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Heavy Metal Concentration in Groundwater in Some Selected Automobile Mechanic Villages in Makurdi, Nigeria

***Msughter Ierve Gyanggyang*[1], *Solomon Gbaa*[2]**

[1]Department of Geography, Benue State University, Makurdi
[2]Climate Observation and Research Unit, Benue State University, Makurdi
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A B S T R A C T

Over the years, industrialization, and urbanization have progressed steadily with little consideration for environmental consequences, thus resulting in groundwater pollution. This study was conducted to assess the effect of automobile mechanic workshop activities on groundwater quality in Makurdi Town, Benue State, Nigeria, to ascertain their suitability for human consumption in line with Nigerian Standards for Drinking Water Quality (NSDWQ). The study objectives included the assessment of the physicochemical parameters of groundwater, as well as the determination of levels of heavy metal concentration in groundwater within the study location. Samples were obtained from nine (9) hand-dug wells within the study location and they were analysed for six heavy metals using Atomic Absorption Spectroscopy (AAS). The results showed that the level of water contamination by heavy metals is relatively higher in the wells within the workshops, compared to the wells outside the workshops, and recommended proper sensitization of residents near mechanic villages, and appropriate treatment of water before consumption. The study also recommended remediation in cases of severe contamination, where feasible, which can be done in the form of partnerships between governments and non-governmental organizations.

Keywords: Heavy Metal, Concentration, Groundwater, Automobile Mechanic, Workshops, Pollution

1. Introduction

The term heavy metal pollution is used to describe situations where the levels of certain elements in soil and water exceed the permissible levels, potentially threatening biological life in these areas (Adelekan and Abegunde, 2011). Heavy metals enter the environment mainly through the following means: airborne particulate matter, the discharge of sludge and effluents enriched with metals, and metal mining by-products. Biochemical processes can mobilize them to pollute water supplies and impact food chains. Heavy metals such as Cu, Cr, Cd, Ni, and Pb are potential soil and water pollutants (Adnan et al., 2022). Soil and water may be polluted by heavy metal and metalloid build-up, which may be caused by emissions from fast-growing industrial waste and by-products, mine tailings, heavy metal waste, leaded gas, paints, etc, (Khan et al., 2009; Raymond and Felix 2011). Subterranean water contamination is frequent because soils are the primary repository for heavy metals and organic contaminants that are released into the environment, either immediately or over time (Duduyemi et al., 2022).

Gazso (2001) asserted that heavy metals are said to come from an array of sources, but industrial processes such as mining, refining, power generation, and to a lesser degree, home sewage are the main culprits. At very low concentrations, certain heavy metals—like Cu, Ni, and Zn—are essential to plants and animals because they function as parts of enzymes, structural proteins, and pigments and help maintain the ionic balance within cells. (Kosolapov et al., 2004). These and other trace elements are essential for the correct functioning of biological systems, and their shortage or excess can result in a variety of illnesses. The presence of heavy metals in food supply chains has been a growing concern in recent years, as they can build up in biosystems through contaminated soil, air and water. Begun et al. (2009) found that, due to urbanization and industrial activities, massive volumes of pollutants are continually being introduced into ecological systems. Metals are long-lasting pollutants that may be biomagnified in food chains, rendering them exceedingly dangerous to humans and animals alike. Heavy metal pollutants in the environment eventually end up in soils as solubility compounds, such as pyrite, or accumulate on surface-reactive phases like oxides of iron and manganese (Adelekan and Abegunde, 2011).

The most prevalent environmental pollutant detected in soils is Lead (Pb). Pb, unlike other metals, has no biological function and may be hazardous to microorganisms (Sobolev and Begonia, 2008). Its overabundance of biological creatures is always harmful. Furthermore, Pb exposure in humans can result in seizures, mental impairment, and behavioural abnormalities. Humans are exposed to heavy metals through three basic routes: inhalation, ingestion, and skin absorption. All of this occurs in a variety of settings, including auto-mechanic workplaces (Li et al., 2014).

In many parts of the world, heavy metal pollution is currently a major issue (Spurgeon et al, 2011; Ali et al, 2013). Chemically, heavy metal elements have an atomic mass greater than 20 and a gravity greater than 5g cm^3 (Kemp 1998; Oves, 2012), including Mercury (Hg), Copper (Cu), Cadmium (Cd), Lead (Pb), Nickel (Ni), Chromium (Cr), Arsenic (As) and Zinc (Zn) (Li, 2014). Metalloid arsenic is frequently placed in the heavy metal sort due to chemical characteristics and environmental response similarities (Chen, 2015; Li, 2014). Since industrialization and technological development emerged, heavy metal poisoning of farming soil has been a significant concern. Adelekan and Abegunde (2011) observed that it is typical for urban areas in Nigeria to have dedicated areas of land for clusters of small-scale automobile mechanic businesses to locate their workshops and repair yards to provide their services to the public. As a result, the greater the city, the more such mechanic villages it contains.

