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Assessment of heavy metal and physicochemical parameters in the soil from automobile mechanic villages in Makurdi, Nigeria

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Abstract

The accumulation of spent oil from mechanic workshops in Makurdi, Nigeria was assessed of heavy metals (zinc, chromium, copper, Nickel) concentration. soil samples were collected from four points each from three different mechanic workshops at depth of (0-5) cm, 20 g of soil was dissolved in 100 ml of distilled water for 30 minutes. Filter using sieve to get the stock, the concentration of heavy metals was detected using Lovibond® Tintometer Model MD 600, the results indicate the following levels, in Kanshio. Zn 020, Cr 900, Cu 300, Ni 000, in Wadata Zn 000, Cr 000, Cu 000, Ni 72.5andnorth bank Zn 60, Cr 0.00, Cu 700, Ni 0.00. Physicochemical parameters where also determine with the use of Hannah Multimeter water tester model HI 98129. pH, Electrical Conductivity, total dissolved solids and Temperature were determined by using HANNA®multimeter water tester model HI 98129.The results indicate the following for Kanshio (pH 5.3, TDS 506000 mg/kg, EC 1012 us/cm, Temperature 27.9 °C, moisture 12.6 %, N 152000 mg/kg, P 2000 mg/kg potassium 800 mg/kg) for Wadata (pH 5.1, TDS 362000 mg/kg, EC 720 us/cm. Temperature 27.2 °C, moisture 6.1%, N 532000 mg/kg, P 1700 mg/kg, potassium 2100 mg/kg). For North bank (pH 7.6, TDS 453000 mg/kg, EC 908mg/cm, Temperature 26.8 °C, moisture 8.9%, N 152000 mg/kg, P 2300 mg/potassium 600 mg/kg). The findings of this pollution levels of these mechanic villages would add to the environmental database which will assist in the monitoring and comprehensive waste management plan of high concentration in heavy metals in the soil.

Keywords: Heavy Metals; Physicochemical Parameters; Pollution Load Index; Geo-accumulated index (Igeo); Soil Contamination

1. Introduction

Soil is a complex mixture of inorganic and organic matter of different component which determine the physical, chemical and biological properties of the soil. It has capacity to influence to a large extend the safety of the environment in terms of pollution (Eluyera &Tukir, 2020). There have been studies conducted in the Southern region of Nigeria regarding soil and vegetation pollution from spent oil (Adeleken et al, 2011). The study also, revealed that automobile workshop may increase heavy metal concentration in soil (Anoliefo & Vwioko, 1995). This may have effects on the soil, crops and human health (Yahaya et al, 2023). Advancement in technology had led to high level of industrialization leading to discharge of heavy metals into our environment. The term "heavy metal" is commonly adopted as group name for the metals and metalloids, which are associated with pollution and toxicity but also, include such metals which are essential for living things at low concentrations (Chioma et al, 2014). Heavy metals are a class of trace metals with density greater than (3.0-5.0) gcm (Lacatusu, (1998). Toxic heavy metals entering the ecosystem may lead to geo- accumulation, bio-accumulation and bio-magnifications. They get accumulated in the soil with time and would have a negative influence

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on physiological activities of plants (e.g. photosynthesis, gaseous exchange and nutrient absorption), determining the reductions in plant growth, dry matter accumulation and yield (Naseer et al., 2023).

