detrimental effects in aquatic systems. Future research is aimed at modeling such treatment using multivariate regression techniques is warranted.

INTRODUCTION

Economic activities in Nigerian urbanized areas have been identified as non-point sources of pollution in natural water bodies (Ohwo & Abotutu 2015). Automobile workshops are included in such activities and generate, *inter alia*, debris, waste, oils, and greases that are conveyed, untreated, via stormwater drainage systems to natural water bodies. This contributes to the high degree of surface water pollution (Chukwu 2017). This stormwater runoff pollution source has received little attention to date.

Because the types and magnitudes of pollutants produced by automobile workshops are unpredictable, it is difficult to predict the quality of runoff water from these workshops. Automobile workshops and the pollution they generate are distinct from typical diffuse urban pollutant sources due to the activities of the host, requiring a case-specific approach. Additionally, automobile workshops are typically spatially dispersed in the study towns making a centralized treatment system impractical; and funding opportunities for stormwater quality improvement applications in these cases are limited.

Dealing with polluted stormwater runoff and implementing adequate treatment measures, necessitates novel approaches influenced by the nature of the pollutants, their sources (automotive workshops), and the lack of funds for water quality improvement in developing countries. Due to difficulties in dealing with the problem, stormwater runoff is a major source of pollutant mass flows to rivers, which poses a risk to the health of human beings, plants, and animals (Gaffield et al. 2003).

In metropolitan regions, the mechanic village option is characterized by higher levels of pollution. (Nwachukwu et al. 2014). Adewoyin et al. (2013) studied the impacts of auto-mechanic workshops on soil and groundwater in Ibadan, Nigeria. The study revealed the presence of Cadmium, Lead, and Iron in high concentrations. Additionally, water quality analyses showed high values of oil and grease concentration. Demie (2015) studied the level of contamination by metals on soils in some selected auto-mechanical workshops in Shashemane, Ethiopia with the aim of comparing results with existing standards and to determine the effects on human beings and surroundings. The results showed that the overall contamination of soils within the selected study areas was very high for Lead, Nickel, Cadmium, and Cobalt. The need for remedial action to reclaim these areas was emphasized. Similarly, Abidemi (2011), collected soil samples from auto-repair workshops in Osun State, Nigeria to determine the levels of Cobalt, Iron, Lead, and Cadmium on the soil of the auto-repair workshop. The results revealed that the soils in the auto repair workshops were heavily polluted with Iron and

Lead. The study recommended the use of Phytoremediation to remove these metals from the soil. It is therefore apparent that automobile workshops and maintenance centers in developing countries, besides being haphazardly placed, lack waste management and stormwater treatment facilities culminating in environmental pollution (Udebuani et al. 2011).

Documented studies, therefore, show automobile workshops to be a significant source of pollutants metals, oil, and grease. These pollutants are washed off via surface water runoff during rain events and discharged into natural water bodies. This can cause significant harm to the natural environment and pollute human water sources. However, limited literature is available on the profile of pollutants from stormwater runoff from automobile workshops in Nigeria.

Multivariate linear regression is a statistical technique that attempts to predict the relationship/association between two or more explanatory (predictor) variables and response (criterion) variables by fitting a linear equation to observed data (Alexopoulos 2010). Literature has reported the wide application of multivariate statistical techniques in water quality assessment, treatment, and modeling ranging from surface water to groundwater (Arora & Reddy 2013, Charulatha et al. 2017, Kazi et al. 2009, Saleem et al. 2012, Zhao & Cui 2009, Liu et al. 2018). Charulatha et al. (2017) reported the usefulness of multivariate statistical techniques for linear correlations where multiple variables of groundwater pH, TDS, nitrate, sodium, chloride, silicate, and fluoride were used as predictor variables to obtain the criterion variable nitrite ion in a linear regression model. Multivariate regression models predicted the electrical conductivity of surface water very well at a 5% significance level from a study carried out by Saleem et al. (2012).

The aims of this study were: (1) to characterize the untreated stormwater runoff from selected automobile workshops in Nigeria to identify the concentration/profile of selected pollutants and (2) to use the multivariate linear regression to predict the pH, oil, and grease as well as the electrical conductivity in relation to the characteristics of the solids and metals pollutants of the untreated automobile workshop stormwater samples.

MATERIALS AND METHODS

Data were obtained from the towns of Idah and Lokoja, both in the Guinea Savanna of North Central Nigeria. Idah is located at 7°05’0” N, 6°45’0” E with a total land area of 36 km^2 while Lokoja is located at 7°48’32” N, 6°44’15” E with a total land area of 64 km^2. The average annual rainfall in the Guinea Savanna is between 1000 and 1200 mm (Salami et al. 2015, Adeoye 2012). Idah is located at the bank of River Niger and Lokoja is located at the confluence of Rivers Niger and Benue in Nigeria. Three (3) automobile workshops were selected for research from Idah and two (2) automobile workshops from Lokoja as given in Table 1. Fig. 1 shows the locations of the study towns from Google Map.

Site inspection revealed that the automobile workshops lacked formal stormwater conveyance systems. The characteristic stormwater runoff was sheet flow. Stormwater

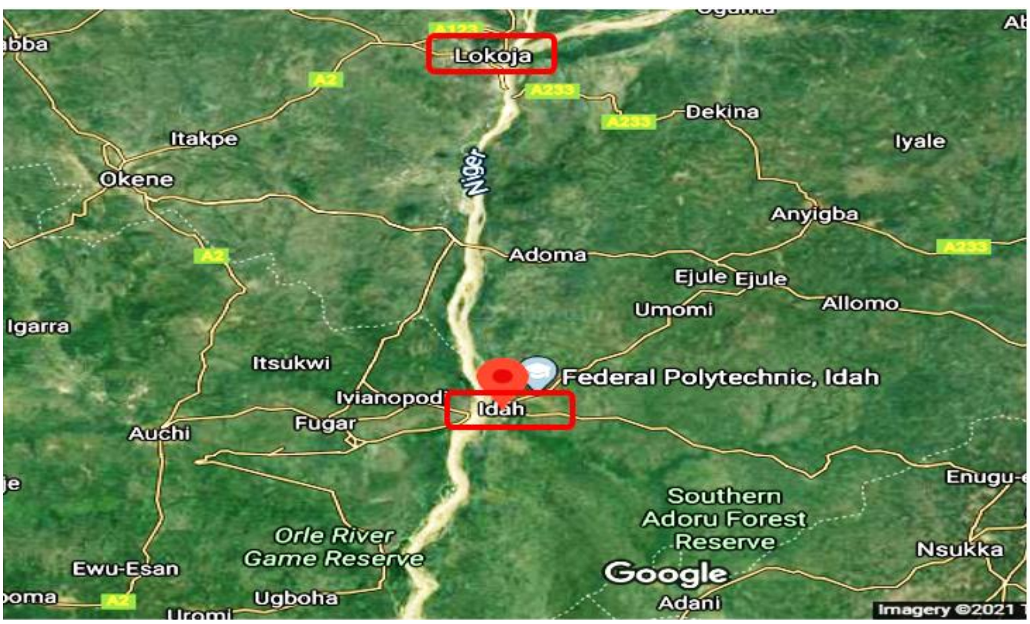

Fig. 1: Satellite imagery of the study areas (Source: Google Map 2021).

