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Filling Stations and Their Effects on Groundwater Quality in Ilorin Metropolis

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Abstract: The study aimed to assess groundwater quality of hand-dug wells at close proximities to filling stations in Ilorin metropolis. The study involved analyses for physicochemical and heavy metal constituents of the water samples. The sample size was purposively selected across the three (3) local government areas of Ilorin, twenty-six (26) accessible functioning stations above 15 years of establishment in the metropolis with hand-dug wells within or around its premises were chosen. Samples were analyzed for physicochemical parameters such as Temperature, Turbidity, Conductivity, Total Dissolved Solid, Total Hardness, Calcium, Magnesium, Chloride, Fluoride, Ammonia, Nitrate, Nitrite, and Heavy metals like Lead, Chromium, Cadmium, Iron, Zinc, Copper, Nickel using standard methods. Results were compared with the Nigerian Standard for Drinking Water Quality which revealed anomaly in concentration of some parameters such as Turbidity, Conductivity, Total Dissolved solids, Total Hardness, Lead, Cadmium, Chromium, and Nickel at some stations. The results from the combined physicochemical and heavy metal analyses of the water samples indicated activities of the filling stations within the area may have polluted groundwater in the environment posing an aesthetically unappealing situation and great health risk to consumers of the water resources.

Keywords: Groundwater, Filling Stations, Physicochemical, Heavy Metals, Water Quality

1. Introduction

Water quality which entails the physical, chemical, and biological properties of naturally occurring water for its designated use can be influenced by natural or anthropogenic activities, causing a deviation from norm hence posing possible health risk to consumers and users of the resource [1]. This is a global concern as over 80% of diseases and deaths in low – middle income countries are related to bad/low water quality [2, 3]. Among the numerous sources of pollutants, some of the reported cases include accidental spills of chemicals, improper waste disposal (liquid and solid), pesticides applications, fertilizers application, runoffs from agricultural sites, waste ponds (sewerage and its likes), septic tanks, salt water intrusion, acid mine drainage, leakages of underground storage tanks, pipeline and injection wells etc. [4, 5].

In Nigeria, there is a geometric increase in the construction of filling stations at irregular and clustered patterns at close proximities to residential settlements nationwide [6-9]. This unchecked proliferation is an issue of environmental and health concern as there are reports of soil and groundwater pollution by leaking underground tanks from filling stations globally [4, 8, 10-16]. Hence, great risks to human health and the environment are posed by unregulated construction of filling stations in our communities. The study hereby

assessed the groundwater quality of hand-dug wells at close proximities to filling stations in Ilorin metropolis.

2. Materials and Methods

2.1. Area Description and Sample Size Determination

The study was carried out across Ilorin Metropolis, which is the urban centre of the ancient Ilorin emirate (the present day capital town) of Kwara State, North-Central, Nigeria. It lies within coordinates of Latitude 8° 30'N and Longitude 4° 30'E respectively and it covers an approximated area of 180 sqkm within 765 sqkm of the three (3) local government areas in Ilorin town. (Figure 1)

The sample size for the present study was purposively selected based on some criteria, a multi-step approach was used to select the final size of the filling station sampled in the study, at the time of study, a total of 297 stations were identified within the Ilorin town across all local governments (Ilorin West, East and South), where 199 stations were within the metropolis, and 166 were functioning [9]. Of the functioning stations, based on the age inclusion criteria, a total of 68 stations were found to be above 15 years of establishment and finally 29 filling stations had wells within its premises or at close proximity. A total of 26 stations were eventually sampled as some challenges were faced in assessing water samples at 3 stations. The limitation of the study to stations above 15 years was guided by a finding that most Chinese made oil quality single tank (like the one's majorly used here in Nigeria) has an average life expectancy of 8 years [17], and hand-dug wells are the most available source of potable water in the metropolis (Figure 2).