1.1 Effects of Heavy Metal Contamination

Toxic metals, in general, inactivate enzymes, harm cells by serving as antimetabolites, or create precipitates or chelates with important metabolites. It is assumed that this technique poses environmental risks. According to Kim (2012), instant poisoning from heavy metals by ingesting or cutaneous contact is uncommon, although it is conceivable. Long-term heavy metal exposure causes mental lapse, has toxicological effects on the kidney, liver, and gastrointestinal tract; skin infection and severe effects on the urinary tract and central nervous system. Long-term copper exposure has been linked to a decrease in cognitive ability among young people (Lenntech, 2009). Chronic cadmium exposure damages the kidneys, causes bone abnormalities, and causes cardiovascular difficulties (Goyer and Clarkson, 2001). Consuming cadmium-contaminated foods has been reported to cause increases in human ailments (Nogawa et al., 1987). Because of their limited mobility and persistent presence in the environment, heavy metals pose a risk to human and animal health (Mench et al., 1994). Pb, for example, is one of the more long-lived metals, with a soil retention time of 150 to 5000 years according to (Sobolev and Begonia, 2008). Cd, a toxic accumulation similar to lead, has a normal biologic half-life of about 18 years according to (Forstner, 1995). Due to the low mobility of these metals in the environment, a single episode of contamination could potentially lead to long-term metal exposure in humans, microbes, plants and animals, and other edaphic communities, requiring long-term monitoring efforts to evaluate the impact of these metals (Adelekan and Abegunde, 2011).

1.2 Justification for the Study

It was not until the 19th century when the effects of increasing industrialization and, as a consequence, the increasing concentration of population in towns and cities and industrial areas, that more attention was paid to the problems of industrial pollution of water and the need to protect public health through the provision of proper sanitation (Hocking, 2005). The first statute specifically aimed at controlling water pollution was the Salmon Fisheries Act 1861 which made it an offence to discharge sewage into salmon and fishing interests, rather than protection of public health.

The increasing demand for water for abstraction purposes both for domestic and industrial use in the late 19th century led to the creation of local bodies responsible for the management of the rivers which served the various towns and districts, and for those serving the major urban and industrial areas, and by the 1930s they existed for most of the more important rivers. In 1979, a Directive (08/68/EEC) on the protection of groundwater against pollution caused by dangerous substances was adopted in December 1981(Huerta-Diaz and Morse 1992). Globally, the problem of heavy metal pollution has begun to raise worry in most major cities, since it may lead to bioaccumulation and biological magnification in ecosystems. The effects of these organic compounds from automobile mechanic workshops have reached a worrying level as environmental pollution is widely distributed on the surface and in groundwater, with serious implications for the phytosanitary chain, flora and fauna, and humans (Popoola and Ayodele, 2016).

The indiscriminate citing of automobile mechanic workshops in Makurdi town can affect the quality of surface water, as well as underground water. This proposition opens up two questions; to what extent are such waters contaminated? How can the contaminated water be remediated? It is pertinent to provide answers to these questions. An attempt to answer these questions forms the focus of this work.

2. Materials and methods

2.1 Study Area

The geographical coordinates of Makurdi town are between Latitude 7°36' and 7°48' North of the equator and between longitude 8°27' and 8°38' East of the Greenwich Meridian. It includes the city centres within Makurdi Local Government Area, including Mission, Clark/Market, Wadata/Ankpa, North Bank I and Wailomayo political divisions or council wards, as well as parts of Fiidi, Modern Market, Bar and North Bank II council wards (Figure 1). Makurdi, with a land area of about 810 square kilometres and situated in the Benue Valley on the banks of River Benue, is a transit/nodal point (rail, road, and inland waterways) between the South-East and Northern parts of Nigeria (Anule and Ujoh, 2018; Nyagba, 1995; Tyubee, 2021).

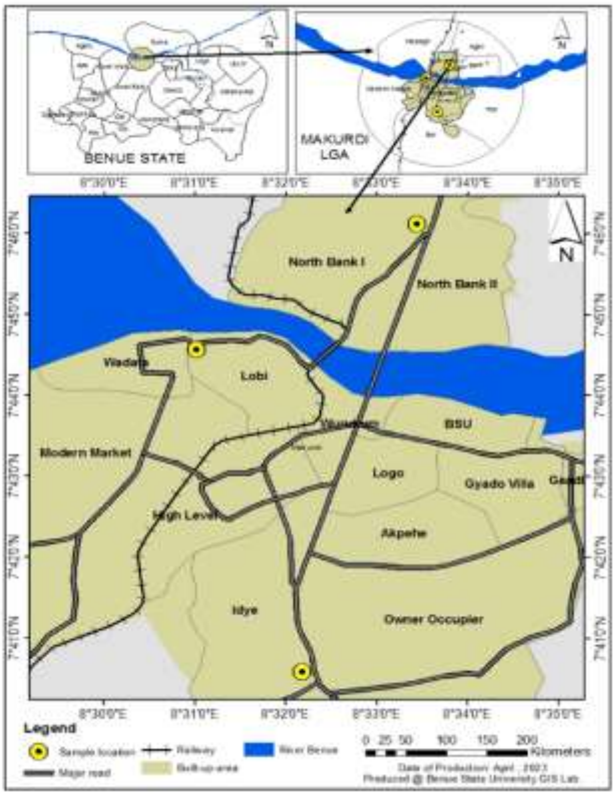

Figure 1 - Makurdi Town Showing the Study Locations

According to Shabu and Tyonum (2013), what is known as Makurdi today has been in existence since 1912. It started as a typical village composed of scattered Tiv compounds and Jukun fishermen settlements. With the advent of colonialism, Makurdi became a centre of river trade, a railway town and an administrative town. It became the provincial headquarters of Benue Province in 1927 when it was transferred from Abinsi. Following the Local Government reforms of 1970, Makurdi became the headquarters of Makurdi Division. Makurdi became the State capital in 1976 after Benue State was established from the Benue Plateau. It also serves as the seat of the Makurdi Local Government Area. The railroad and the trunk 'A' road that connects the Eastern states to the North and the Northeast make Makurdi a major crossroad centre. Makurdi's population has grown over the last 30 years. In 1991, Makurdi had a population of 226,198 with a density of 323 persons per square kilometre. In 2006, Makurdi's population figures were recorded as 300,377 with a density of over 400 persons per square kilometre, showing an annual growth rate of 3.2% according to the National Population Commission (2009). Based on the annual growth rate of 3.2% and the assumption of continuous growth at the same pace, the projected population of Makurdi in 2023 is 513,123 persons.

