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Groundwater Contamination due to the Activities of Auto - Mechanics in Lagos Metropolis, South-western Nigeria

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Abstract
The release of wastes generated from the activities at automobile workshops leads to heavy metals contamination of groundwater which can be harmful to human health. The study is aimed at investigating the physicochemical and heavy metal contamination of groundwater from three automobile workshops at Super, Jankara and Kola areas located at Alimosho, Ifako – Ijaye and Agege Local Government areas of Lagos State. Fifteen (15) samples were collected from residential houses near the automobile workshops, at 5m – 75m depth and taken to Federal Institute of Industrial Research (FIIRO) laboratory at Oshodi, Lagos. Electrical conductivity (EC), pH, temperature and total dissolved solids (TDS) were measured onsite using a 107 model pH meter. The samples were analysed for lead, magnesium, manganese, cadmium, arsenic, chromium and mercury using Atomic Absorption Spectroscopy; Perkin Elmer model Analyst 3000.The TDS value of all the samples in this research ranged from 0.017 mg/l - 0.097mg/l which is within the W.H.O. standards of 500mg/l. The pH value of all the analysed groundwater samples ranged from 4.4 - 7. This implied that groundwater in the study area are slightly acidic to neutral. The groundwater samples from JW03 are below the acceptable pH limit of W.H.O while the groundwater from the remaining 14 sampling points have pH values less than 6.5, hence, they are slightly acidic. Only two sampling points in Jankara; JW06 and JW07, falls within the W.H.O acceptable limit while the remaining samples have values lower than 6.5. The electrical conductivity in the water analysed ranged from 0.72 µS/cm – 194 µS/cm. The electrical conductivity value of all the water samples analysed are below the W.H.O standard of 1000µS/cm. This result reflects a low input of solute in the groundwater. The temperature values of the groundwater samples of the three areas of the research ranged from 26.8 ºC – 37.8ºC with a median value of 30.2ºC. The values exceeded that of W.H.O limit of 25ºC. The concentration of heavy metal in groundwater of the three mechanic workshops are in this trend; Pb>Mn>Cd>Cr. Arsenic was not detected in all the groundwater samples from the three mechanic workshops. The metal Pb have a range of 0.382 mg/l - 1.895mg/l and an average of 1.070mg/l, Mn ranged from 0.067 mg/l - 2.0933mg/l with an average of 0.7468mg/l, Cd ranged from 0.146 mg/l - 0.5937mg/l with an average of 0.36mg/l while Cr ranged from 0.036 mg/l -0.098mg/l with an average of 0.060mg/l.

***Keywords**: Magnesium, Lead, Automobile workshop, Electrical conductivity, Total dissolved solids, Heavy metals*

Introduction

Groundwater can be defined as that contained in an aquifer beneath the earth. It contributes to almost 97% of the world freshwater used mainly for domestic purposes. (Adekitan, *et al.*, 2017). In several section of the globe, groundwater is still a critical source of water used for domestic, especially in communities whose sources of water are contaminated (Adekitan, *et al.*, 2017; Oliver, *et al.,* 2006). Groundwater as described by many authors as a constant source of water which is not visible (Adekitan, *et al.*, 2017; Chappelle, 1997). It is an important resource in the globe. The great quantity of groundwater that is always available, and its exceptional innate value (potality), led to it increase around the globe thereby making it an imperative reserve (Soladoye and Ajiba, 2014). Substantial figure of studies revealed that groundwater is being contaminated after an analysis of its physical parameters vis-a-vis the World Health Organization (W.H.O) standard for drinking water (Adekitan, *et al.,* 2017; Owoso, *et al.*, 2017).

Auto - mechanic workshops in the country are distributed based on population (Adekitan, *et al.*, 2017). Human actions in auto - mechanic workshops leading to the production of toxic dumps in the environment are welding, scrapping, soldering of vehicles, using of carbide for panel-beating, painting, recycling of both engine and gear box, wiring of vehicles, etc. The increasing importation of second-hand vehicles into the country has increasingly led to the discriminate spread of auto-mechanic workshops.

The discharge of heavy oils on such workshops, pollute groundwater thereby contaminating them. And where such auto-mechanic workshops are located close to inhabited areas like Lagos state which is densely populated, the residents might be forced to use the water ford not only other domestic activities, also drinking (Owoso, *et al.*, 2017). Heavy oil pollutants from such workshops contain heavy metals which are of course potential hazard to the community. Such heavy metals can be stored on/in soils thereby percolating into the groundwater and causing pollution.

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Several reports that were reviewed, (Ugya, *et al.,* 2018) gave more attention to man – made activities like: mining, random refuse and other disposables that can cause pollution of groundwater. Little or no consideration has been given to this study of pollution from the aut – mechanic source, hence the intensity and vigour in the current study.

Heavy metals pollution in soils and groundwater was extensively by Lawrence *et al* (2015) at the auto – mechanic workshops located at Obosi and Nnewi, Anambra State, Eastern Nigeria. Also, trace metals were analysed using Atomic Absorption Spectrometer the results revealing the concentration values exceeding the background values. Nickel was discovered to also be in above the international standards. Sample analysis of water exposed that copper, manganese; nickel and iron were above the WHO standards for drinking water (WHO 2009) and Nigerian Standard for Drinking Water Quality (NSDWQ 2001).