Heavy metals are non-biodegradable; hence they are not readily detoxified and removed by metabolic processes. This leads to their build up (bioaccumulation) to toxic levels in the ecosystem. Heavy metal pollution in the biosphere is now one of the most serious environmental concerns due to its severe long-term implications on human health and the environment (Ali et al., 2019 & Abeje et al, 2023). The environmental impacts of waste from automobile workshop are greatly influenced by their heavy metal contents and lead to soil pollution resulting from heavy metals from lubricating oil in the vicinity of selected mechanic workshops and other mechanic activities (Naseer et al., 2023). Plants have the ability to take up and sequester heavy metals and other hydrocarbons and hence, pose health risk and hazards to humans and the ecosystem through direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal-human), drinking of contaminated ground water, reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems (Amaechi & Onwuka, 2021). The escalation in automotive maintenance and repair establishments and their operations in part of Nigeria is as a result of the rise in demand for private vehicles, a large portion of which are of foreign origin. This has led to the issue of soil contamination in several urban areas. Automobile waste consists of waste oil, oxidation byproducts and metallic fragments that result from the wear and tear of machinery, organic and inorganic chemicals found in oil additives, used batteries and metals. The existence of trace elements in soil is rapidly becoming a global concern, particularly since soil is a vital component of both rural and urban environments (Yahaya et al., 2023) and (Adeleken et al. ,2011). Heavy metals of highest concern include arsenic, cadmium, cobalt, chromium, copper, mercury, manganese, nickel, lead, tin and thallium (Balali-Mood, 2021). Some of these elements are necessary for humans in little quantities while others are very toxic and not needed by the body. They can affect the central nervous system, kidneys, liver, skin, bones or teeth. Plants growing in polluted areas with increasing impartation of heavy metals may serve as bio-indicators of Pollution Index (Abeje et al., 2023).

Heavy metals have harmful effects on human health, and exposure to these metals has been increased by industrial and anthropogenic activities and modern industrialization. Contamination of water and air by toxic metals is an environmental concern and hundreds of millions of people are being affected around the world. Food contamination with heavy metals is another concern for human and animal health. Concentration of heavy metals in water resources, air, and food is assessed with this regard (Mousavi et al., 2013; Ghorani-Azam et al., 2016). Metals among the other environmental pollutants may also occur naturally and remain in the environment. Hence, human exposure to metals is inevitable, and some studies have reported gender differences in the toxicity of metals (Vahter et al., 2007). They may frequently react with biological systems by losing one or more electrons and forming metal cations which have affinity to the nucleophilic sites of vital macromolecules. Several acute and chronic toxic effects of heavy metals affect different body organs. Gastrointestinal and kidney dysfunction, nervous system disorders, skin lesions, vascular damage, immune system dysfunction, birth defects, and cancer are examples of the complications of heavy metals toxic effects. Simultaneous exposure to two or more metals may have cumulative effects (Fernandes Azevedo et al., 2012).

High-dose heavy metals exposure, particularly mercury and lead, may induce severe complications such as abdominal colic pain, bloody diarrhea, and kidney failure (Bernhoft, 2012). On the other hand, low-dose exposure is a subtle and hidden threat, unless repeated regularly, which may then be diagnosed by its complications, e.g., neuropsychiatric disorders including fatigue, anxiety, and detrimental impacts on intelligence quotient (IQ) and intellectual function in children (Mazumdar et al., 2011). The fact that several metals have emerged as human carcinogens is another important aspect of the chronic exposure. While the exact mechanism is unclear, aberrant changes in genome and gene expression are suggested as an underlying process. Carcinogenic metals such as arsenic, cadmium, and chromium can disrupt DNA synthesis and repair (Clancy et al., 2012). The toxicity and carcinogenicity of heavy metals are dose dependent. High-dose exposure leads to sever responses in animal and human which causes more DNA damage and neuropsychiatric disorders (Gorini et al., 2014).

The toxic mechanism of heavy metals functions in similar pathways usually via reactive oxygen species (ROS) generation, enzyme inactivation, and suppression of the antioxidant defense. However, some of them cause toxicities in a particular pattern and bind selectively to specific macromolecules. Different toxic mechanisms of heavy metals increase our knowledge on their harmful effects on the body organs, leading to better management of animal and human poisonings. The findings of this study would provide adequate idea of the pollution levels of these mechanic villages and would add to the environmental database of the soil of this mechanic workshop, which will assist in the monitoring and comprehensive waste management plan, standard guidelines for establishment of mechanic villages, remediation strategies for heavy metal contaminated soil, code of practice, and continuous education for the mechanics.