Table 1: Automobile Workshops.

Label	Location	Approximate Area (m^2)
Workshop 01	Idah	1 600
Workshop 02	Idah	1 800
Workshop 03	Idah	1600
Workshop 04	Lokoja	3 600
Workshop 05	Lokoja	2 400

catch-pits were constructed at low points on the workshop premises for the collection of runoff samples. The methodology described in Lowe et al. (2018) was adopted for the collection of the stormwater runoff samples. Sampling involved the collection of stormwater runoff samples from each automobile workshop and water quality tests carried out on weekly basis for a period of nine weeks during the rainy season. Samples were collected in clean laboratory sampling bottles of one and half (1.5 L) Liters capacity for laboratory water quality testing. The following water quality parameters were tested for pH, Conductivity, Turbidity, Oil and Grease, Dissolved Oxygen, Total Dissolved Solids, Total Solids, Total Suspended Solids, Cadmium, Copper, Lead and Iron. Tests were carried out in accordance with APHA (2017) Method 1664B (USEPA 2010). Testing apparatus used: ICE 3000 Series AA spectrometer. All water quality analyses were performed by the Water Quality Control Laboratory at the National Geosciences Research Laboratories in Kaduna, Nigeria. The profile of the pollutants has been shown in Figs. 2-13. The results obtained from the characterization were used for the multivariate regression analyses.

In carrying out the multivariate regression analyses, three different pollutants concentrations namely: pH, electrical conductivity as well as oil & grease were selected as dependent variables while the solids and heavy metals (total dissolved solids, total suspended solids, cadmium, copper, lead, and iron) were used as the independent variables. The mathematical and statistical computations in this work were carried out using Microsoft Excel at 5% significance as described in Charulatha et al. (2017). The association between the dependent and independent variables was determined. The equation for the multivariate regression as adopted from Charulatha et al. 2017 is described in equation 1:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_m X_m + \varepsilon \quad \ldots(1)$$

Where,

Y represents the dependent variable,

$X_1 \ldots X_m$ = the several independent variables,

$\beta_o \ldots \beta_m$ = the regression coefficient

ε = the standard error from the analyses.

The contributions of each pollutant to the total variation in the measured independent variable concentration MR^2 for each of the automobile workshop was computed using equation 2

$$T_x(\%) = \frac{R^2(i)}{\sum MR^2} * 100 \quad \ldots(2)$$

Where

Tx = Contribution of the pollutant in question to the total variation in the measured independent variable concentration

$R^2(i)$ = coefficient of determination of the pollutant concentration under consideration

MR^2 = Multivariate coefficient of determination for all the pollutants concentration considered for each (automobile) workshop

The estimated multivariate regression equations relating EC, pH, and O&G with the studied pollutants of the solids and metals were derived for all 5 workshops by the authors. The details of the equations could not be included in this article because of limited space. However, interested readers can contact the corresponding author for further details.

RESULTS AND DISCUSSION

Automobile Workshop Stormwater Characterization

Water quality analysis results are presented in Figs. 2 to 13. The Nigerian Standards (NESREA 2011) and USEPA Standard (USEPA 1986, 1988) are also indicated. In this research, the authors have used the upper limits of the standards which serve as the threshold for a disposal to surface water, to compare with the tested parameters as depicted by the red and black dotted lines in Figs. 2- 13. pH values in all cases were highly alkaline (Fig. 2). It ranged from 11.36 (Workshop 03) to 13.95 (Workshop 02). pH values were in all cases higher than the Nigerian and USEPA effluent discharge standards of 6.5 – 8.5 (NESREA 2011, USEPA 1986). A possible cause of high pH may be waste incineration in the workshops. These values indicate that runoff from automobile workshops could be harmful to aquatic ecosystems. For example, fish species typically do not survive in water with a pH above 10 (Cole et al. 1999).

Electrical Conductivity (EC) ranged from 1078.76 µS.cm-1 (Workshop 02) to 4380.5 µS.cm-1 (Workshop 04) (Fig. 3). Workshops 01-03 (Idah) had notably lower values than Workshops 04-05 (Lokoja). However, all values obtained were higher than both the Nigerian and USEPA approved standards range of 200-1000 µS.cm^{-1} (NESREA 2011, USEPA 1986). Reasons for differences in the values for different locations could not be determined. Discharging water with very high conductivity into surface water has been reported as harmful to aquatic animals (et al. 2017).

Turbidity ranged from 302 NTU (Workshop 04 and 05) to 444 NTU (Workshop 02) as shown in Fig. 4. Workshops 01-03 (Idah) typically had higher turbidities than Workshops 04-05 (Lokoja). All values obtained were notably higher than the Nigerian approved standard of 70 NTU and USEPA approved standard of 50 NTU (NESREA 2011, USEPA 1986). It is posited that bare earth platforms used in Workshops 01 – 03 may have been the cause of differences in turbidity values between the different locations (Workshops 04 – 05 had concrete platforms). Stormwater discharge with high turbidity is detrimental to aquatic ecosystems such as reducing the amount of light available for photosynthesis of aquatic plants which some aquatic animals consume and increasing the temperature of water (Boyd 2015) among other effects.

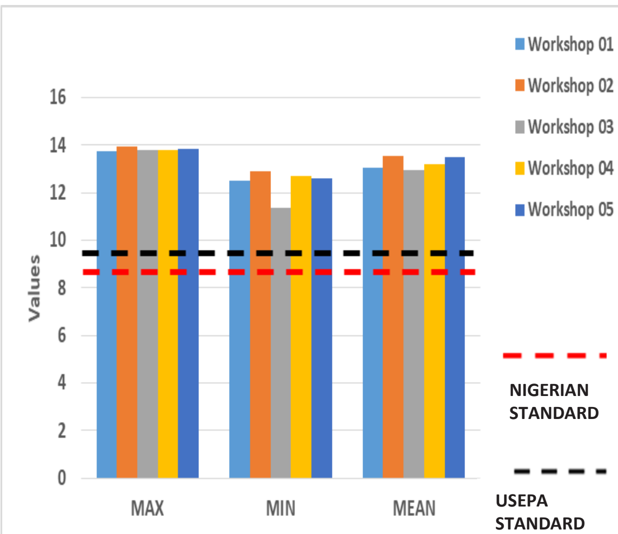

Fig. 2. pH values.