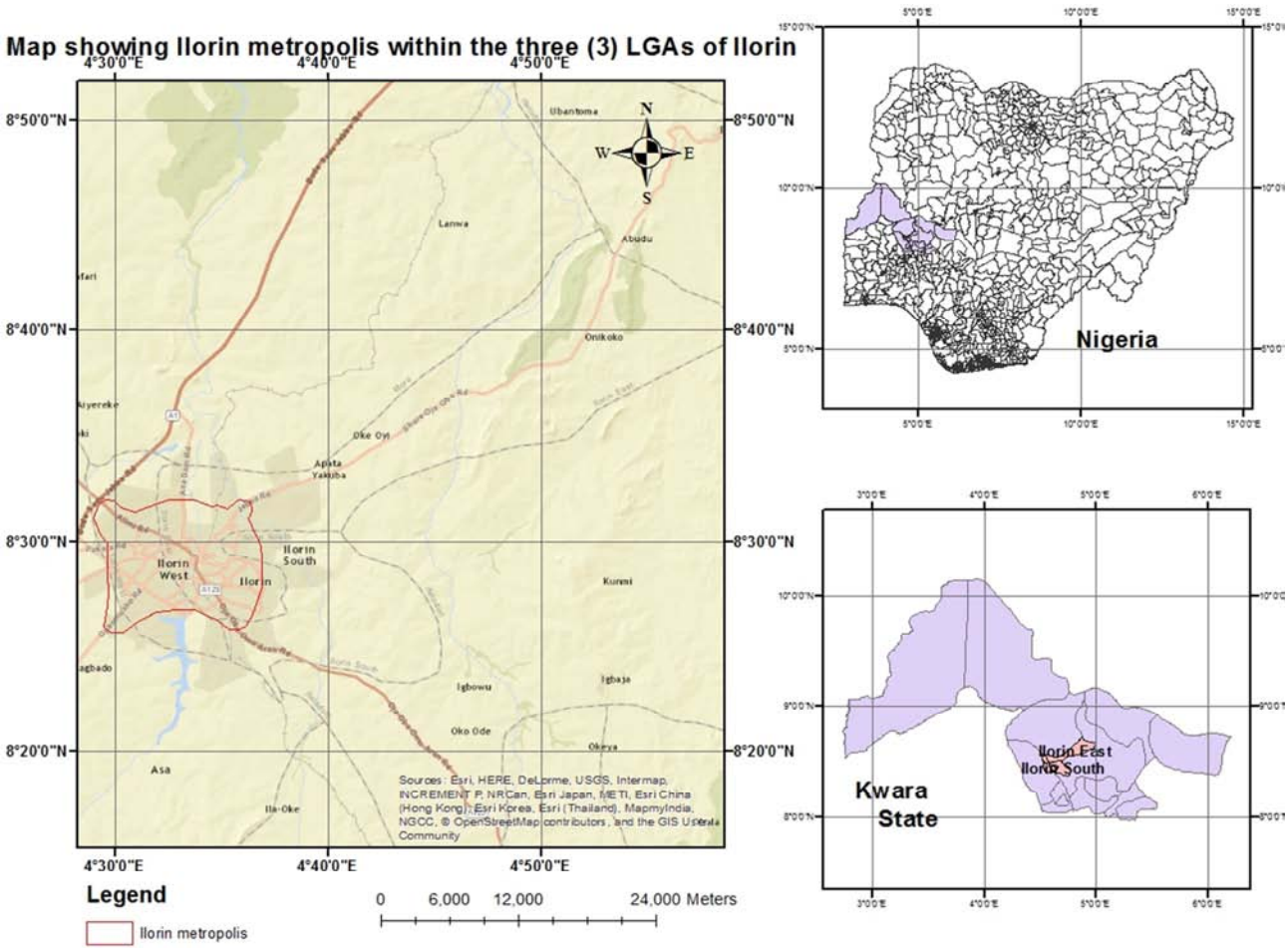

Figure 1. *Showing the map of Ilorin metropolis within the three (3) local government areas of Ilorin town.*

2.2. Water Sample Collection and Analysis

Groundwater samples were collected from hand dug wells within and around the premises of 26 filling stations that were above 15years of age and functioning. The distance of the well (sample points) to the underground storage tanks were measured. The method of sampling was the grab/spot sampling. The water samples were collected into 100ml sample bottles, which were labelled at the point of collection and transported to the laboratory for analysis immediately. Duplicate samples were also taken from the sampled wells for precision.