Adekitan, *et al.*,(2017) in assesing physical parameters of groundwater and its effect of heavy oils from an auto – mechanic workshops in some parts of Ogun State using Flame photometer (FLAPHO). It was revealed that some samples analysed have low pH but their TDS and EC were very high. Other parameters analysed were within the suitable WHO (2011) standard for drinking water but for Pb that was above the WHO standard. The enrichment of Pb in such sources was high due to the activities of men in the auto - mechanic villages. Owoso, *et al.,* (2017) also analysed heavy metal pollution of water and soil in the course mining in Lagos metropolis. The samples were tested with inductively coupled plasma emission spectroscopy (ICP-AES) after acid absorption. The end revealed a high measure of contamination in such areas (DC>>36) revealing pollution caused by the activities of men.

High-quality water is colourless, without odour and also without taste. It is considered a fundamental for all persons. Water should be free from some physical, chemical and microbial activities prior to be used for domestic purposes and also drinking. Some factors that have impacts on the quality of groundwater can be classified into natural and anthropogenic. The natural sources mostly are the underlying geology, plants in the environment, easy passage of liquid of sediments and also depths of the sub - surface soils. Man – made or anthropogenic sources are industrialization, mining activities, improper waste disposal, and urbanization. Presence of such heavy metals in groundwater is very harmful and usually not safe for human consumption because it can cause lead to health deterioration of humans. (Martin and Grisworld, 2009).

Location of Study

Lagos state is located in south -western Nigeria between latitudes 6^0 22'N to 6^0 52'N and longitudes $2^°$42'E to $3^°$ 42' E (Odumosu, *et al.*, 1999). Lagos is bounded to the west by Republic of Benin, at the southern border, by the Atlantic Ocean (Soladoye and Ajiba, 2014), its Northern and Eastern boundaries by Ogun State (Odumosu, *et al.*, 1999). Its area extent is 3,577km of which almost 22% is predominantly water. According to Soladoye and Ajiba, 80% of its population are residents in the metropolis.

The study was conducted at three automobile workshops within three local government areas (Figure 1) in Lagos Metropolis namely; Super mechanic workshop (Alimosho local government), Jankara (Ifako-Ijaye local government) and Kola (Agege local government) mechanic workshops. Activities at these mechanic workshops includes; welding, panel beating, cars and trailer repairs.

Lagos State is strategically located on the Dahomey basin, western Africa. (Pugh, 1954; Adegoke, 1977; Adepelumi, *et al.*, 2008). It is chiefly dominated by coastal plain sands also known the Benin Formation which lies beneath (Jones and Hockey, 1964; Reyment, 1965; Adeyemi, 1972) (figure 2).

Materials and Methods

Sampling

Fifteen (15) water samples were collected within three (3) mechanic workshops in three local governmentareas of Lagos state (table 1). These mechanic workshops have been established for over twenty (20) years as attested by the residence of the areas. The water samples were collected from both wells and boreholes with depths ranging from 5m – 75m, within the environments of the mechanic workshops (figure 3).

The samples were collected into sample containers, labelled and coordinates taken at each location with the aid of Global positioning system (GPS) and were immediately transported to the laboratory, Federal Institute of Industrial Research, Oshodi, Lagos (FIIRO).

The heavy metals were analysed using spectrometry method of Atomic Absorption Spectrometer (AAS). A Perkin Elmer model Analyst 300 AAS using a hollow