2. Materials and method

2.1. Study Area

This study was carried out in Makurdi, Benue State Capital of Nigeria, covering three (3) locations. These include North Bank, Kanshio (Apir) and New Garage (Wadata). Makurdi, the capital of Benue State, North Central Nigeria, is a town that lies between Latitude 7044’N and Longitude 8032’E covering an area of 820 km2 with an estimated population of 348,990 people (National Population Commission of Nigeria, 2011). The vegetation type in Makurdi is guinea savannah with annual rainfall between 150 -180m and temperature of 26 ^oC-40 ^oC.

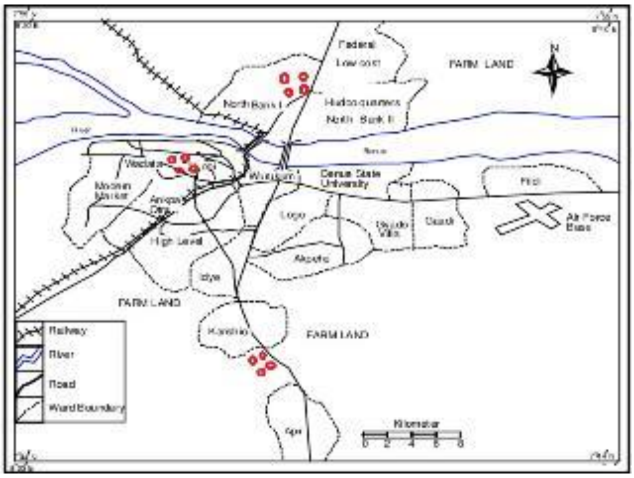

Figure 1 The map of Makurdi showing the three locations where samples were taken.

2.2. Parameter Experimental Procedure

The experimental procedures that were perform in this study are explained below step by step

2.2.1. Sample preparation and Analysis

In each of the sample locations, samples were taken at four points (North, South, East and West) within the workshop. Four (4) samples of soil (0-15) cm were taken at distances of 0, 20, 40 and 60 meters using a soil auger. To determine the presence of heavy metals, the soil samples were placed in plastic bags, tagged, and submitted to a laboratory at the department of fishery and aquaculture, Joseph Sarwuan Tarkaa University Makurdi. Using a Scintillation method, the soil samples were air dried, then used to make a stainless-steel sieve after being smashed using a mortar and pestle. Lovibond® Tintometer Model MD 600 was used to evaluate heavy metals. The sample was inserted into the well of the equipment after been cleaned and zeroed using the meter zero key. The desired parameter to be determined was selected using the mode key. A 10ml of the stock was measured into a vial. Reagents was added in two drops in the stock in10ml vial, the sample was removed and shaken for one minute after which it was placed in the hollow space in the equipment, the sample containing the reagent was inserted and allow to be steady before readings/result were taking.

2.2.2. Measurement of soil physicochemical parameters

A sample was randomly selected from the four points of collection, 20g of soil was dissolved in 100ml of distilled water, it was stirred with a glass rod and allowed to stand for 30 minutes. Filter using sieve to get the stock, Hannah Multiparameter water tester model HI 98129 was dipped into the stock and allowed to read the desired parameter. This preparation serves as a stock solution for all the physicochemical parameters. pH, Electrical Conductivity, Total dissolved solids and Temperature were determined by using HANNA® Multiparameter water tester model HI 98129. The probe was immersed in water sample and the mode was set to read the desired parameter using the MODE keypad, readings were taken after it was left to stabilize for about five (5) minutes.