While collecting water samples, some physical measurements were taken at the sample location to give more scientific details of the surrounding environment before further analysis were carried out in the laboratory.

Samples were analysed for different physico-chemical

parameters such as, temperature, turbidity, pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl-), Fluoride (F-), Ammonia (NH_3), Nitrate (NO_3^-), and Nitrite (NO_2) following described standard procedures [31].

Heavy metals were measured using the atomic absorption spectrophotometer. This method as described by the Association of Official Analytical Chemist (2005) [32] was used for mineral analysis. The heavy metals measured were Lead (Pb), Cadmium (Cd), Copper (Cu), Chromium (Cr), Nickel (Ni), Zinc (Zn) and Iron (Fe).

The quality of groundwater was later compared to the Nigerian drinking water quality standards [18] desirable limit for the measured parameters.

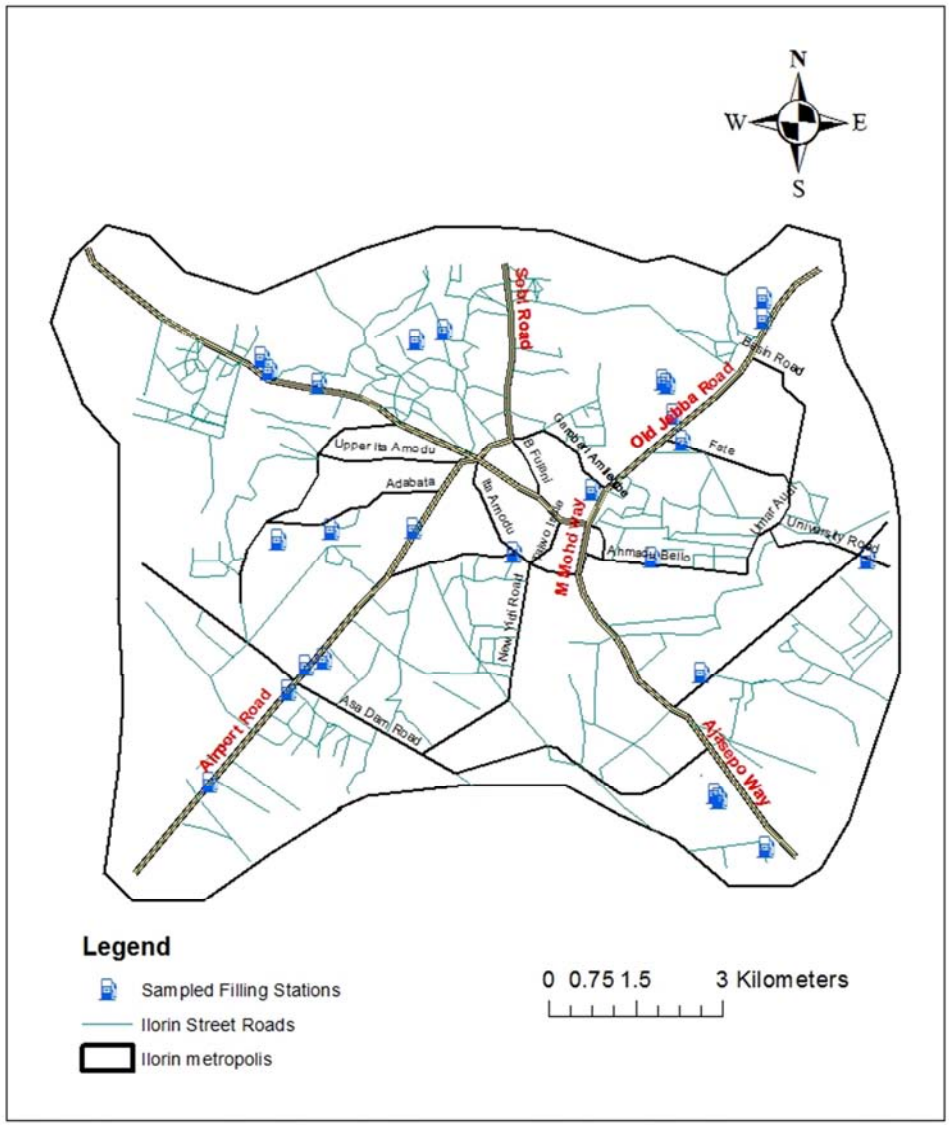

Figure 2. *The Spatial Distribution of the Selected Sample Stations.*

3. Results

The study revealed that 23 (88.5%) of the 26 water sources were located within the filling stations and a total of 17 (65.4%) were at a distance of less than 30 m from the Underground storage tanks in these stations.

3.1. Physicochemical Parameters

Table 1 presents the profiles of the physicochemical parameters at each station. After which parameters with significant values indicating possible anomaly from the country's standards for drinking water were represented in Figures 3 - 6 showing the variations for Turbidity, Conductivity, Total Dissolved solids, and Total Hardness.

3.2. Heavy Metals Concentration

Table 2 presents the results of the heavy metal concentrations at the sampled stations. After which parameters with significant values indicating possible anomaly from the country's standards for drinking water are represented in Figures 7 - 10 showing the variations of concentrations in Lead (Pb), Cadmium (Cd), Chromium (Cr), and Nickel (Ni).