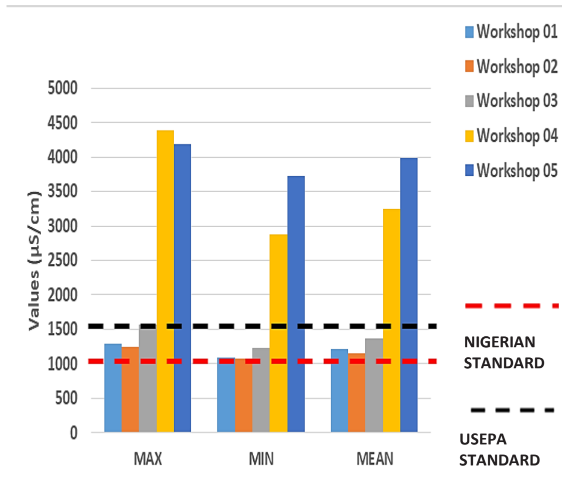

Fig. 3. Electrical conductivity values.

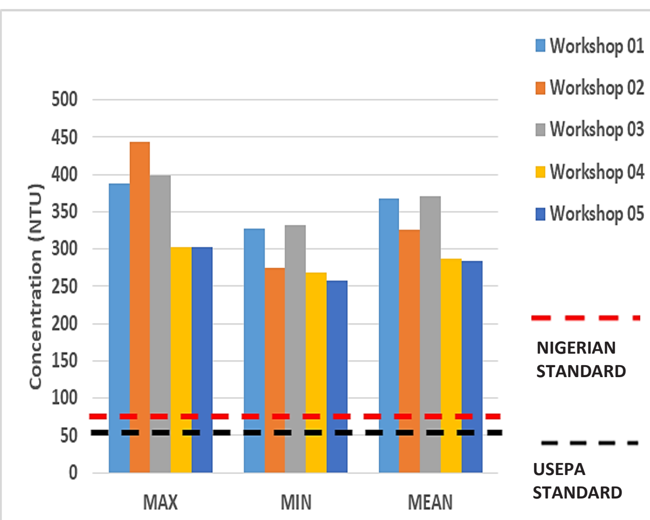

Fig. 4. Turbidity concentration.

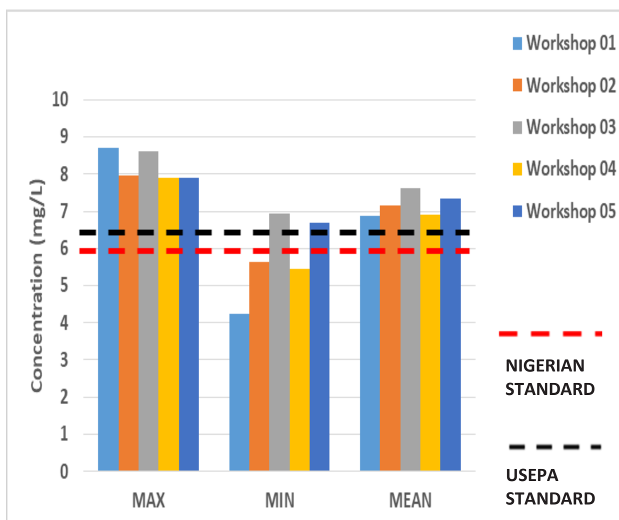

Fig. 5. Dissolved oxygen concentration.

Dissolved Oxygen (DO) ranged from 4.24 mg.L^{-1} (Workshop 01) to 8.7 mg.L^{-1} (also Workshop 01). The mean dissolved oxygen values obtained from Workshops 01-05 ranged between 6.8 and 7.62 mg.L^{-1} (Fig. 5). The values were within acceptable Nigerian and USEPA approved standards of 6.0 mg.L^{-1} and 6.5 mg.L^{-1} minimum respectively (NESREA 2011, USEPA 1986) as values higher than the minimum standards are practically desired (USEPA 1988). Dissolved oxygen is important for respiration by aquatic species (Droste and Gehr 2019).

Total dissolved solids concentrations (TDS) ranged from 936 mg.L^{-1} (Workshop 02) to 3041 mg.L^{-1}(Workshop 05) (Fig. 6). Mean values ranged between 832 and 2774 mg.L^{-1}. Results varied between locations with TDS from Workshops 01-03 (Idah) mostly close to or below the Nigerian limits of 1000-2000 mg/L (NESREA 2011) and USEPA limits of 1000 mg.L^{-1}, and TDS from Workshops 04-05 (Lokoja) above USEPA limits in all cases and Nigerian limits in some cases. Similar trends were observed in the EC results as can be expected due to the capacity of the water sample to conduct electricity being principally dependent on the concentration of dissolved ions (Taylor et al. 2018). Specific reasons for differences in results from the different locations could not be determined. Discharging stormwater with elevated TDS into surface waters inhibits the growth and development of aquatic animals/organisms (Weber-Scannel & Duffy 2007).

Total suspended solids concentrations (TSS) ranged between 465 mg.L^{-1} (Workshop 04) and 2984 mg.L^{-1}(also Workshop 04) (Fig. 7). Mean TSS ranged between 1588 and 2504 mg.L^{-1}. All values in all cases were higher than Nigeria's discharge limit of 500 mg.L^{-1} and USEPA discharge limit of 100 mg.L^{-1} (NESREA 2011, USEPA 1986). This result is unsurprising and can be explained by the generation of particles through typical automobile workshop activities (grinding, welding, the addition of dirt brought on car tire surfaces, etc.). Discharging stormwater with a high concentration of TSS can affect water clarity with a host of subsequent detrimental effects on aquatic ecosystems (Boyd 2015).

Total solids result from different waste materials generated in the automobile workshops and carried in the runoff stream as solids, liquids, or particles. This study recorded the highest total solids value of 6668 mg/L from Workshop 02. The lowest total solids value of 1336 mg.L^{-1} was obtained from Workshop 01. Mean TS ranged between 2577 and 5278 mg.L^{-1}(Fig. 8). The maximum TS concentrations were higher than the Nigerian maximum limit of 2500 mg.L^{-1} and USEPA maximum limit of 1100 mg.L^{-1} (NESREA 2011, USEPA 1986).

Oil and Grease ranged between 3.2 mg.L^{-1} (Workshop 01) and 6.9 mg.L^{-1} (Workshop 02). The mean values are between 5.1 and 6.2 mg.L^{-1} (Fig. 9). The narrow range of mean concentrations is interesting and could indicate a typical concentration of this parameter to be expected from Automobile Workshops. This indicates that future research into this possibility is warranted. All concentrations were significantly higher than Nigeria and USEPA approved standard of 0.1 mg.L^{-1} (NESREA 2011, USEPA 1986). Vehicle servicing activities are indicated as the main contributor of oil and grease in stormwater runoff. Spillage of oil from the change of engine oil in these workshops was observed to be minimal as onsite used oil management involved the collection of used oils from the vehicle engines directly into

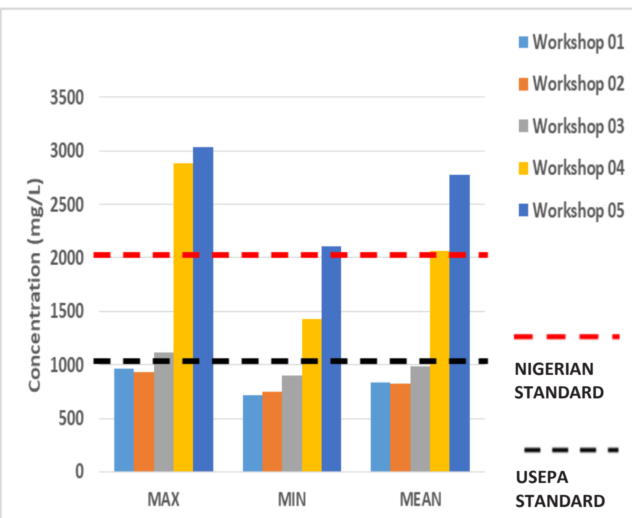

Fig. 6. Total Dissolved Solids concentration.