2.2.3. Pollution Load Index (PLI)

The Pollution Load Index (PLI) is obtained as degree of overall contamination using the concentration factors (CF). CF is the quotient obtained by dividing the concentration of each metal with background value. The PLI of the place are calculated by obtaining the n root from the n-CFs that was obtained for all the metals. Mathematically, it is stated as

$CF = \frac{C_{metal}}{C_{background\ value}}$ ……………………………………….1

PLI = n√(CF1 × CF2 × CF3 × … … CFn)……….2

Where, CF = Contamination factor and 0 =none, 1=none-medium, 2=moderate, 3=moderately-strong, 4=strongly polluted, 5=strong-very polluted, 6=very polluted, n= number of metals, C_{metal}= Metal Concentration in polluted soil sediments, $C_{background\ value}$ = Background value of the metal. The PLI value of > 1 is polluted, whereas < 1 is no pollution.

2.2.4. Geo-accumulated index (I_{geo})

Geo-accumulated index (I_{geo}) is a quantitative measure used to assess the level of heavy metal contamination in the soils or segment. It provides an indication of the degree of pollution in the environment due to human activities or natural processes. Mathematically, it is stated as

(I_{geo}) = $\log_2$(Cn/Bn1.5) …………………………………..3

Where Cn = measured concentration of the element in the soil(mg/kg), Bn = geochemical background value of the element in the soil.

2.2.5. Permissible limits and classifications set by WHO, Federal Ministry of Environment (FME), National Environmental Standards and Regulations Enforcement Agency (NESREA)

Table 1 Permissible limits for heavy metals in soil (mg/kg)

Elements	Target value
Zn	50
Ni	35
Cu	36
Cr	I00

Table 2 Classification of Geo-accumulation index

Classes	(I_{geo}) Value	Soil/Sediment Quality
0	<0	Unpolluted
1	0-1	Unpolluted to moderately polluted
2	1-2	Moderately polluted
3	2-3	Moderately to strongly polluted
4	3-4	Strongly polluted
5	4-5	Strongly to very strongly polluted
6	>5	Very strongly polluted

Table 3 Physicochemical parameters permissible limits

Parameter	Target value
Ph	3.5-4.4 extremely acidic 4.5-5.0 very strong acid 5.1-5.5 strongly acidic 5.6-6.0 moderately acidic 6.1-6.5 slightly acidic 6.6-7.3 neutral 7.4-9 Alkaline
TDS	500000mg/kg
EC	0.1 to 2.43µs/cm
Temperature	10-24°
Moisture	20-25%
Nitrogen	Above 10 and < 50mg/kg
Phosphorus	500-800mg/kg
Potassium	Low < 50 Moderate 50-100 Ideal 101-150 High > 150

3. Results

Table 4 Heavy metal concentrations in the Soil Sample showing the mean and Standard deviation (STD) value

Location/Parameters	Sample depth(cm)	Zn(mg/kg)	Cu(mg/kg)	Ni(mg/kg)	Cr(mg/kg)
Kanshio 1	0-15	40	300	NIL	NIL
Kanshio 2	0-15	10	100	NIL	NIL
Kanshio 3	0-15	20	400	NIL	NIL
Kanshio 4	0-15	10	400	NIL	NIL
Mean		20	300		
STD		12.25	122.47		
Wadata 1	0-15	NIL	NIL	90	NIL
Wadata 2	0-15	NIL	NIL	70	NIL
Wadata 3	0-15	NIL	NIL	60	NIL
Wadata 4	0-15	NIL	NIL	70	NIL
Mean				72.5	
STD				10.90	
North bank 1	0-15	80	500	NIL	NIL
North bank 2	0-15	60	700	NIL	NIL
North bank 3	0-15	50	900	NIL	NIL
North bank 4	0-15	50	700	NIL	NIL

Mean		60	700		
STD		12.25	141.42		

Table 5 Contamination Factor and Pollution Load Index (PLI) of Metals

Sample Location	CF_{Zn}	CF_{Cu}	CF_{Ni}	PLI
Kanshio	0.306	13.33	Nil	1.117
Wadata	Nil	Nil	2.581	2.581
North Bank	0.917	22.581	Nil	4.358