Table 1. *Mean values of Physico-chemical characteristics of Water Samples from Hand Dug wells around Filling Stations.*

SAMPLED STATIONS	T (°C)	TBD. (NTU)	pH	CON. (µS/cm)	TDS (mg/l)	TH (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl^- (mg/l)	F^- (mg/l)	NH_3 (mg/l)	NO_3 (mg/l)	NO_2 (mg/l)
A	26.9	5.5	7.1	975	558	375	53	40	263	0.16	0.11	8.12	0.11
B	27.0	5.4	7.2	970	553	370	52	45	256	0.13	0.11	8.11	0.12
C	27.0	5.5	7.1	965	540	355	50	42	260	0.18	0.12	8.11	0.11
D	27.3	5.4	7.1	980	565	384	54	42	265	0.18	0.12	8.11	0.12
E	27.1	5.4	7.1	960	538	355	52	44	260	0.17	0.11	8.12	0.12
F	26.6	2.1	7.1	733	515	220	54	34	262	0.18	0.14	4.10	0.10
G	27.3	8.2	7.3	215	294	168	20	116	155	0.12	0.20	10.14	0.30
H	27.5	8.4	7.3	218	297	165	20	119	158	0.11	0.25	10.15	0.30
I	26.8	2.2	7.0	748	520	225	54	35	253	0.18	0.14	4.10	0.10
J	27.8	9.0	7.4	205	98	154	63	20	14	0.06	0.25	10.20	0.30
K	27.3	5.6	7.2	950	555	350	55	40	255	0.18	0.25	8.15	0.16
L	27.2	5.6	7.2	960	240	144	85	40	40	0.16	0.18	8.14	0.13
M	27.7	8.8	7.4	200	295	160	28	12	150	0.14	0.21	10.17	0.31
N	27.3	5.8	7.3	955	564	360	57	38	260	0.16	0.11	8.15	0.15
O	27.9	9.0	7.4	202	94.3	161	60	18	12	0.05	0.20	10.17	0.30
P	26.8	2.8	7.3	730	508	215	57	32	251	0.34	0.14	4.12	0.12
Q	27.0	2.9	7.2	741	508	220	53	32	252	0.38	0.14	4.12	0.11
R	27.3	5.7	7.3	950	553	350	55	42	254	0.14	0.13	8.14	0.15
S	27.2	5.8	7.1	960	570	375	59	40	263	0.17	0.18	8.14	0.15
T	27.0	2.8	7.2	734	215	142	15	39	32	0.12	0.14	4.12	0.12
U	27.3	5.8	7.1	946`	564	345	54	41	251	0.17	0.11	8.14	0.14
V	27.2	5.8	7.3	960	340	141	53	46	38	0.15	0.11	8.15	0.15
W	27.3	5.8	7.2	946	260	133	52	48	42	0.15	0.10	8.14	0.13
X	27.8	8.9	7.5	205	298	163	29	14	155	0.13	0.27	10.2	0.32
Y	27.3	5.7	7.1	960	253	130	42	47	40	0.14	0.24	8.15	0.15
Z	27.3	5.9	7.2	950	268	138	64	49	42	0.15	0.13	8.14	0.15
NSDQW [18]	Ambient	5	6.5-8.5	1000	500	150	75	2.0	250	1.5	-	50	0.2