The town has three major mechanic villages namely; North Bank Mechanic Village, Apir Mechanic Village (near Kanshio), and the New Garage Mechanic site in Wadata as shown in Figure 1.

3. Methodology

3.1 Water Sampling and Analysis

A purposive sampling strategy was employed to select functional hand-dug wells within the three major automobile mechanic workshops (Kanshio, New Garage, and North Bank) in Makurdi town. The spatial information about the hand-dug wells was obtained with the use of a Garmin eTrex 10 Outdoor Handheld GPS Navigation Unit, while the well and water depth were measured using a 15-meter Vintage Tricle Measuring tape. Water samples were taken from nine (9) hand-dug wells, including those with no vehicle maintenance activity in the vicinity to be used as Control wells. Water samples were collected in pre-labelled, sterilized 1-litre screw-capped plastic bottles that had previously been washed, rinsed, and dried in hydrochloric acid, to prevent contamination by physical, chemical, or microbial sources.

Water samples collected from hand-dug wells in the study locations were analysed both in the field and at the Advanced Analytical Laboratory, Department of Soil Science, Joseph Sarwuan Tarkaa University, Makurdi, Benue State using the standard methods for water physicochemical analysis by American Public Health Association (APHA). The results were verified against the Nigerian Standard for Drinking Water Quality defined by the Standards Organisation of Nigeria.

4. Results

4.1 Physical Properties of Water Samples

The physical parameters of water samples from two hand-dug wells within each of the three major automobile mechanic workshops in Makurdi town, as well as a control site at each research location, are shown in Table 1. The physical parameters include pH, Temperature, Colour, Odour, Taste, Turbidity, Electrical Conductivity and Total Dissolved Solid

Table 1 - Physical properties of water samples collected from the sample sites.

Site	**pH**	**Temp. (°C)**	**Colour (TCU)**	**Odour**	**Taste**	**Turbidity (NCU)**	**Electrical Conductivity (µS/cm)**	**Total Dissolved Solids (mg/L)**
APK01	6.95	33	20	Odourless	Tasteless	12	1996	6595
APK02	6.88	32.6	15	Odourless	Tasteless	18	1698	2336
APC01	6.9	32.4	10	Odourless	Tasteless	16	1714	8668
NBM01	7.02	32.4	10	Odourless	Tasteless	15	1703	7416
NBM02	7.11	32.1	10	Odourless	Tasteless	15	7801	3977
NBC01	7.1	32	5	Odourless	Tasteless	15	1074	7904
NGM01	7.11	32	5	Odourless	Tasteless	15	9246	4187
NGM02	7.12	32	5	Odourless	Tasteless	16	1468	6287
NGC01	7.14	31.8	10	Odourless	Tasteless	17	9246	7600
NSDWQ STANDARD	6.5 - 8.5	-	15	Unobjectionable	Unobjectionable	5	1000	500

KEY

APK01: = First site at Kanshio

APK02: = Second site at Kanshio

APC01: = Control site at Kanshio

NBM01: = First site at North Bank

NBM02: = Second site at North Bank

NBC01: = Control site at North Bank

NGM01: = First site at New Garage

NGM02: = Second site at New Garage

NGC01: = Control site at New Garage

4.2 Chemical Properties of Water Samples

The chemical characteristics of groundwater samples were determined through laboratory analyses. The concentration levels of each of the parameters were analysed based on the guidelines specified by the American Public Health Association & Water Environment Federation. The heavy metals analysed in the study locations included Cadmium, Chromium, Copper, Iron, Lead, and Zinc. The results of the analysis of the water sample are shown in Table 2.

Table 2 - Chemical properties of water samples collected from the sample sites

Site	Iron (Fe) (mg/L)	Zinc (Zn) (mg/L)	Lead (Pb) (mg/L)	Copper (Cu) (mg/L)	Cadmium (Cd) (mg/L)	Chromium (Cr) (mg/L)
APK01	3.800	3.260	1.820	2.540	0.024	0.380
APK02	4.300	3.290	1.860	2.550	0.028	0.410
APC01	3.100	2.960	1.790	2.510	0.031	0.340
NBM01	3.900	3.230	1.830	2.540	0.019	0.400
NBM02	4.400	3.280	1.910	2.560	0.026	0.460
NBC01	3.000	2.980	1.800	2.510	0.016	0.360
NGM01	3.180	3.240	1.820	2.520	0.022	0.370
NGM02	3.120	3.180	1.680	2.490	0.020	0.320
NGC01	3.100	3.000	1.800	2.510	0.018	0.340
NSDWQ STANDARD	0.300	3.000	0.010	1.000	0.003	0.050

5. Discussion of results

5.1 Cadmium

Cadmium (Cd) is a heavy metal that occurs naturally in the environment, although it may also enter the environment through human activities such as automobile mechanic activities. Cd is a toxic metal that can have harmful effects on human health, even at low levels of exposure. From the results in Table 1, Cadmium concentrations in water samples varied from 0.016 milligrams per litre (mg/L) to 0.031 mg/L, with a mean Cd content of 0.023 mg/L in groundwater near automobile mechanic workshops.