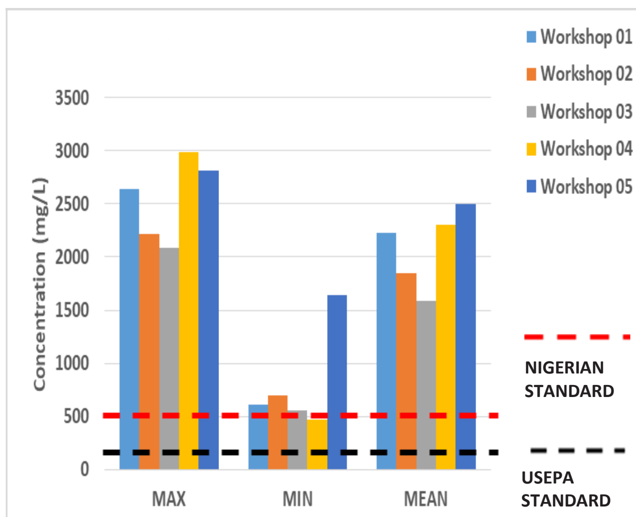

Fig. 7. Total Suspended Solids concentration.

plastic gallons, which are stored and sold for some other uses such as preservatives, for wood seasoning, etc. Much of the oil spillage resulted from the cleaning of oil/grease parts with premium motor spirit (PMS). High oil and grease concentration in surface waters can cause damage to plants and animals in the aquatic ecosystem (Khwakarami 2016).

A range of metal particles is generated in Automobile Workshops. Scraps of vehicle parts, mechanic tools, auto-electrical parts/activities, wear from vehicle tires, etc. are major sources of metals that can easily be transported in any stormwater runoff from an automobile workshop. A possible major source of Lead and Cadmium Automobile Workshops is car battery discharge. (Utang et al. 2013) Fuel in Nigeria (Premium Motor Spirit or PMS) is unleaded and is therefore not a probable source of Lead. Welding and bodywork activities as well as vehicle engine fixing are major sources of Iron Oxide particles (Abidemi 2011, Utang et al. 2013). Electrical activities, metal bushings, and metal-bearing wears are major sources of Copper and Iron (Mohammed & Naik 2011).

Metals concentrations as shown in Figs. 10-13 indicated a trend similar to the work of Prestes et al. (2006) in some cases. The mean concentrations of Lead, Copper, and Cadmium in the stormwater runoff were in the order *Pb>Cu>Cd* for Workshops 01, 03, and 04. Minimum concentrations were, Method Detection Limit (MDL) of 0.005 mg.L^{-1} for Lead; 0.00044 mg.L^{-1} for Cadmium (Workshop 03, Zhong et al. 2016, Golbedaghi et al. 2012) and 0.01 mg.L^{-1} for Copper (Workshop 02). Maximum concentrations were 1.91 mg.L^{-1} for Lead (Workshop 04), 0.062 mg.L^{-1} for Cadmium (Workshop 05) and 0.06 mg.L^{-1} for Copper (Workshops 03 and 05). The mean Copper and Cadmium concentrations from all Workshops ranged between 0.014-0.040 mg.L^{-1}. These were higher than Nigerian and USEPA limits of 0.01 mg.L^{-1} and 0.02 mg.L^{-1} for Copper and Cadmium respectively (NESREA 2011, USEPA 1986). The mean Lead concentrations ranged between 0.30-1.33 mg.L^{-1}. These were also higher than the Nigerian and USEPA limits of 0.1 mg.L^{-1}(NESREA 2011, USEPA 1986).

For Iron, concentrations ranged between 25.4 mg.L^{-1} (Workshop 03) and 43.6 mg.L^{-1} (Workshop 01). Mean values ranged between 32.7-38.0 mg.L^{-1}. The mean values obtained for the iron concentration were higher than Nigerian and USEPA limits of 0.5 mg.L^{-1} and 1 mg.L^{-1} respectively (NESREA 2011, USEPA 1986). It is notable that the Iron concentrations were at least 30 times higher than the acceptable discharge limits (Fig. 13). Additionally, the narrow ranges in results indicate that further research into a typical runoff Iron concentration for Workshops is indicated.

Metals concentrations from different workshops were variable, with the exception of Iron. Cadmium in runoff from Workshop 05 was notably high when compared to other workshops, possibly due to more auto-electrical and welding works activities. Copper concentrations in runoff from Workshop 03 were generally higher than that of other workshops, possibly due to auto-electrical works. Workshops 01, 04, and 05 had higher concentrations of Lead when compared with Workshops 02 and 03, possibly due to the high level of auto-electrical repair/servicing activities generating this pollutant there. As noted above, Iron concentrations were similar for all workshops, possibly due to the high level of activities generating this pollutant in all the

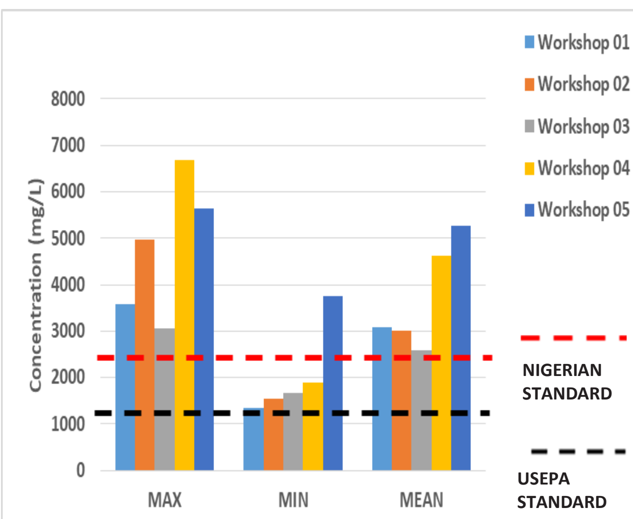

Fig. 8. Total Solids concentration.