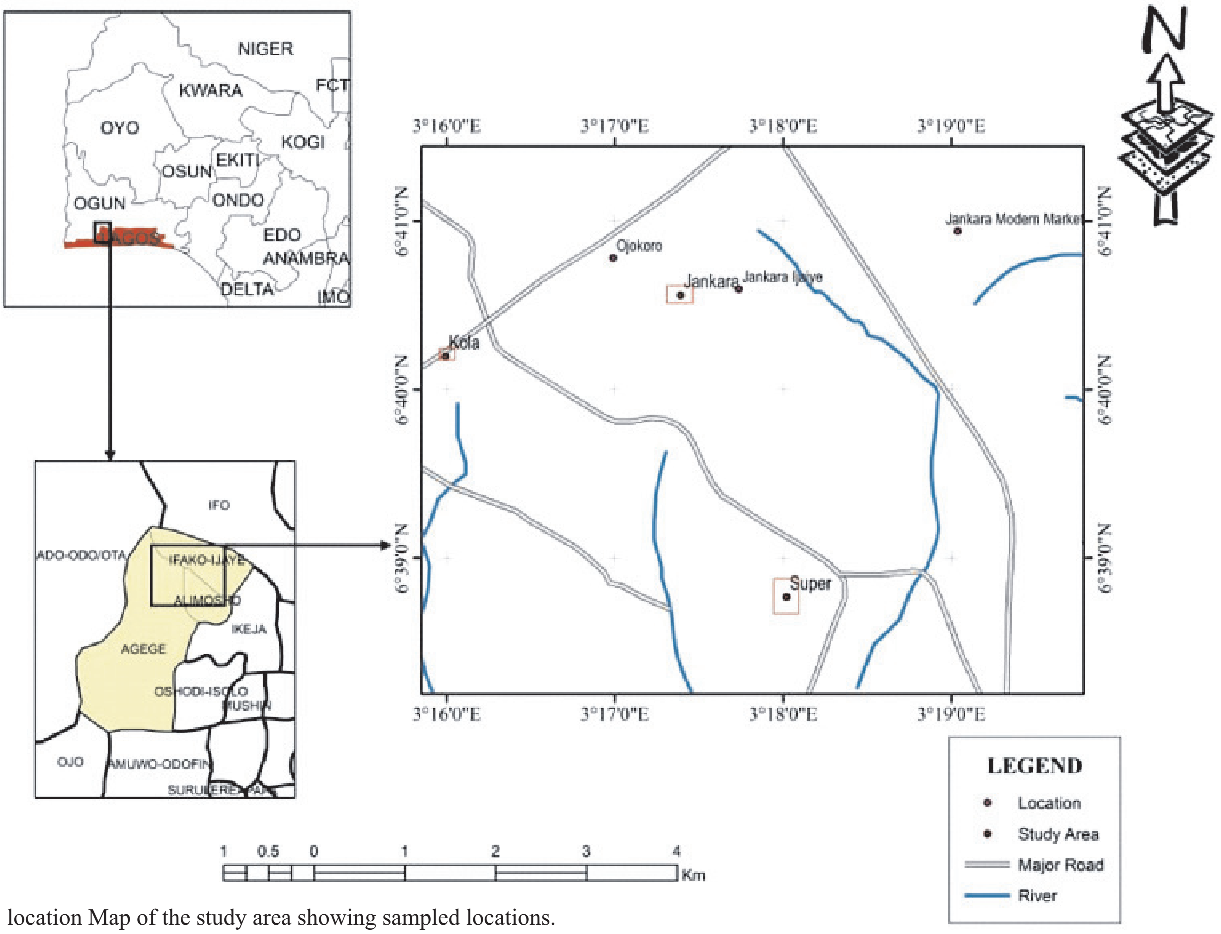

Fig. 1: location Map of the study area showing sampled locations.

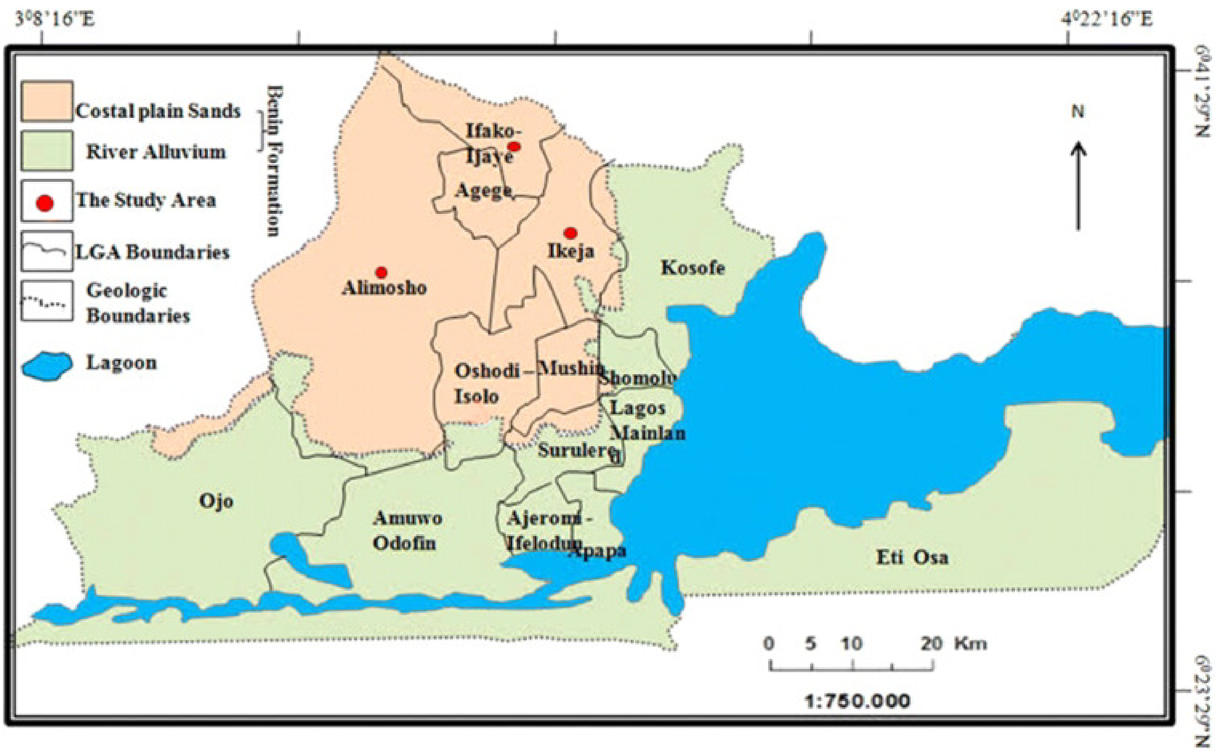

Fig. 1: location Map of the study area showing sampled locations.

cathode lamp and a fuel rich flame (Air acetylene A-AC) and (Nitrous oxide acetylene N-AC). The analysis was carried out in triplicates. Metals were analysed, the mean signal responses were recorded at the element's respective wavelengths.

Table 1: Coordinates of sampling locations at the three locations

Sample code	Latitude	Longitude	Sample type
JW1	6°40′ 31.65"	3°17 ′23.71"	Groundwater
JW2	6°40 ′32.01"	3°17′ 22.14"	Groundwater
JW3	6°40 ′35.42"	3°17 ′21.07"	Groundwater
JW4	6°40 ′36.19"	3°17 ′21.21"	Groundwater
JW5	6°40 ′34.84"	3 °17′ 22.3"	Groundwater
SW1	6°38′ 42.49"	3 °18 ′2.17"	Groundwater
SW2	6° 38′ 48.6"	3°17 ′59.73"	Groundwater
SW3	6°38′ 49.52"	3°17′ 58.36"	Groundwater
SW4	6°38′ 51.43"	3 °17 ′58.7"	Groundwater
SW5	6° 38′ 45.5"	3 °18 ′1.52"	Groundwater
KW1	6°40 ′12.79"	3 °16 ′1.91"	Groundwater
KW2	6°40 ′11.99"	3 °16 ′0.5"	Groundwater
KW3	6 °40′ 11.3"	3°15′ 59.12"	Groundwater
KW4	6°40 ′11.03"	3°15 ′58.37"	Groundwater
KW5	6°40 ′14.14"	3 °15′ 59.7"	Groundwater

The heavy metals were analysed using spectrometry method of Atomic Absorption Spectrometer (AAS). A Perkin Elmer model Analyst 300 AAS using a hollow cathode lamp and a fuel rich flame (Air acetylene A-AC) and (Nitrous oxide acetylene N-AC). The analysis was carried out in triplicates. Metals were analysed, the mean signal responses were recorded at the element's respective wavelengths.