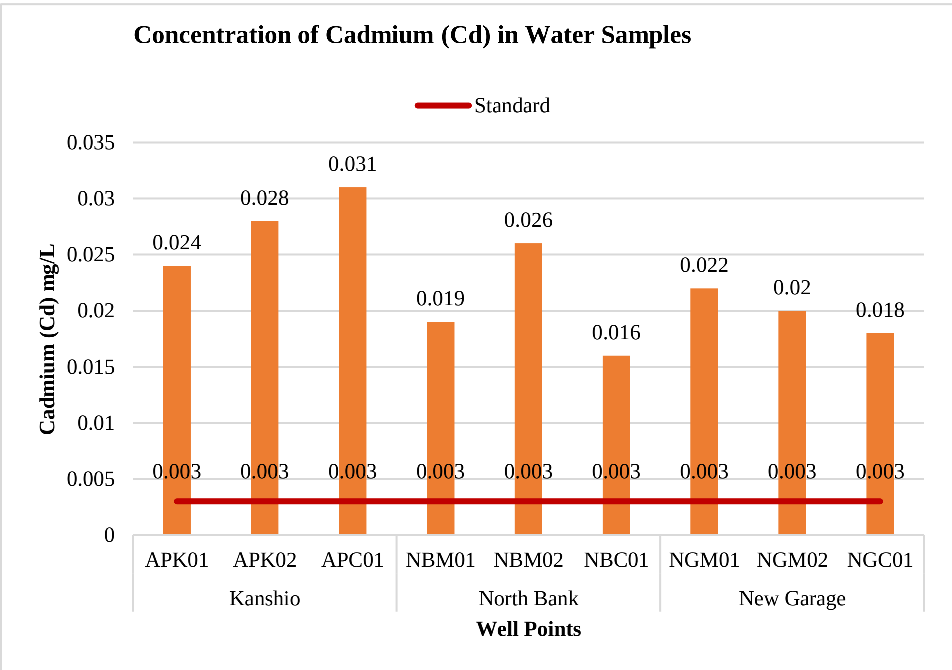

Figure 2 - Concentration of Cadmium in Water Samples from Study Locations

Figure 2 shows that the concentrations of Cd in groundwater within automobile mechanic workshops were all greater than the maximum allowable level for Cd in drinking water of 0.003 milligrams per litre (mg/L), as established by the Nigerian Standards for Drinking Water Quality (NSDWQ). The high concentrations of Cd in groundwater near automobile mechanic workshops are likely due to the use of Cd-containing products and materials in these workshops, such as brake pads, brake linings, and battery plates. Oloruntoba & Ogunbunmi (2020), in a study in South-West Nigeria on the impact on groundwater quality by activities of informal automobile mechanic workshops, reported the presence of Cadmium in all the sampled points, as well as significantly higher mean concentrations of heavy metals in groundwater than the permissible limits for both NSDWQ and WHO.

The high concentrations of Cd in groundwater near automobile mechanic workshops pose a health risk to people who drink this water. Cd can cause a variety of health problems, including kidney damage, liver damage, and cancer (Azorji et al., 2021; Sadick et al., 2015)

5.2 Chromium

Chromium (Cr) is found naturally in the environment and is used in many industrial applications, including automotive mechanics. Chromium may enter groundwater from several different sources including natural leaching from rocks and soil, industrial waste, municipal wastewater, and automobile exhaust. From the results in Table 1, the concentration of Chromium in water samples ranged from 0.32 mg/L to 0.46 mg/L, with a mean Cr concentration in the groundwater near the automobile mechanic workshops of 0.39 mg/L.

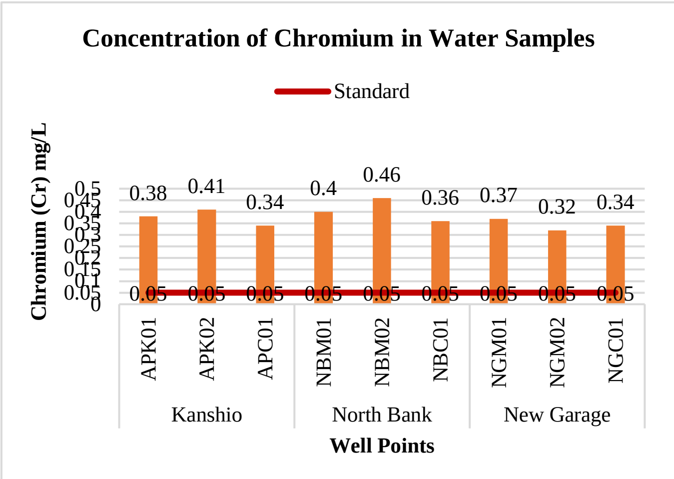

Figure 3 - Concentration of Chromium in Water Samples from Study Locations

The Nigerian Standards for Drinking Water Quality (NSDWQ) set a maximum allowed content of chromium in drinking water at 0.05 (mg/L). Figure 3 shows that the concentration of chromium in the groundwater near automobile mechanic workshops was higher than the NSDWQ limit. This suggests that automobile mechanic shops are a source of chromium contamination in the groundwater around them. Oloruntoba & Ogunbunmi (2020) in their study on the impact of informal automobile mechanic workshop activities on groundwater quality also revealed the presence of Chromium at all measured points, as well as considerably higher mean heavy metal concentrations in groundwater than the permissible limits for both NSDQW and WHO.

Chromium is a known carcinogen. It can also cause a variety of other health problems, including mouth ulcers, indigestion, acute tubular necrosis, vomiting, abdominal pain, kidney damage, liver damage, and respiratory problems (Chatterjee, 2015; Oloruntoba & Ogunbunmi, 2020). Using water from hand-dug wells within automobile mechanic workshops in the study location for drinking purposes will require some form of treatment.