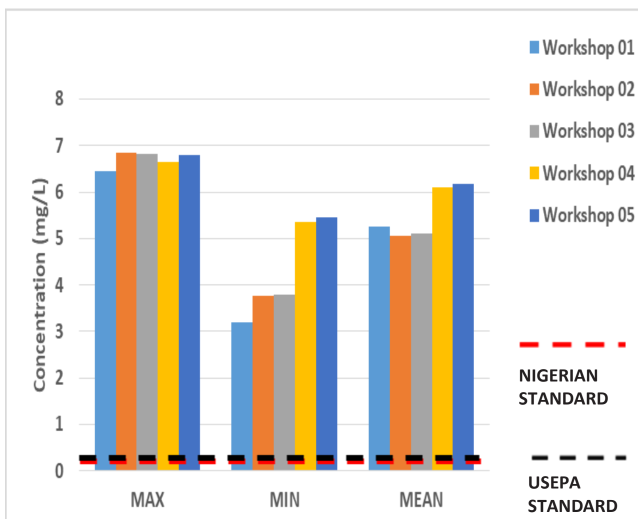

Fig. 9. Oil and Grease concentration.

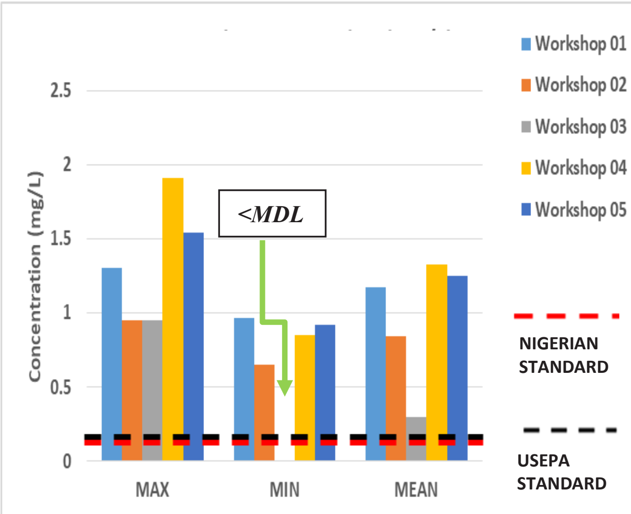

Fig. 10. Lead concentration.

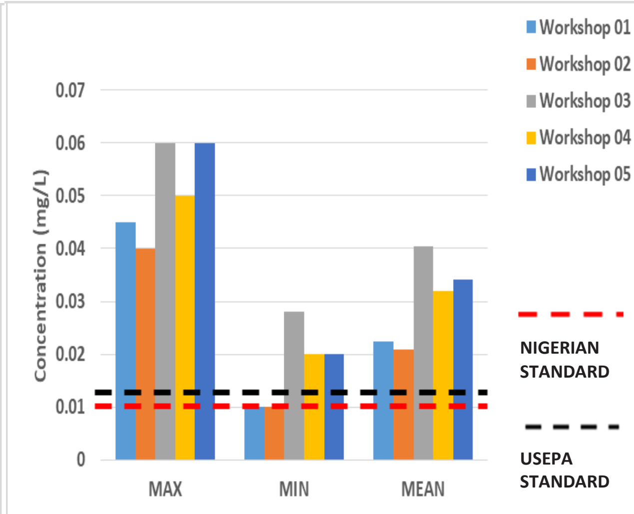

Fig. 11. Copper concentration.

workshops. Metals pollution in surface runoff causes poisoning of aquatic life, human organs, and the nervous system (Shah 2017).

Multivariate Regression Analyses

The results of the multivariate regression analyses showing the multivariate coefficient of correlation (MR), multivariate coefficient of determination (MR^2), and statistical F- values from the ANOVA test have been presented in Tables 2-4. These analyses have investigated the associations/relationships of the EC, pH, and O&G concentrations with metals and solids concentrations in raw automobile workshop stormwater characteristics.

Electrical Conductivity (EC) vs the Solids and the Metals

From Table 2, the untreated stormwater from workshops 1-4 exhibited very strong R^2 ranging from 0.949 to 0.992 for electrical conductivity vs total dissolved solids with an average overall multivariate R^2 = 0.998. Similarly, untreated stormwater from workshops 1-3 exhibited strong-very strong positive R^2 ranging from 0.686-0.917 for electrical conductivity vs copper concentration. It was observed that an increase in the concentration of copper and total dissolved solids was positively associated with an increase in the electrical conductivity of the untreated stormwater samples from workshops 01-05 as identified above.

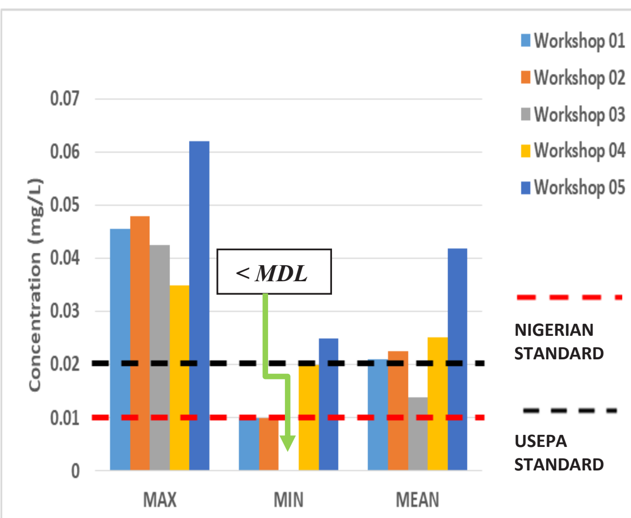

Fig. 12. Cadmium concentration.

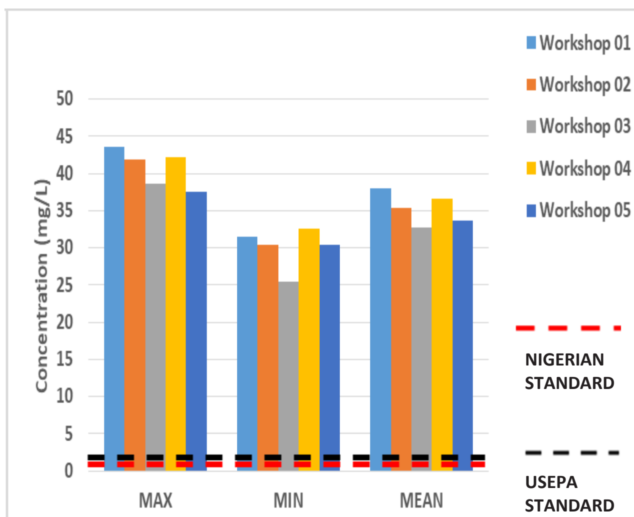

Fig. 13. Iron concentration.

Workshops 02 and 03 exhibited strong R^2 (0.670 and 0.766) for electrical conductivity vs lead concentration from untreated stormwater samples. Strong R^2 values of 0.686, 0.67, and 0.642 were obtained for EC vs Cu concentration, EC vs Pb concentration, and EC vs Fe concentration respectively from untreated stormwater from workshop 03 while EC vs Cd from untreated stormwater from Workshop 02 produced $R^2 = 0.606$.