Contamination Factor

The extent of Contamination was determined using Contamination Factor (CF) calculation method. The calculation factor was developed by Hakanson, 1980. It was aimed at revealing an extent of the degree of total contamination in a sampled location.

$$CF = \frac{C_{sample}}{C_{background}} \quad (1)$$

where;

CF is the ratio attained when mean concentration for each metal is divided by the baseline value obtained.

C_{sample} - concentration ratio of heavy metals in each sample.

$C_{background}$- average crustal abundance of the element.

$C_{background}$ is for groundwater sample used in this study is WHO, 2019 water standards

Geo-Accumulation Index

Geo-accumulation index (I_{geo}) aids in evaluating contamination with background concentrations of sample (Muller, 1969). It is now widely applicable to both water and soil contamination (Likuku, *et al.*, 2013). The formula for obtaining the geo-accumulation index was later expressed by (Boszke, *et al.*, 2004) to be;

$$I_{geo} = Log_2 \frac{C_n}{1.5B_n} \quad (2)$$

Where Cn = determined metal concentration of the samples

Bn = average abundance of metal in the earth crust.

Bn = W.H.O. water standards for Groundwater samples.

1.5: baseline matrix correction factor.

Table 2: Geo-accumulation Index and Contamination factor classification source: (Sarala and Uma, 2013; Singh, *et al.*, 2014)

Igeo/CF	Terminology
<1	Low contamination
1-3	Moderate contamination
3-6	Considerable contamination
>6	Very high contamination

Enrichment Factor

The concept of Enrichment Factor was developed by Covelli and Fontolan, (1997)and mostly used for environmental related research. It is to show heavy metal pollution degree in soil by normalizing elemental distributions to a reference element. Enrichment Factor (EF) for an element is the measure of concentration of element in the environmental media examined as proposed by Sinex and Helz (1981).

$$EF = \frac{(Metal/RE)_{sample}}{(Metal/RE)_{Background}} \quad (3)$$

Where:

$(Metal/RE)_{sample}$ is the ratio of the metal of interest to the reference element in the sample

$(Metal/RE)_{background}$ is the ratio of the calculated natural background value of the metal of interest to calculated background of reference element Manganese is the reference element used in this study.

Zhang and Liu, 2002 suggests that pollution was due to natural sources.

Pollution Load Index

Tomilson *et al* (1980) proposed PLI equation for evaluation of level of contamination in a given site. The