5.3 Copper

Copper (Cu) is an element that is found in the earth in both elemental and mineral form. Copper plays an important role in human health. It is also a common component of many industrial and consumer products. Copper is occasionally used as a fungicide or pesticide, and it can be washed into groundwater from agricultural areas. Copper can leach into groundwater when these minerals weather or decompose. From the results in Table 1, the concentration of Cu in water samples ranged from 2.490 mg/L to 2.560 mg/L, with a mean Cu concentration in the groundwater near the automobile mechanic workshops of 2.528 mg/ L.

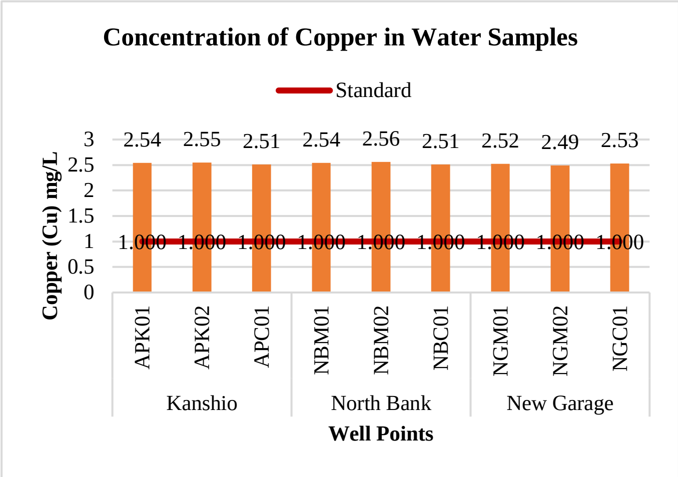

Figure 4 - Concentration of Copper in Water Samples from Study Locations

Copper in drinking water has a maximum permitted value of 1.00 mg/L according to the Nigerian Standards for Drinking Water Quality (NSDWQ). The results of this study show that the concentration of copper in the groundwater near automobile mechanic workshops was higher than the NSDWQ limit. This suggests that automobile mechanic workshops are also a source of copper contamination in the groundwater around the study locations. Oloruntoba & Ogunbunmi (2020), reported the presence of copper in all the sampled points, as well as significantly higher mean heavy metal contents in groundwater than the NSDQW and WHO allowable levels.

The amount of copper in groundwater depends on the source of copper and the geological conditions of the site. In general, groundwater near copper mines or smelters is more likely to contain high copper levels. Even groundwater in places not renowned for copper mining or smelting can have increased concentrations of copper owing to other factors such as corrosion of copper piping or agricultural runoff. Within automobile mechanic workshops, the use of copper-containing products, such as brake fluids, lubricants, and coolants, can release copper into the environment. These products can be spilt or leaked during the repair and maintenance of vehicles, and they can also be washed into the soil and groundwater during rainfall (Nduka, Kelle, Ogoko, and Okafor, 2020).

The health effects of copper depend on the level of exposure. Low levels of copper exposure are generally considered to be safe. However, high levels of copper exposure can cause a variety of health problems, including liver damage, kidney damage, and neurological problems (Jyothi, 2020).

5.4 Iron

Iron (Fe) is an element that occurs naturally in the Earth's crust. It is also a prevalent groundwater pollutant, particularly in locations with iron-rich soil or rocks. Iron may enter groundwater from several sources including the weathering of iron-rich rocks and minerals, the discharge of industrial wastewater, and the disposal of septic tank effluent, as well as by agricultural fertilizers. From the results in Table 1, the concentration of Iron (Fe) in water samples ranged from 3.00 mg/L to 4.40 mg/L, with a mean Fe concentration in the groundwater near the automobile mechanic workshops of 3.544 mg/L.

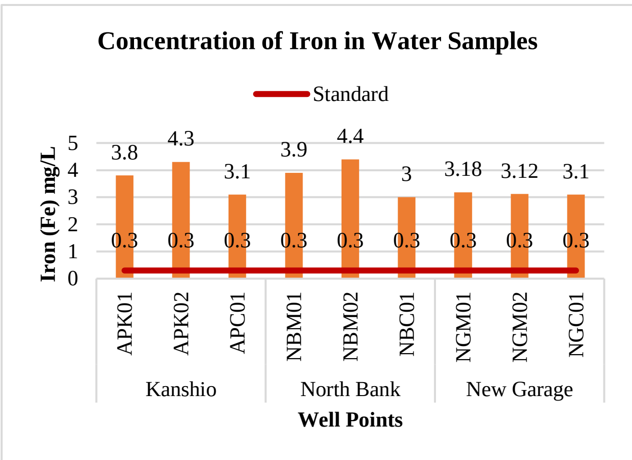

Figure 5 - Concentration of Iron in Water Samples from Study Locations

The Nigerian Standards for Drinking Water Quality (NSDWQ) limits Iron (Fe) concentration in drinking water to 0.30mg/L. According to the findings of this study, groundwater concentrations of Fe in the vicinity of automobile mechanic workshops were all above NSDWQ levels across all mechanic sites. This indicates that the activities of automobile mechanics are a contributing factor to the presence of iron in the surrounding groundwater. Pipe corrosion can occasionally be a source of iron in a drinking water supply. While iron is a non-hazardous element that is more of a nuisance in a water supply than a specific health concern, water with high iron levels tastes terrible and can bioaccumulate in the human body, causing harm to the liver, bone/bone marrow, thyroid, heart, and other glands/organs (Nduka et al., 2020; Oram, 2019).

A study by Oyeku & Eludoyin (2010), on the impact of automobile mechanic workshops on the quality of groundwater in Ibadan, Nigeria, also found that iron concentrations in wells near the workshops were significantly higher than those in wells away from the workshops, and exceeded the NSDWQ limit. They attributed this to the disposal of waste oil, grease, and metal scraps from the workshops into the environment.