The relationships between EC and the other parameters produced a fairly strong R^2 with $0.5 \leq R^2 \leq 0.599$: EC vs TSS from Workshops 03 and 04; EC vs Cd from Workshops 01 and 03; as well as EC vs Pb from Workshop 05. Similarly, the relationships between EC and the other parameters produced weak R^2 with $0.3 \leq R^2 \leq 0.499$: EC vs TSS from Workshop 02; EC vs Cd from Workshops 04 and 05; EC vs Pb from Workshop 01; as well as EC vs Fe from Workshops 01, 02 and 05. It was also observed that very week R^2 values were obtained from the relationships between EC and other parameters with $0.001 \leq R^2 \leq 0.299$: EC vs TDS from Workshop 05, EC vs TSS from Workshops 01 and 05, EC vs Fe from Workshop 04, EC vs Cu from Workshops 01 and 02 as well as EC vs Pb from workshop 04.

From the overall analyses for the electrical conductivity of the untreated stormwater from Workshops, EC concentrations from Workshops 01-05 exhibited a very strong association/relationship with TDS, TSS, Cd, Cu, Pb, and Fe (R^2 ranging from 0.991 to 0.999) with multiple correlation R = 0.995 to 0.999.

From Table 5, an EC prediction with a multivariate R^2 value of 0.999 in Workshop 01, which represented 99.9% variation in the measured EC, could be attributed to the combined effect of TDS, TSS, Cd, Cu, Pb, and Fe concentrations in the following proportion 37.74%, 0.71%, 20.68%, 10.69%, 16.0%, and 16.08% respectively as determined from equation 2. The same principle was applied to all the Workshops (Table 5) for the prediction of EC concentration in relation to the mentioned pollutants.

The association/relationship between EC and TDS with an average R^2 of 0.802 is similar when compared with the research carried out by Noori et al. (2010). These researchers used the canonical correlation analysis and reported that the association between EC and TDS was dominantly very strong with R^2 values of 0.993 and 0.822.

pH vs the Solids and the Metals

Considering the overall analyses for the pH of the untreated stormwater from the automobile workshops, pH concentration from workshop 03 exhibited a very strong association/relationship with Fe ($R^2 = 0.909$) with multiple correlation R = 0.830. Similarly, the pH concentration from workshops

Table 2: R^2 from multivariate regression analyses of electrical conductivity with respect to solids and metals pollutants.

Automobile Workshop	EC vs TDS	EC vs TSS	EC vs Cd	EC vs Cu	EC vs Pb	EC vs Fe	Remarks
01	0.956	0.019	0.553	0.286	0.428	0.43	MR = 0.999, MR^2 = 0.999, F = 7671
02	0.949	0.319	0.606	0.294	0.766	0.433	MR = 0.999, MR^2= 0.999, F = 10728
03	0.992	0.589	0.598	0.686	0.67	0.642	MR = 0.999, MR^2= 0.997, F = 116
04	0.957	0.536	0.309	0.899	0.253	0.02	MR = 0.999, MR^2= 0.997, F = 123.73
05	0.158	0.001	0.406	0.917	0.52	0.487	MR = 0.995, MR^2= 0.991, F = 35.686

Table 3: R^2 from multivariate regression analyses of pH with respect to solids and metals pollutants.

Automobile Workshop	pH vs TDS	pH vs TSS	pH vs Cd	pH vs Cu	pH vs Pb	pH vs Fe	Remarks
01	0.096	0.079	0.1	0.554	0.11	0.015	MR = 0.843, MR^2= 0.711, F = 0.822
02	0.601	0.104	0.405	0.264	0.469	0.183	MR = 0.722, MR^2= 0.522, F = 0.364
03	0.744	0.371	0.392	0.473	0.45	0.909	MR = 0.830, MR^2= 0.689, F = 0.739
04	0.31	0.254	0.329	0.488	0.02	0.001	MR = 0.899, MR^2= 0.808, F = 1.405
05	0.211	0.005	0.018	0.334	0.09	0.024	MR = 0.903, MR^2= 0.815, F = 1.470

02 and 03 exhibited strong association/relationship with TDS (R^2 = 0.601 and 0.744 respectively). An increase in TDS and Fe concentrations resulted in an increase in the pH of the stormwater in the mentioned workshops. This implied that the alkalinity of the stormwater samples from workshops 02 and 03 increased with the concentration of the TDS and Fe concentrations. The relationship between the pH of the untreated stormwater and the other pollutants as shown in Table 3 revealed that fairly strong, weak, and very weak associations exist. From Table 6, a pH prediction with a multivariate R^2 value of 0.522 in automobile workshop 02, representing 52.2% variation in the measured pH, could also be attributed to the combined effect of TDS, TSS, Cd, Cu, Pb, and Fe concentrations in the following proportion 15.48%, 2.68%, 10.43%, 6.80%, 12.08%, and 4.72% respectively as computed from equation 2. The same principle was also applied to all the automobile workshops (Table 6) for the prediction of pH concentration in relation to the mentioned pollutants.

O&G vs the solids and the metals

The overall analyses for the O&G of the untreated stormwater from automobile workshops, (Table 4) have revealed that O&G concentration from automobile workshop 04 exhibited a very strong association/relationship with Pb ($R^2 = 0.912$) with multiple correlation R = 0.929. Table 4 also revealed that fairly strong, weak, and very weak relationships exist between the O&G concentration of untreated stormwater and the other pollutants. O&G prediction with a multivariate R^2 value of 0.695 in automobile workshop 05 shown in Table 7, represented 69.5% variation in the measured O&G concentration, could be attributed to the combined effect of TDS, TSS, Cd, Cu, Pb, and Fe concentrations in the following proportion: 0.20%, 7.60%, 18.55%, 12.44%, 9.03%, and 21.67% respectively as calculated from equation 2. The same procedure was also used for all the workshops (Table 7) for the prediction of O&G concentration in relation to the pollutants mentioned above.

The results have also revealed a dominantly weak association/relationship between O&G and TSS with an average R^2 of 0.113 from automobile workshops 1-5.

This study has shown that there is a strong association between the electrical conductivity of the automobile workshop stormwater and the total dissolved solids contained in the water sample. This trend was also reported in Saleem et al (2012) from a study where EC concentration exhibited a strong significant and positive relationship with Cl^-, $HCO3^-$, $Mg2^+$ and TS with an R^2 value of 0.804. This phenomenon could mean that bulk of the electrical conductivity of the stormwater is associated with the concentrations of the total dissolved solids and copper (mean values of 25% and 20.5% respectively) from Table 5. Similarly, from Table 6 the bulk of the pH of the stormwater is associated with the concentrations of copper and the total dissolved solids (mean values

Table 4: R^2 from multivariate regression analyses of O&G with respect to solids and metals pollutants.