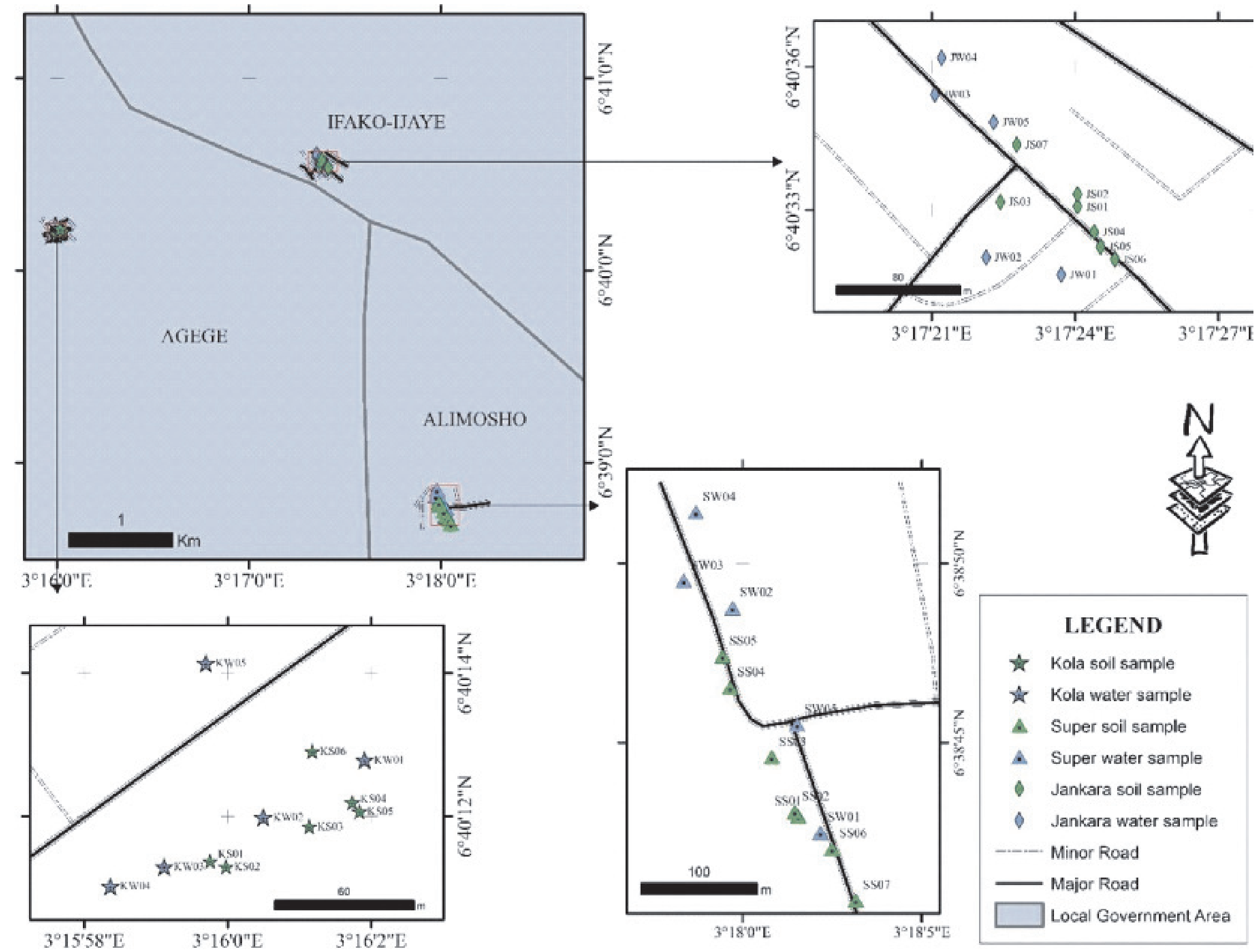

Fig. 3: Sampling map of the Study Area.

Table 3: Enrichment Factor categories (Barbieri, 2016)

Enrichment Factor (EF)	Terminology
<2	Deficiency to minimal enrichment
2 - <4	Moderate Enrichment
5 - <20	Significant Enrichment
20 - <40	Very high Enrichment
≥40	Extremely high Enrichment

equation is given as;

$$PLI = (CF_1 \times CF_2 \times CF_3 \times ... \times CF_n)^{1/n} \qquad (4)$$

Where n = number of metals
CF = contamination factor
PLI = Pollution load index

The CF is computed using the relation;

$$CF = \frac{\textit{Metal concentration in sample}}{\textit{Background value of the metal}} \qquad (5)$$

Table 4: Pollution Load Index Classification (Tomlinson *et al.* 1980)

Pollution Load Index (PLI)	Terminology
<1	Unpolluted
1 - <2	Unpolluted-to-moderately polluted
2 - <3	Moderately polluted
3 - <4	Moderately-to-highly polluted
4-<5	Highly polluted
≥5	Very highly polluted

.Results and Discussion

Groundwater Physical Parameters

The physical parameters of the groundwater were tabulated in table 5 below.

Table 5: Physical parameters of the Groundwater samples

Sample Code	pH	EC (µS/cm)	TDS mg/l)	Temperature (°C)
JW1	4.4	0.74	0.037	26.8
JW2	5.6	0.72	0.036	28.4
JW3	7.0	56.00	0.028	37.8
JW4	5.4	136.00	0.068	28.4
JW5	4.8	56.00	0.028	28.4
SW1	4.5	70.00	0.035	29.2
SW2	5.0	110.00	0.055	33.4
SW3	4.5	194.00	0.097	28.4
SW4	4.5	110.00	0.055	28.4
SW5	4.6	56.00	0.028	30.0
KW1	4.9	34.00	0.017	28.8
KW2	5.9	112.00	0.056	30.0
KW3	5.2	110.00	0.055	34.2
KW4	5.2	92.00	0.046	29.2
KW5	5.3	132.00	0.066	31.2

Hydrogen Ion Concentration (pH) of Water Samples

The pH value of all the analysed groundwater samples ranged from 4.4 - 7. This implied that groundwater in the study area are slightly acidic to neutral. The groundwater samples from JW3 are below the acceptable pH limit of W.H.O while the groundwater from the remaining 14 sampling points have pH values less than 6.5, hence, they are slightly acidic. Only two sampling points in Jankara; JW06 and JW7, falls within the W.H.O acceptable limit while the remaining samples have values lower than 6.5 (figure 4).

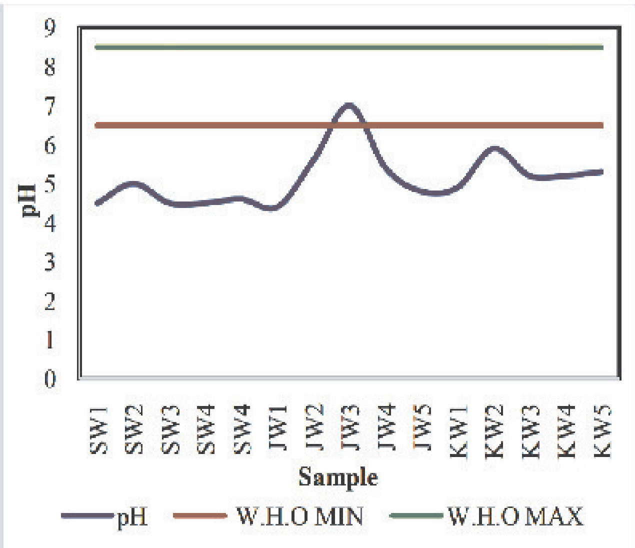

Fig. 4: pH and W.H.O acceptable limit for water sample in the study area.

Electrical Conductivity (EC) of Water Samples of the Study Areas

The electrical conductivity (EC) is part of the essential quality to outline when assessing the worth of water for drinking. The electrical conductivity stands as a measure of electrical current water can carry. The electrical conductivity in the water analysed ranged from 0.72 µS/cm – 194 µS/cm. The electrical conductivity value of all the water samples analysed are below the W.H.O standard of 1000µS/cm. This result reflects a low input of solute in the groundwater.