5.5 Lead

Lead (Pb) is a heavy metal that can be harmful to human health. Lead can enter groundwater through natural processes like the weathering of rocks and human activities such as mining, industrial discharges, and improper waste disposal. Industries like metal smelting and battery manufacturing, as well as lead-based paint in older buildings, contribute to lead contamination. Additionally, lead can come from atmospheric deposition, agricultural practices, lead plumbing, and road traffic. From the results in Table 1, the concentration of Lead (Pb) in water samples ranged from 1.680 mg/L to 1.910 mg/L, with a mean Pb concentration in the groundwater near the automobile mechanic workshops of 1.812 mg/L.

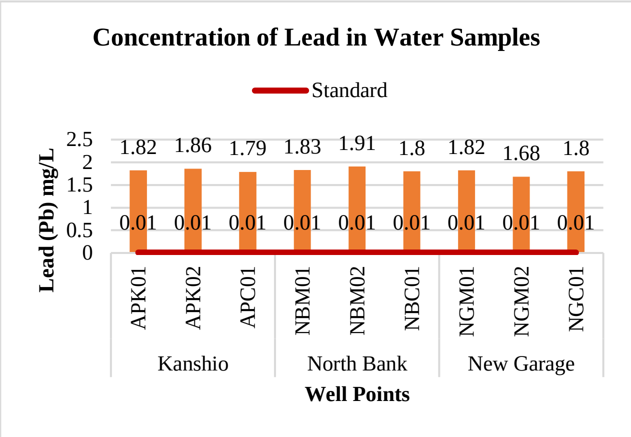

Figure 6 - Concentration of Lead in Water Samples from Study Locations

The Nigerian Standards for Drinking Water Quality (NSDWQ) establishes a maximum allowable value of 0.01 mg/L for Lead (Pb) in drinking water. According to the findings of this study, the concentration of Pb in groundwater around automobile mechanic workshops was greater than the Nigerian Standards for Drinking Water Quality (NSDWQ) limit at all mechanic locations. This suggests that automobile mechanic activities are a source of Lead contamination in the groundwater around them.

The results of the study were consistent with the findings of Oyeku & Eludoyin (2010), who investigated the influence on groundwater quality by vehicle mechanic workshops in Ibadan. They found that lead concentrations in wells near the workshops were significantly higher than those in wells away from the workshops, and exceeded the NSDWQ limit. They attributed this to the disposal of waste oil, grease, and metal scraps from the workshops into the environment. The handling of lead-containing materials such as batteries and metal scraps, as well as the use of lead-based products and cleaning solvents, can contribute to lead pollution. Also, improper waste disposal and accidental spills of leaded fluids may have led to groundwater contamination. Once lead enters the groundwater, it poses serious health risks, especially for children, including developmental delays and neurological disorders (Landrigan & Goldman, 2011).

5.6 Zinc

Zinc (Zn) is an essential trace element for human health, but it can also be toxic at high levels. From the results in Table 1, the Zinc concentrations in groundwater samples collected from the study locations ranged from 2.96 mg/L to 3.29 mg/L, with a mean Zn concentration of 3.158 mg/L.

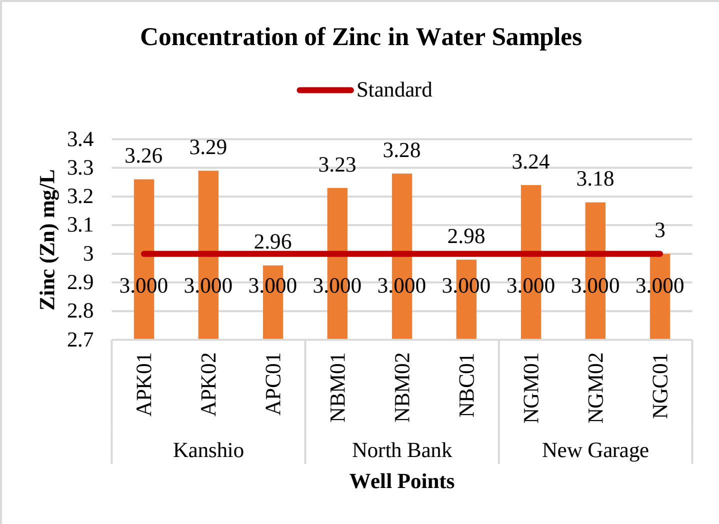

Figure 7 - Concentration of Zinc in Water Samples from Study Locations

The Nigerian Standards for Drinking Water Quality (NSDWQ) limits zinc in drinking water to 3.00 milligrams per litre (mg/L). According to this study, zinc levels in groundwater near automotive mechanic workshops were slightly above the NSDWQ limit. Zinc is one of the micronutrients required by human bodies to operate, and zinc deficiency has been linked to diarrhoea and pneumonia. Zinc poisoning symptoms include low blood pressure, urine retention, jaundice, seizures, joint pain, fever, coughing, and a metallic taste in the mouth, while elevated zinc levels have been linked to stomach cramps, nausea, and vomiting (McMahon, 2023; Oram, 2019).

Oyeku & Eludoyin (2010) found higher concentrations of Zinc in wells near the workshops in Ibadan than in wells away from the workshops. The values were also higher than the NSDWQ allowed limit for drinking water. In the same vein, in their research on the effects of automotive workshops on the presence of heavy metals in groundwater in North Central Nigeria, Odoma et al. (2013) found zinc concentrations above the maximum allowable limits in groundwater near mechanic villages in Makurdi, attributing this to the fact that zinc is used in galvanizing most iron materials, which are common in mechanic villages. Furthermore, as these materials disintegrate, the outer layer formed of Zn is the first to erode into water, contaminating it.