Automobile Workshop	O&G vs TDS	O&G vs TSS	O&G vs Cd	O&G vs Cu	O&G vs Pb	O&G vs Fe	Remarks
01	0.096	0.185	0.469	0.028	0.438	0.501	MR = 0.980, MR^2 = 0.960, F = 8.025
02	0.391	0.092	0.149	0.00009	0.481	0.215	MR = 0.984, MR^2 = 0.967, F = 9.863
03	0.128	0.021	0.381	0.32	0.362	0.00004	MR = 0.983, MR^2 = 0.966, F = 9.473
04	0.358	0.0004	0.041	0.216	0.912	0.046	MR = 0.929, MR^2 = 0.863, F = 2.097
05	0.007	0.266	0.649	0.435	0.316	0.758	MR = 0.934, MR^2 = 0.695, F = 0.759

Table 5: Proportion of R^2(%) for EC relationship with each pollutant making up the overall multivariate R^2 for each automobile workshop.

Automobile Workshop	EC vs TDS (%)	EC vs TSS (%)	EC vs Cd (%)	EC vs Cu (%)	EC vs Pb (%)	EC vs Fe (%)	Multivariate R^2(%)
01	35.74	0.71	20.68	10.69	16.00	16.08	99.9
02	28.16	9.46	17.98	8.72	22.73	12.85	99.9
03	23.68	14.06	14.27	16.37	15.99	15.32	99.7
04	32.08	17.97	10.36	30.14	8.48	0.67	99.7
05	6.29	0.04	16.16	36.51	20.70	19.39	99.1

Table 6: Proportion of R^2(%) for pH relationship with each pollutant making up the overall multivariate R^2 for each automobile workshop.

Automobile Workshop	pH vs TDS (%)	pH vs TSS (%)	pH vs Cd (%)	pH vs Cu (%)	pH vs Pb (%)	pH vs Fe (%)	Multivariate R^2(%)
01	7.15	5.89	7.45	41.29	8.20	1.12	71.1
02	15.48	2.68	10.43	6.80	12.08	4.72	52.2
03	15.35	7.66	8.09	9.76	9.29	18.76	68.9
04	17.87	14.64	18.96	28.12	1.15	0.06	80.8
05	25.21	0.60	2.15	39.91	10.76	2.87	81.5

Table 7: Proportion of R^2(%) for O&G relationship with each pollutant making up the overall multivariate R^2 for each automobile workshop.

Automobile Workshop	O&G vs TDS (%)	O&G vs TSS (%)	O&G vs Cd (%)	O&G vs Cu (%)	O&G vs Pb (%)	O&G vs Fe (%)	Multivariate R^2(%)
01	5.37	10.34	26.22	1.57	24.49	28.01	96.00
02	28.47	6.70	10.85	0.01	35.02	15.66	96.71
03	10.20	1.67	30.37	25.50	28.85	0.00	96.60
04	19.64	0.02	2.25	11.85	50.04	2.52	86.32
05	0.20	7.60	18.55	12.44	9.03	21.67	69.50

of 25.2% and 16.2% respectively). However, the bulk of the O&G concentration (Table 7) of the automobile workshop stormwater is associated with the concentrations of lead and cadmium (mean values of 29.5% and 17.7% respectively).

CONCLUSION

Automobile workshop runoff was typically very alkaline (pH > 11) in all cases. EC was greater than 1000 µS/cm, Turbidity was greater than 300 NTU, TSS was greater than 465 $mg.L^{-1,}$ and Oil and Grease were higher than 3.2 $mg.L^{-1}$ in all cases. All these values were greater than both the Nigerian and USEPA discharge limits NESREA 2011; USEPA 1986). TDS concentrations were close to or below discharge limits for workshops located in Idah, and above limits for Workshops located in Lokoja. Reasons for these differences could not be determined. Cadmium, Lead, Copper, and Iron had mean values greater than discharge limits in all cases. Iron concentrations were notably more than 30 times higher than discharge limits.

Some parameters had narrow ranges despite being tested in different locations and even different towns. For example, the narrow range of mean Oil and Grease as well as Iron concentrations is interesting and could indicate a typical concentration of this parameter to be expected from Automobile Workshops.

The multivariate analyses of the concentration of the pollutants using regression analyses enabled the identification of contributions of these pollutants in the overall stormwater quality from the selected automobile workshops. The study has revealed that while the association/relationship between EC and TDS was dominantly the strongest, the association/relationship between O&G and TSS was dominantly the weakest from all the automobile workshops. It is possible that the influence of certain factors such as the volume of automobile servicing activities as well as the waste generated from these activities that are carried in the stormwater runoff have affected variations in results obtained.

Automobile workshop runoff, therefore, has a great potential of harm to receiving aquatic ecosystems and even humans. It is therefore recommended that designs for onsite treatment of stormwater runoff from automobile workshops be implemented to reduce the concentration of pollutants before discharge into the receiving water. The need for future research into establishing typical runoff parameters or ranges for certain pollutants, to be used in future design, is warranted.

ACKNOWLEDGMENT

This research was funded by the Tertiary Education Trust Fund, Nigeria.

REFERENCES

Abidemi, O.O. 2011. Levels of Pb, Fe, Cd, and Co in soils of automobile workshops in Osun State, Nigeria. J. Appl. Sci. Environ. Manage., 15(2): 279-282.

Adeoye, N.O. 2012. Spatio-Temporal analysis of land use/cover change of Lokoja: A confluence town. J. Geogr. Geol., 4(4): 40-51.

Adewoyin, O.A., Hassan, A.T. and Aladesida, A.A. 2013. The impacts of auto-mechanic workshops on soil and groundwater in Ibadan metropolis. Afr. J. Environ. Sci. Technol., 7(9): 891-898.

Alexopoulos, E.C. 2010. Introduction to multivariate regression analysis. Hippokratia, 14(Suppl 1): 23-28.

APHA. 2017. Standard Methods for the Examination of Water and Wastewater. 23rd Edition. American Public Health Association, U.S.A.

Arora, A.S. and Reddy, A.S. 2013. Multivariate analysis for assessing the quality of stormwater from different urban surfaces of the Patiala city, Punjab (India). Urban Water J., 10 (6): 422-433.

Boyd, C.E. 2015. Water Quality: An Introduction. Second Edition. Springer International Publishing Switzerland. 357pp.

Charulatha, G., Srinivasalu S., Uma Maheswari, O., Venugopal, T. and Giridharan, L. 2017. Evaluation of groundwater quality contaminants using linear regression and artificial neural network models. Arab. J. Geosci., 10: 128.

Chukwu, K.E. 2017. Pollution of surface water resources in Nigeria. Int. J. Academic Res. Environ. Geogr., 4(1): 78-92.

Cole, S., Codling, I., Parr, W. and Zabel, T. 1999. Guidelines for Managing Water Quality Impacts within UK European Marine Sites. Water Research Council (WRC), Swindon, 441pp

Demie, G. 2015. Analyzing soil contamination status in garage and auto mechanical workshops of Shashemane City: implication for hazardous waste management. Environ. Systems Res., 4(15): 46-71.