N.B: T- Temperature, TBD- Turbidity, CON- Conductivity, TDS- Total Dissolved Solid, TH- Total Hardness, Ca- Calcium, Mg- Magnesium, Cl^-- Chloride, F^-- Fluoride, NH_3- Ammonia, NO_3- Nitrate, NO_2- Nitrite, NSDQW – Nigerian Standard for Drinking Water Quality.

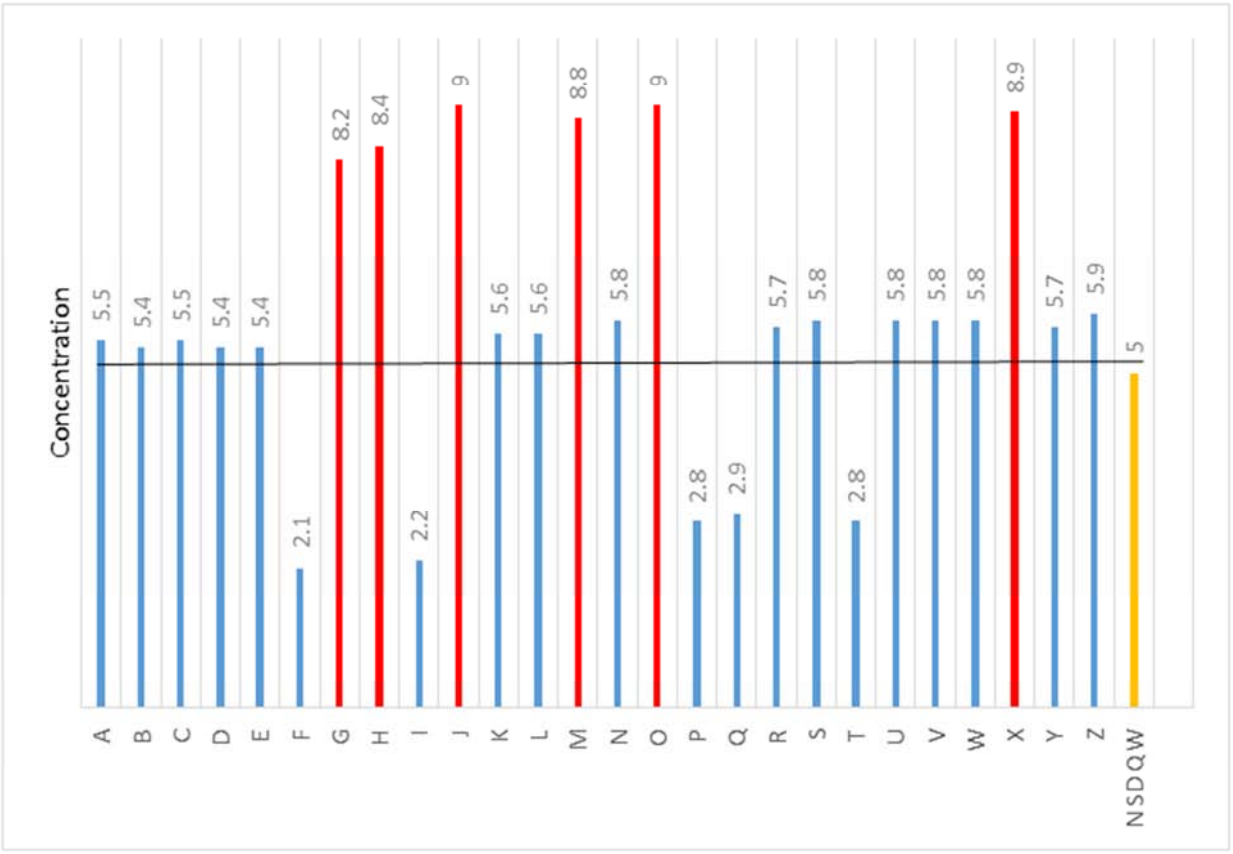

Figure 3. *Concentration of turbidity of water samples from sampled stations.*

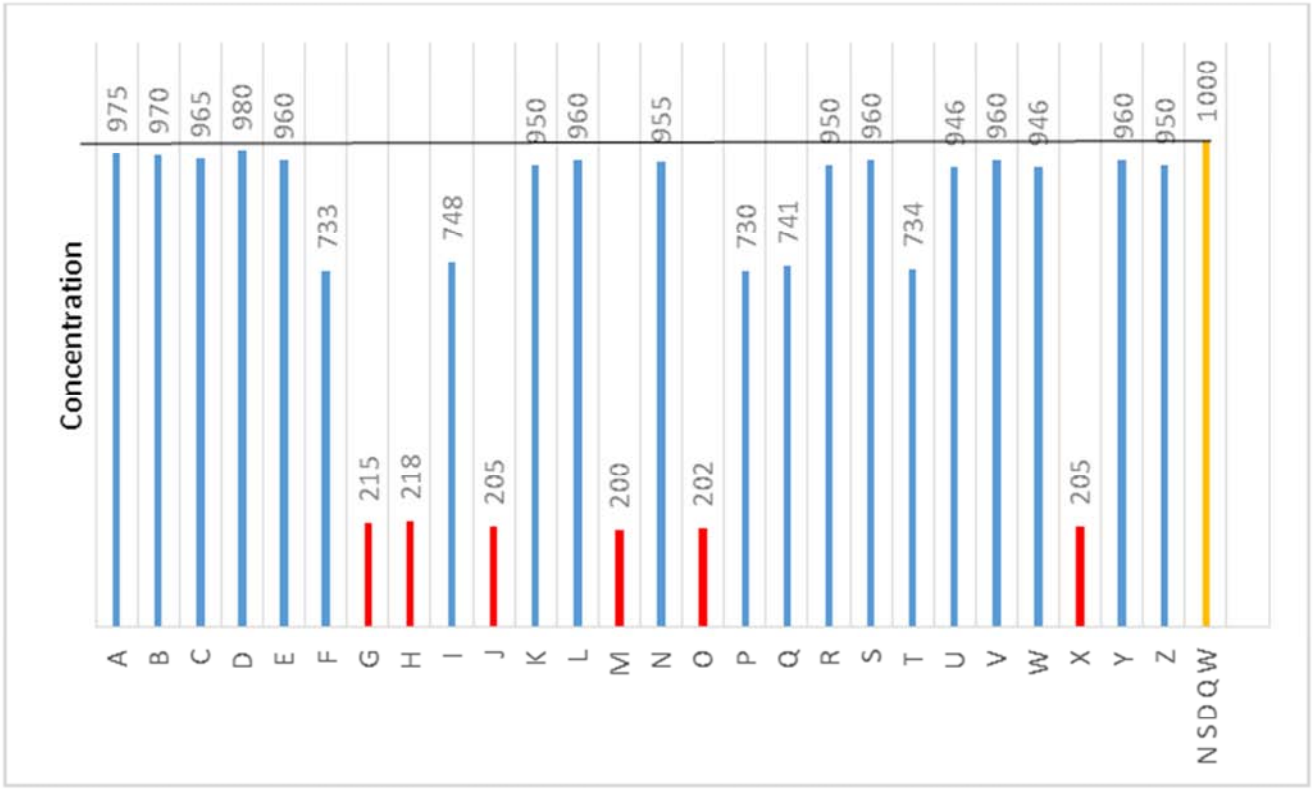

Figure 4. *Concentration of hydraulic conductivity of water samples from sampled stations.*