6. Recommendation

Given the results, the study recommends that the indiscriminate proliferation of automobile mechanic sites (commonly called mechanic villages) should be checked. Residents of homes within/around automobile mechanic shops should treat well water appropriately before consumption. Also, people should be sensitized to the health implications of consuming metal-contaminated water. Lastly, in case of severe contamination, remediation should be done where feasible. In such cases, a site characterization must be conducted to determine the type and concentration of metals present and to evaluate remedial alternatives. Metals are generally inert in subsurface environments due to precipitation or adsorptive reactions. Therefore, remediation activities in metals-affected sites should focus on solid-phase sources, i.e. contaminated soil, sludge, waste, or debris as mandated by WHO (2014).

7. Conclusion

The study found that groundwater around automobile mechanic sites is contaminated with heavy metals, which has influenced the physical properties of the water. All six (6) sites show higher concentration in values of heavy metal concentration compared to the sites outside the sites (control site). The result also conforms to previous research works captured in the literature. The study therefore recommends that the proliferation of automobile mechanic villages should be controlled, and residents within and around automobile mechanic villages should be made aware of the risks associated with drinking water contaminated with heavy metals. The study further recommends that in cases of serious water contamination, appropriate remediation measures should be taken.

References

Adelekan, B. A., & Abegunde, K. D. (2011). Heavy metals contamination of soil and groundwater at automobile mechanic villages in Ibadan, Nigeria. International Journal of the Physical Sciences, 6(5), 1045-1058.

Adnan, M., Xiao, B., Xiao, P., Zhao, P., & Bibi, S. (2022). Heavy metal, waste, COVID-19, and rapid industrialization in this modern era—fit for a sustainable future. Sustainability, 14(8), 4746.

Ali, H., Khan, E., & Sajad, M. A. (2013). Phytoremediation of heavy metals—concepts and applications. Chemosphere, 91(7), 869-881.

Anule, P., & Ujoh, F. (2018). Geospatial Analysis of Wetlands Degradation in Makurdi, Nigeria. Journal of Geography, Environment and Earth Science International, 14(4), 1–12. https://doi.org/10.9734/jgeesi/2018/39505

Azorji, J. N., Okechukwu, R. I., Udebuani, A. C., & Duru, C. M. (2021). Evaluation of Physicochemical Properties and Heavy Metal Levels in Soils from Selected Auto Mechanic Workshops in Imo State, Nigeria. Asian Journal of Advances in Research, 8(1), 19–29. https://scholar.google.com/citations?view_op=view_citation&hl=en&user=CtnEbPUAAAAJ&cstart=20&pagesize=80&citation_for_view=CtnEbPUAAAAJ:k_IJM867U9cC

Begum, A., Ramaiah, M., Khan, I., & Veena, K. (2009). Analysis of heavy metals concentration in soil and litchens from various localities of Hosur road, Bangalore, India. Journal of Chemistry, 6, 13-22.

Chatterjee, S. (2015). Chromium Toxicity and its Health Hazards. International Journal of Advanced Research, Volume 3, 167–172.

Chen, H., Teng, Y., Lu, S., Wang, Y., & Wang, J. (2015). Contamination features and health risk of soil heavy metals in China. Science of the total environment, 512, 143-153.

Duduyemi, O. Moronkolaa, O. Adebanjo, S.A. Adedeji, K.A. Adefuye, A.O. (2022). Metallic Percolations and Environmental Impacts of Spent Lubesat Local Auto-Mechanic Workshops. International Journal of Environment, Agriculture and Biotechnology Vol-7, Issue-2; Mar-Apr, 2022.

Forstner, U. 1995. Non-linear release of metals from aquatic sediments. In: Salomons, W. and Stigliani, W.M. (eds) Biogeodynamics of Pollutants in Soil and Sediments, pp 247-307. Springer-Verlag, Berlin.

Gazso L.G. (2001). The Key Microbial Processes in the Removal of Toxic Metals and Radionuclides from the Environment. A review. Cent. Eur.J. Occup. Environ. Med., 7(3): 178–185.

Goyer RA, Clarkson TM (2001). Toxic effects of metals. In: Klaassen, C.D., ed. Casarett and Doull’s Toxicology. New York: McGraw-Hill, pp. 811-868.

Hocking M.B. (2005) Handbook of Chemical Technology and Pollution Control, 3rd Edition January 2005 DOI:10.1016/B978-012088796-5/50018-1

Huerta-Diaz, M.A. and Morse, J.W. (1992) Interactions of trace metals with authigenic sulfide minerals: implications for their bioavailability.

Jyothi, N. R. (2020). Heavy Metal Sources and Their Effects on Human Health. In M. K. Nazal & H. Zhao (Eds.), Heavy Metals - Their Environmental Impacts and Mitigation (p. Ch. 2). IntechOpen. https://doi.org/10.5772/intechopen.95370

Kemp, D.D. (1998). The Environment Dictionary; Psychology Press: Hove, UK, 1998.

Kim, J.A., Lee, S.H., Choi, S.H. et al. Heavy Metal Risk Management: Case Analysis. Toxicol Res. 28, 143–149 (2012). https://doi.org/10.5487/TR.2012.28.3.143 United Nations Environmental Protection/Global Program of Action (2004). Why the marine environment needs protection from Heavy Metals, Heavy Metals 2004.

Kosolapov, D.B.; Kuschk, P.; Vainshtein, M.B.; Vatsourina, A.V.; Wiebner, A.; Kasterner, M.; Miler, R.A. 2004. Microbial Processes of Heavy Metal Removal from Carbon Deficient effluents in constructed wetlands. Eng. Life. Sci., 4(5), 403–411.