Table 6 The Geo-accumulation Index (I_{geo}) index representation of heavy metal in the sample soil of the three mechanic villages

Sample Location	Heavy metals	Classes	(I_{geo}) Values	Soil/sediment quality
Kanshio	Zinc	4	$3 < I_{geo} \leq 4$	Strongly polluted
Kanshio	Copper	4	$3 < I_{geo} \leq 4$	Strongly polluted
Wadata	Nickel	0	$< I_{geo}\ 0$	unpolluted
Northbank	Zinc	1	$0 < I_{geo} \leq 1$	Unpolluted or moderately polluted
Northbank	Copper	6	5	Very strongly polluted

Table 7 Physicochemical parameter of the soil sample

S/N0	Samples	pH	TDS (mg/kg)	EC (µs/cm)	Temperature (ºC)	Moisture (%)	Nitrogen (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)
1	Kanshio	5.3	506000	1012	27.9	12.6	152000	2000	800
2	Wadata	5.1	362000	720	27.2	6.1	532000	1700	2100
3	N/Bank	7.6	453000	908	26.8	8.9	152000	2300	600

TDS=Total dissolved solids, EC=Electrical conductivity. pH= potential of Hydrogen

4. Discussion

4.1. Determination of Heavy metals concentrations in the Soil Sample

The heavy metals of interest were detected in the soil analyzed, the concentrations of the heavy metals in the contaminated soil are shown in Table 7.

4.1.1. Zinc Concentration

Kanshio (Apir) mechanic workshop recorded a range of 10-40 mg/kg with a mean value of 20mg/kg, it was not found in Wadata (new garage) and a variation of (50-80) mg/kg with mean value of 60mg/kg was recorded in north bank. The results indicates that the mechanic workshops in sample points 1 in Kanshio (Apir) and sample point 1 in North bank are more contaminated with zinc with Kanshio (Apir) recording lower than the critical level and sample 1 at north bank above the critical level. This revealed that the increase in zinc level in the study area was from the auto mechanic shops since the study location has no industry, this element is formed as a part of many additives to lubricating oil. the concentration may also be due to factors such as age of the mechanic workshops, volume of the work done on each site, Types of automobile service or repaints, types of lubricants commonly used, mode of waste disposal and type of soil.

Excess of this zinc in soil may lead to nausea, vomiting diarrhea, headaches. In chronic cases, it may cause anemia and kidney problems.

4.1.2. Copper

A range of 100-400mg/kg with mean value of 300mg/kg was recorded for copper in Kanshio (Apir) mechanic village. It was not detected in Wadata mechanic village and a range of (500-900) mg/kg with mean value of 700mg/kg was recorded in north bank mechanic village. This indicates that the activities in automobile workshops highly contains the copper content as against WHO's permissible limit. The amount of copper detected in the soil at this level in all sample locations indicates that the soil is highly polluted. the presence of copper in the soil of study area could be as a result of mechanic waste containing electrical and electronic parts such as copper wires, electrodes and copper pipes, alloys from corroding vehicles scraps which have been deposited on soil for a long time. high level of copper can cause vomiting, nausea, diarrhea, headaches, dizziness, muscle pain. In critical conditions, can cause liver damage and nervous system damage.

4.1.3. Nickel

The concentration of nickel was only detected at the Wadata (new garage) mechanic village with a range of 60-90mg/kg and a mean value of 72.5mg/kg. This could be as a result of disposal of spent oil and different paint wastes directly on the soil. Exposure to too much Nickel can cause skin irritation like: dermatitis, redness of the skin, itching of the skin and swelling of the skin, and in chronic situations, respiratory problems such as asthma and chronic bronchitis.

4.2. Determination of contamination factor and pollution index.

4.2.1. Contamination factor

It was observed that Zinc in kanshio and north bank has low contamination factor, indicating low contamination, Copper in Kanshio and North bank has very high contamination factor and Nickel was found to have moderate contamination factor. the high contamination factor value of metals (zinc and copper) indicates significant contribution of anthropogenic origin.