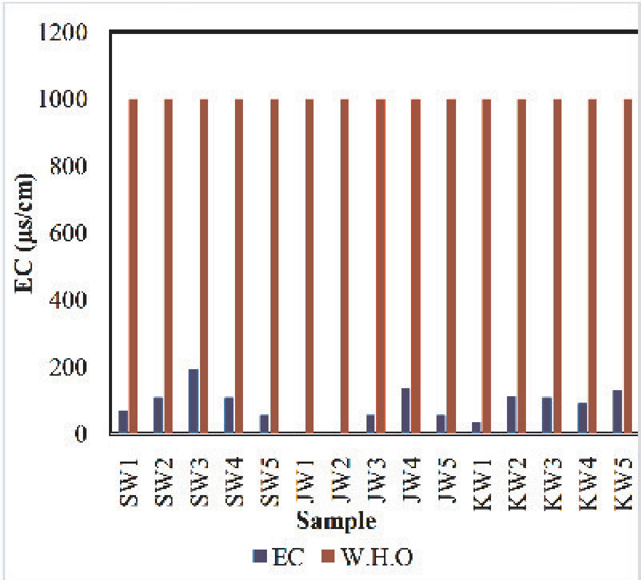

Fig. 5: EC and W.H.O acceptable limit for water sample in the study area

Total Dissolved Solids (TDS) of Water Samples

Dissolved solids in groundwater is the measure of dissolved substances like inorganic salts which include chlorides, bicarbonates, sulphates, phosphates, and nitrates of magnesium, calcium, iron it also include small amount of organic matter and dissolved gases. Elevated value of TDS in groundwater may suggest the presence of toxic metals which may affects the taste and also pose a serious health challenge for its users. The TDS value of all the groundwater samples in this research ranged from 0.017 mg/l - 0.097mg/l which is within the W.H.O standards of 500mg/l.

Temperature

The temperature value of the groundwater samples of the three areas of the research ranged from 26.8 °C – 37.8°C with a median value of 30.2°C. The values

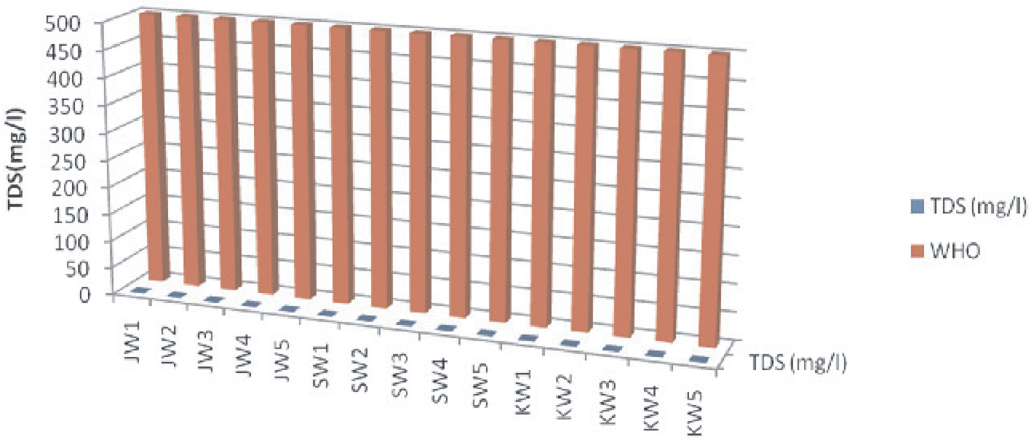

Fig. 6: TDS and W.H.O acceptable limit for water sample in the study area

exceeded that of W.H.O limit of 25ºC. High value of temperature in groundwater negatively affects the water as it causes taste and odour and also causes micro-organisms growth in the water (UNICEF, 2008).

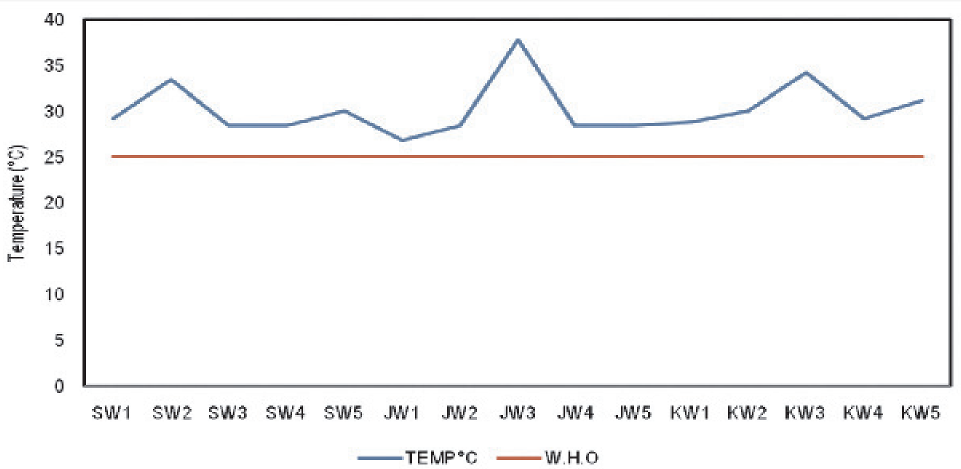

Fig. 7: Temperature and W.H.O acceptable limit for groundwater

Heavy Metal Concentration in Groundwater

The concentration of heavy metal in groundwater of the three mechanic workshops are in this trend; Pb>Mn>Cd>Cr. Arsenic was not detected in all the groundwater samples from the three mechanic workshops. The metal Pb have a range of 0.382 mg/l - 1.895mg/l and an average of 1.070mg/l, Mn ranged from 0.067 mg/l - 2.0933mg/l with an average of 0.7468mg/l, Cd ranged from 0.146 mg/l - 0.5937mg/l with an average of 0.36mg/l while Cr ranged from 0.036 mg/l -0.098mg/l with an average of 0.060mg/l (table 6).