Landrigan, P. J., & Goldman, L. R. (2011). Children’s vulnerability to toxic chemicals: a challenge and opportunity to strengthen health and environmental policy. Health Affairs, 30(5), 842-850.

Lenntech, l. (2009). Heavy metals: www.lenntech.com/processes/heavy/heavymetal (http://www.lenntech.com/processes/heavy/heavy- metal). Retrieved March 12, 2011.

Li, Z.; Ma, Z.; van der Kuijp, T.J.; Yuan, Z.; Huang, L. (2014). A review of soil heavy metal pollution from mines in China: Pollution and health risk assessment. Sci. Total Environ. 2014, 468, 843–853. [CrossRef]

McMahon, M. (2023, October 9). Zinc Poisoning. The Health Board. https://www.thehealthboard.com/what-are-the-symptoms-of-zinc-poisoning.htm

Mench M.J., Fargues S. (1994). Metal uptake by iron-efficient and inefficient oats.Plant soil 165:227

National Population Commission. (2009). Legal Notice on Publication of 2006 Census Final Results. The Federal Republic of Nigeria Official Gazette, 96(2), B1–B42.

Nduka, K. J., Kelle, I. H., Ogoko, C. E., & Okafor, C. P. (2020). Review of Environmental and Public Health Impact of Automobile Wastes and Automobile Transportation in Nigeria. In Ivan Uher (Ed.), Environmental Factors Affecting Human Health (1st ed.). www.intechopen.com

Nogawa K, Honda R, Kido T, Tsuritani I, Yamanda Y (1987). Limits to Protect People Eating Cadmium in Rice, based on Epidemiological Studies. Trace Subst. Environ. Health, 21: 431-439.

Nyagba, J. L. The Geography of Benue State, Benue State the Land Great Potentials, Denga, D. J. (Ed), Rapid Educational Pub. Ltd, Calabar, 1995.

Odoma, A. N., Usman, A. A., & Ozulu, G. U. (2013). Impact of Automobile Workshop Activities on Heavy Metals in Some Ground Water of North Central Nigeria. International Journal of Water Research, 2(1), 1–4. http://www.urpjournals.com

Oloruntoba, E. O., & Ogunbunmi, T. O. (2020). Impact of Informal Auto-Mobile Mechanic Workshops Activities on Groundwater Quality in Ibadan, Nigeria. Journal of Water Resource and Protection, 12(07), 590–606. https://doi.org/10.4236/jwarp.2020.127036

Oram, B. (2019, June 27). Get Informed. KnowYourH2O. https://www.knowyourh2o.com/indoor-6/total-dissolved-solids

Oves, M.; Khan, M.S.; Zaidi, A.; Ahmad, E. (2012) Soil contamination, nutritive value, and human health risk assessment of heavy metals: An overview. In Toxicity of Heavy Metals to Legumes and Bioremediation; Springer: Berlin/Heidelberg, Germany, 2012; pp. 1–27.

Oyeku, O. T., & Eludoyin, A. O. (2010). Heavy metal contamination of groundwater resources in a Nigerian urban settlement. In African Journal of Environmental Science and Technology (Vol. 4, Issue 4). http://www.academicjournals.org/AJEST

Popoola, O.O.; Ayodele, F.O. (2016). Effects of Automobile Repair Workshop on Water Quality of Selected Area in Ado – Ekiti, Nigeria. Journal of Multidisciplinary Engineering Science and Technology (JMEST) ISSN: 2458-9403 Vol. 3 Issue 8, August – 2016.

RaymondA.W. and Felix E. O. (2011). Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. International Scholarly Research Notices https: //doi.org/10. 5402/2011/402647.

Sadick, A., Amfo-Otu, R., Acquah, S. J., Abrefa Nketia, K., Asamoah, E., & Adjei, E. O. (2015). Assessment of Heavy Metal Contamination in Soils around Auto Mechanic Workshop Clusters in Central Agricultural Station, Kumasi-Ghana. Applied Research Journal, 1(2), 12–19. http://www.arj.presbyuniversity.edu.gh

Shabu T. & Tyonum T. E. (2013). Residents Coping Measures in Flood Prone Areas of Makurdi Town, Benue State Journal of Applied Ecology and Environmental Sciences, 1(6), 120-125.

Sobolev D, Begonia MFT (2008). Effects of Heavy Metal Contamination upon Soil Microbes: Lead-induced Changes in General and Denitrifying Microbial Communities as Evidenced by Molecular Markers. Int. J. Environ. Res. Public Health, 5(5): 451.

Spurgeon, D.J.; Lawlor, A.; Hooper, H.L.; Wadsworth, R.; Svendsen, C.; Thomas, L.D.; Ellis, J.K.; Bundy, J.G.; Keun, H.C.; Jarup, L. (2011). Outdoor and indoor cadmium distributions near abandoned smelting works and their relations to human exposure. Environ. Pollut. 2011, 159, 3425–3432. [CrossRef] [PubMed]

Standards Organization of Nigeria. (2015a). Nigerian Standard for Drinking Water Quality. Nigerian Industrial Standard (NIS 554), 16–22.

Tyubee, B. T. (2021). Estimating Per Capita Land Use/Land Cover Change (LULCC) in Makurdi, Northcentral Nigeria. Urban Studies and Public Administration, 4(1), p97. https://doi.org/10.22158/uspa.v4n1p97

World Health Organization (W.H.O) (2014). W.H.O Guidelines for Drinking Water Quality, 4th Ed, Available: http://www.who.int, 2014.