Droste, R. and Gehr, R. 2019. Theory and Practice of Water and Wastewater Treatment. Second Edition. John Wiley, USA. 816pp.

Gaffield, S.J., Goo, R.L., Richards, L.A. and Jackson, R.J. 2003. Public health effects of inadequately managed stormwater runoff. Am. J. Public Health, 93(9): 1527-1533.

Golbedaghi, R., Jafari, S., Yaftian, M.R., Salehzadeh, S. and Jaleh, B. 2012. Determination of cadmium(II) ion by atomic absorption spectrometry after cloud point extraction. J. Iran Chem. Soc., 9: 251-256.

Google Map. 2021. Locational Map of Idah and Lokoja Towns in Nigeria. https://www.google.com/maps/search/Idah+and+Lokoja/@7.4380131,6.5431331,8.12z. (Accessed on 13th February 2021).

Imo, C.I., Nwakuba, N.R., Asoegwu, S.N. and Okereke, N.A.A. 2017. Impact of brewery effluents on surface water quality in Nigeria: A review. Chem. Res. J., 2: 101-113.

Kazi, T.G., Arain, M.B., Jamali, M.K., Jalbani, N., Afridi, H.I., Sarfraz, R.A., Baig, J.A. and Shah, A.Q. 2009. Assessment of water quality of polluted lake using multivariate statistical techniques: A case study. Ecotoxicol Environ. Safety, 72(2): 301-309.

Khwakarami, A.I. 2016. Effects of fat, oil, and grease discharge pollutants on water quality of Qalyasan Stream, Tanjero River and impact of fat, oil, and grease on Darbandikhan Reservoir in Sulaimani City-Kurdistan region of Iraq-Iraq. Inter. J. Environ. Eco. Family Urb. Studies, 6: 1-12.

Liu, Z., Joo, J.C., Choi, S.H., Heo, N., Jang, J. and Hur, J.W. 2018. Assessment of surface water quality in Geum River Basin, Korea using multivariate statistical techniques. Int. J. Appl. Eng. Res., 13(9): 6723-6732.

Lowe, J., Deleon, D., Collins, J., Hoover, R. and Book, S. 2018. Standard Operating Procedure for Collecting Grab Samples from Stormwater Discharges v1.1. Washington State Department of Ecology, Olypia,WA. 15p.PublicationNo. 18-10-023. https://fortress wa.gov/ecy/publications/summarypages/1810023.html.

Mohammed, S.A.S. and Naik, M. 2011. Utilization of red soils and amended soils as a liner material for attenuation of copper from aqueous solution: Isotherm and kinetic studies. J. Environ. Sci. Technol., 4: 504-519.

NESREA 2011. National Environmental (Surface and Ground Water Quality Control) Regulations. National Environmental Standards and Regulations Enforcement Agency. Federal Ministry of Environment. Federal Republic of Nigeria Official Gazette, 98(49).

Noori, R., Sabahi, M.S., Karbassi, A.R., Baghvand, A. and Zadeh, H.T. 2010. Multivariate statistical analysis of surface water quality based on correlations and variations in the data set. Desalination, 260(1-3): 129-136.

Nwachukwu, M.A., Umunna, N.A., Ntesat, B. and Umunna, C.P. 2014. Concept and design of environmentally friendly automobile mechanic village. J. Civil Environ. Eng., 4, 136.

Ohwo, O. and Abotutu, A. 2015. Environmental impact of urbanization in Nigeria. Current Journal of Appl. Sci. Technol., 9(3): 212-221.

Prestes, E.C., dos Anjos, V.E., Sodré, F.F. and Grassi, M.T. 2006. Copper, lead and cadmium loads and behavior in urban stormwater runoff in Curitiba, Brazil. J. Braz. Chem. Soc., 17(1): 53-60.

Salami, A.W., Mohammed, A.A., Adeyemo, J.A. and Olanlokun, O.K. 2015. Assessment of the impact of climate change on runoff in the Kainji lake basin using statistical methods. Int. J. Water Resour. Environ. Eng., 7(2): 7-16.

Saleem, A., Dandigi, M.N. and Vijaykumar K. 2012. Correlation-regression model for physico-chemical quality of groundwater in the South Indian city of Gulbarga. Afr. J. Environ. Sci. Technol., 6(9): 353-364.

Shah, A.I. 2017. Heavy metal impact on aquatic life and human health – An overview. In: Proceedings of the 37th Annual Conference of the International Association for Impact Assessment. 4-7 April 2017, Le Centre Sheraton, Montréal, Canada.

Taylor, M., Elliot, H.A. and Navitsky, L.O. 2018. Relationship between total dissolved solids and electrical conductivity in Marcellus hydraulic fracturing fluids. Water Sci. Technol., 77(8): 1998-2004.

Udebuani, A.C., Okoli, C.I., Nwaigwe, H. and Ozoh, P. 2011. Effect of spent engine oil pollution on arable soil of Nekede mechanic village Owerri, Imo State Nigeria. Int. J. Nat. Appl. Sci., 7: 257-260.

USEPA 2010. Method 1664, Revision B: n-Hexane Extractable Material (HEM; Oil and Grease) and Silica Gel Treated n-Hexane Extractable Material (SGT-HEM; Non-polar Material) by Extraction and Gravimetry. The United States Environmental Protection Agency, 35pp.

USEPA 1988. Dissolved Oxygen. Water Quality Standards Criteria Summaries: A compilation of State/Federal Criteria. The United States Environmental Protection Agency Office of Water Regulations and Standards, Washington DC 20460. Report No. 460/5-88-024.

USEPA 1986. Quality Criteria for Water. The United States Environmental Protection Agency Office of Water Regulations and Standards, Washington DC 20460. Report No. 440/5-86-001.

Utang, P., Eludoyin, O. and Ijekeye, C. 2013. Impacts of automobile workshops on heavy metals concentrations of urban soils in Obio/Akpor LGA, Rivers State, Nigeria. Afr. J. Agric. Res., 8: 3476 – 3482. http://dx.doi.org /10.5897/AJAR2013.6753.

Weber-Scannell, P.K. and Duffy, L.K. 2007. Effects of total dissolved solids on aquatic organisms: A review of literature and recommendations for Salmonid Species. Am. J. Environ. Sci., 3(1): 1-6.

Zhao, Z.W., and Cui, F.Y. 2009. Multivariate statistical analysis for the surface water quality of Luan River, China. J. Zhejiang Univ. Sci. A, 10: 142-148.

Zhong, W.S., Ren, T. and Zhao, L.J. 2016. Determination of Pb (Lead), Cd (Cadmium), Cr (Chromium), Cu (Copper), and Ni (Nickel) in Chinese tea with high-resolution continuum source graphite furnace atomic absorption spectrometry. J. Food Drug Anal., 24(1): 46-55,