4.2.2. Pollution load index

The value of pollution index was found to be polluted in all three sites with north bank been the most polluted. This could be as a result of improper disposal of spent oil, paints, hydrocarbons from vehicles to the soil over the years.

4.3. Determination of Geo-accumulation Index (I_{geo})

The mean $I_{geo=}$ Geo-accumulation index values for the various metals in the mechanic villages were spotted to be moderately or highly contaminated by zinc in kanshio and practically uncontaminated at North bank, Nickel and was found to be uncontaminated in Wadata. Copper was moderately or highly contaminated in Kanshio and was very strongly polluted in North bank. Therefore, Kanshio is moderately/highly contaminated and North bank is very strongly polluted as at the time of investigation.

4.4. Determination of physicochemical parameters in the soil sample

From Table 7;

4.4.1. pH

The averaged pH values of the soil samples from four points each in a location of three automobile workshops and Kanshio (Apir) was found to be 5.3 slightly acidic, in Wadata (new garage) pH was found to be 5.1 which is moderately acidic and at north bank pH was found to be 7.6 which is said to be alkaline.

4.4.2. Total Dissolved Solid

TDS of the soil sample from Kanshio (Apir) mean value was 506000mg/kg, at wadata (new garage) mean value was 362000mg/kg and north bank mean value was 453000mg/kg. the result showed that kanshio and north bank were higher than the permissible values which could be as a result of improper disposal of automotive fluids like oil and antifreeze and this could cause salinity stress and reduce plant growth.

4.4.3. Electrical Conductivity (EC)

Electrical conductivity of the soil in kanshio (apir) had a mean value of 1012us/cm, wadata (new garage) had mean value of 720us/cm and north bank had a mean value of 908us/cm. The high electric conductivity could be due to the high ionic concentration of the heavy metals in the contaminated soil.

4.4.4. Temperature

The temperature of the soil sample from Kanshio (Apir) mean value was 27.9 ^{o}C, at Wadata (new garage) mean value was 27.2 ^{o}C and north bank mean value was 26.8 ^{o}C. High temperature can increase the rate of nutrient leaching, thereby causing loos of nitrogen, potassium and phosphorus in most cases.

4.4.5. Moisture

The moisture of the soil sample from Kanshio (Apir) mean value was 12.6%, at Wadata (new garage) mean value was 6.1% and north bank mean value was 8.9%. The low moisture in the sample locations recorded may over the time become a problem causing soil erosion and barren soil.

4.4.6. Nitrogen

The nitrogen in the soil sample from Kanshio (Apir) mean value was 152000mg/kg at Wadata (new garage) mean value was 532000mg/kg and North bank mean value was 152000mg/kg, this is high in all locations but higher in Wadata which could lead to nitrate leaching, plant toxicity and altering of soil pH overtime.

4.4.7. Phosphorus

The phosphorus in the soil sample from Kanshio (Apir)mean value was 20000mg/kg, at Wadata (new garage) mean value was 17000mg/kg and North bank mean value was 23000mg/kg, the high phosphorus may reduce plant growth in affected area.

4.4.8. Potassium

The potassium in the soil sample from Kanshio (Apir) mean value was 8000mg/kg at Wadata (new garage) mean value was 21000mg/kg and north bank mean value was 6000mg/kg, the high potassium may lead to nutrient imbalance, reduce water uptake in plant, and altering of pH in soil.