Lead Concentration in Groundwater of the Study Areas

The concentration of lead in the water samples gotten from the three mechanic workshops are above the W.H.O and NSDWQ limit of 0.01mg/l. the highest concentration of lead is found in JW4; 1.895mg/l, this makes the water not safe for drinking. Lead is toxic metal that affects the body structures and is mostly dangerous to young children. Lead, if found in the human body distributes itself to the brain, liver, kidney and bones and it accumulates over time. It affects the brain and nervous system of children while in adults it causes a long term sickness like kidney damage and high blood pressure. (W.H.O, 2019).

The source of lead in these study areas may likely be from indiscriminate discharge of lead from batteries, from the leaching of some car parts, from metallic alloys and also from car paints that have lead in them.

Manganese Concentration in Groundwater

The concentration of manganese in groundwater from

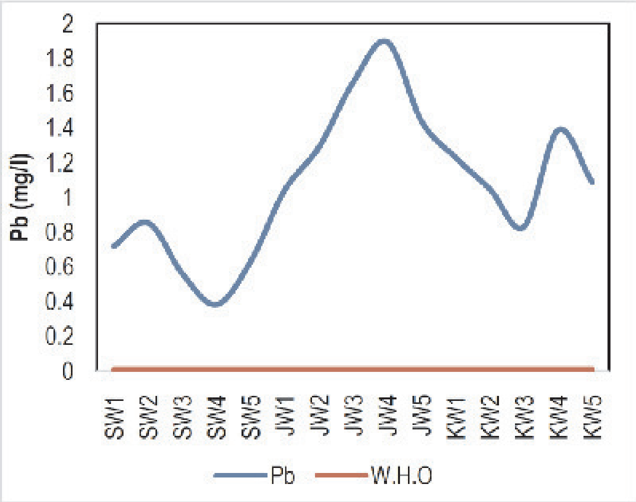

Fig. 8: Lead concentration of groundwater in the study areas.

the three mechanic workshops ranged from 0.067 mg/l - 2.0933mg/l with an average of 0.7468mg/l, the highest concentration of manganese is found in KW04 groundwater sample 244.1733mg/l at super mechanic workshop, only SW3 that the value falls within the NSDWQ standard of 0.2mg/l, the remaining SW1, SW2, SW4 and SW5 have values below the recommended standard of NSDWQ. At Jankara mechanic workshop all the water samples have values above the NSDWQ Standard. Also at Kola workshop, all the groundwater samples have manganese concentration value above the NSDWQ standard. High level of manganese in drinking water can lead to impairment and reduced intelligence quotients in school children (Bouchard, *et al.*, 2008).

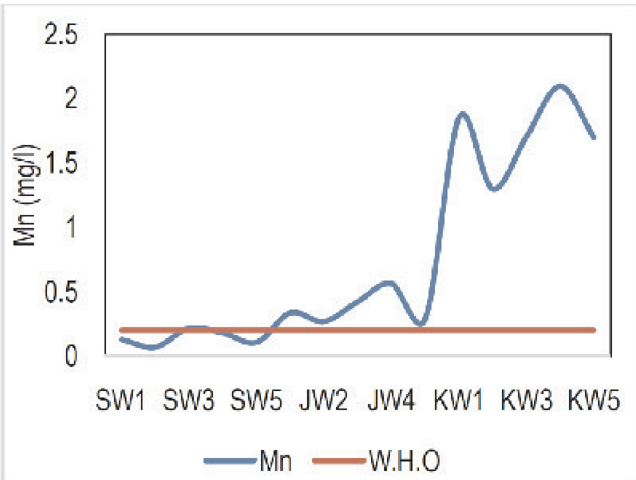

Fig. 8: Lead concentration of groundwater in the study areas.

Cadmium Concentration in Groundwater

All the groundwater samples in the three mechanic workshops have concentration of cadmium above the W.H.O limit of 0.003mg/l. The highest concentration of cadmium was recorded in KW01 sample with 0.593mg/l. Results shows that the concentration of cadmium in groundwater in the three areas; Super, Jankara, and Kola have high level of cadmium concentration.

High consumption of cadmium in water can results in lung, breast and prostate cancer in human. (Julin, *et al.*, 2012). The source of cadmium from this study can be from batteries, chemicals, fuels, etc..