4.5. To Compare the concentration of heavy metals and physicochemical parameters in the soil sample locations.

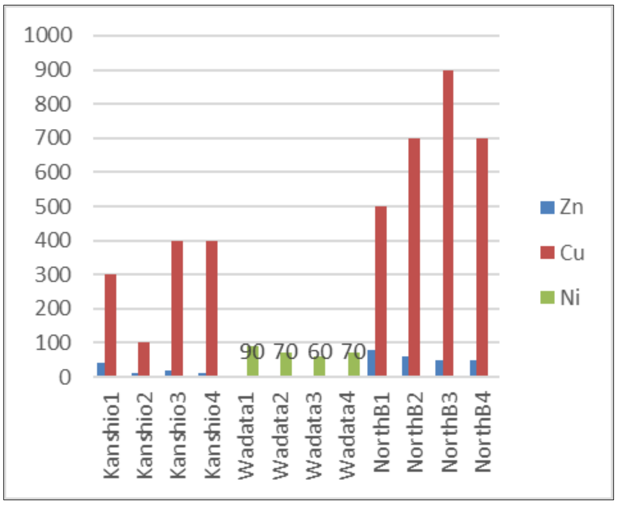

Figure 2 Heavy metal concentration values with soil sample location

Figure 2, Showed that the copper has high mean value in North bank than in other sample locations followed by Kanshio and none detected in Wadata.

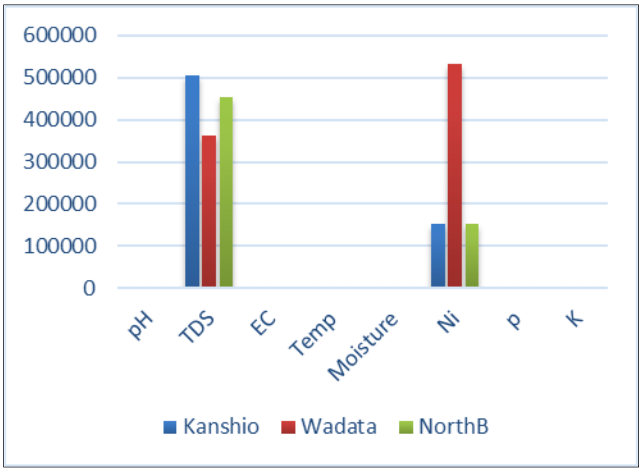

Figure 3 Physicochemical Parameter Values of the soil with sample Locations

Figure 3 showed that TDS was found to be greater in Kanshio and nitrogen was found to be greater in Wadata. The high value of TDS in Kanshio may be as a result of improper disposal of oil and antifreeze over the years, the high value of nitrogen in Wadata could be as a result of deposition of automobile release of nitrogen oxides in the soil.

5. Conclusion

The heavy metals of interest in the study, zinc, Nickel and copper Determine in the soil form different spots of the mechanic village Were compared with the WHO, Federal Ministry of Environment (FME), National Environmental Standards and Regulations Enforcement Agency (NESREA) Soil criteria level, the I_{geo} was calculated as well as the contamination factor (CF). The order of the mean concentration of heavy metal content in the contaminated soil was Ni < Cu <Zn. The results showed that the concentration of heavy metals in the soil sample were higher than the compare Organization standard critical soil level except for zinc that is lower than the criteria soil level. The mean I_{geo} values for the various metals in the mechanic villages were spotted to be moderately or highly contaminated by zinc in Kanshio and practically uncontaminated at North bank, Nickel and was found to be uncontaminated in Wadata. Copper was moderately or highly contaminated in Kanshio and was very strongly polluted in North bank. Therefore, Kanshio is moderately/highly contaminated and North bank is very strongly polluted as at the time of investigation.

The study revealed that if the government will allocate appropriate areas that can serve as automobile villages were repairs can be performed at a safe distance from the residential area with safe disposal of waste materials, education and legislation on waste management in places will avert the consequences of heavy metals related waste on the environment.

Compliance with ethical standards

Disclosure of conflict of interest

Authors have declared that no competing interests exist.

Author's contribution

This work was carried out in collaboration among all authors. Author RMA, GOF and OSO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MIA, EEO and FEW managed the research analyses and the literature searches. All authors read and approved the final manuscript.

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