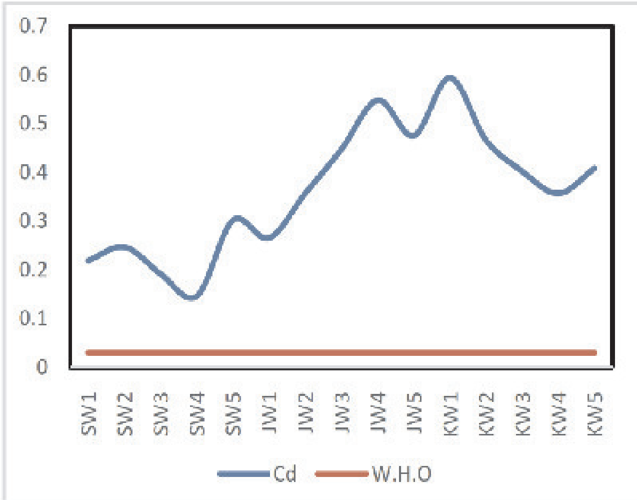

Fig. 10: Cadmium concentration for groundwater in the study areas

Chromium Concentration in Groundwater

At super mechanic workshop all the groundwater samples have concentration values above the W.H.O standards of 0.05mg/l except for sample SW5 that have a value of 0.043mg which falls below the W.H.O standard of 0.05mg/l. The highest concentration of chromium was recorded at JW1 water sample with value of 0.098mg/l. At Jankara mechanic workshop, only JW4 have a concentration value of 0.043mg/l which is also below the W.H.O standard all the other groundwater samples have a concentration value higher than 0.05mg/l. at Kola mechanic workshop KW1 sample has value of 0.050mg/l which is within the W.H.O standard while all other samples have a value below 0.05mg/l.

Arsenic Concentration in Groundwater

Arsenic was not detected in all the groundwater samples from the three automobile workshops.

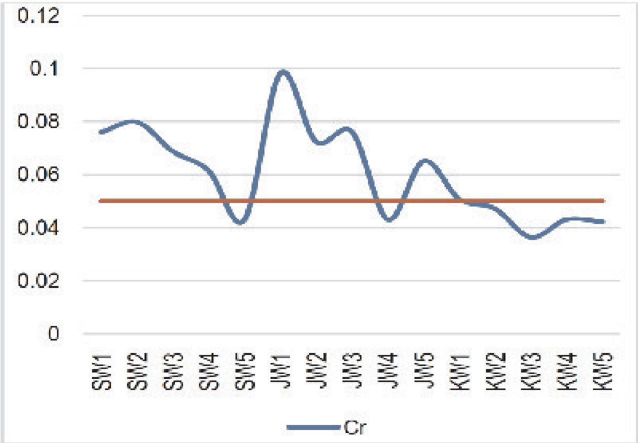

Fig. 11: Chromium concentration for groundwater in the study areas

Comparing Mean Concentration of Heavy Metals of the Three Mechanic Workshops

As shown infigure 12, Kola mechanic workshop have the highest concentration of manganese in groundwater samples analysed while Super workshop have the least mean concentration from the three mechanic workshops. At Jankara, the mechanic workshops has the highest mean concentration of lead in groundwater samples and Super mechanic has the least mean concentration of the three mechanic workshops.

Kola mechanic workshop has the highest mean concentration of cadmium, while Super mechanic workshop has the least mean concentration of cadmium. Jankara mechanic workshop has the highest mean concentration of chromium, while Kola mechanic workshop has the least chromium mean concentration.

Conclusion

The outcome of this research shows that heavy metals concentration in groundwater of the area is above the tolerable limits in all the auto mobile workshops (table 7). This, however, implies that the concentration of the heavy metals has affected both plants and animals in the areas. The toxicity is dependent on time of exposure and rate of intake. Regular intake of the water for a long time could be harmful to human health by leading to kidney damage. This is due to the effect of waste generated from mechanic workshops on the groundwater. The waste (grease, oil, carbide, diesel, and petrol) accumulates on the soil and during raining season its percolates into the groundwater thereby posing harm to human health. Cadmium and Lead were generated from activities like vehicle painting, car batteries, leaching of metals, electrical components, and carbide.

Table 7: Computed Pollution load Index for groundwater samples

Sample Id	PLI	Comment
JW1	4.7323	Highly Polluted
JW2	4.4010	Highly Polluted
JW3	4.7939	Highly Polluted
JW4	3.7727	Moderate-highly Polluted
JW5	4.1005	Highly Polluted
SW1	7.4038	Very highly polluted
SW2	7.3709	Very highly polluted
SW3	9.4417	Very highly polluted
SW4	9.5664	Very highly polluted
SW5	8.0869	Very highly polluted
KW1	12.2851	Very highly polluted
KW2	9.9792	Very highly polluted
KW3	9.1122	Very highly polluted
KW4	11.0325	Very highly polluted
KW5	10.1428	Very highly polluted

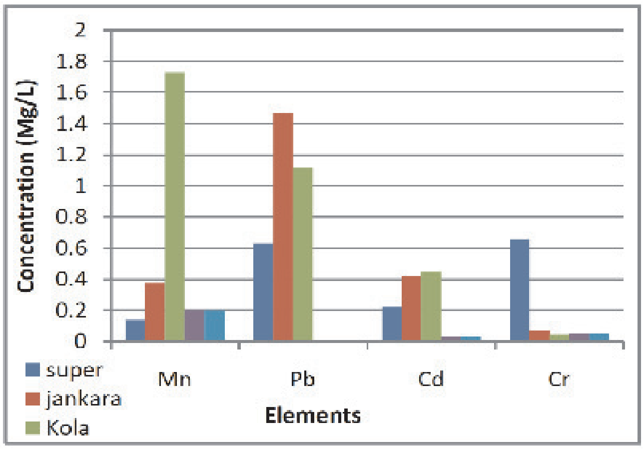

Fig. 12: The mean concentration of heavy metals of the three mechanic workshops

Declarations

1. The availability of data and materials for this manuscript will be on request
2. We wish to state that there is no any competing interest for the purpose of this submission
3. The work was strictly funded by the authors as there was no sponsorship
4. The manuscript was written and formatted by Allu Augustine Umbugadu, while the table and figures were handled by Akinwumi Tolulope Victoria
5. Special acknowledgements to people working in the FIIRO laboratory in Lagos where the analyses were carried out.

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