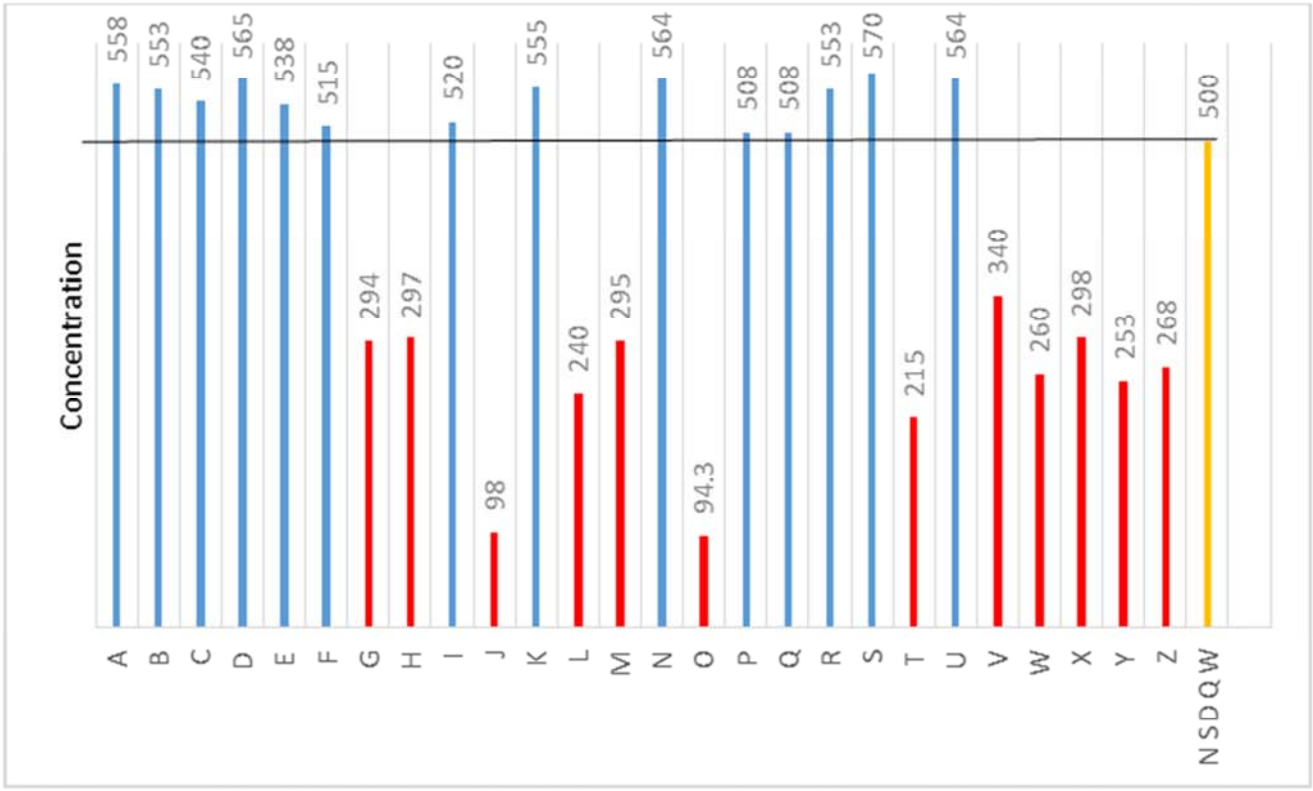

Figure 5. *Concentration of total dissolved solids in water samples from sampled stations.*

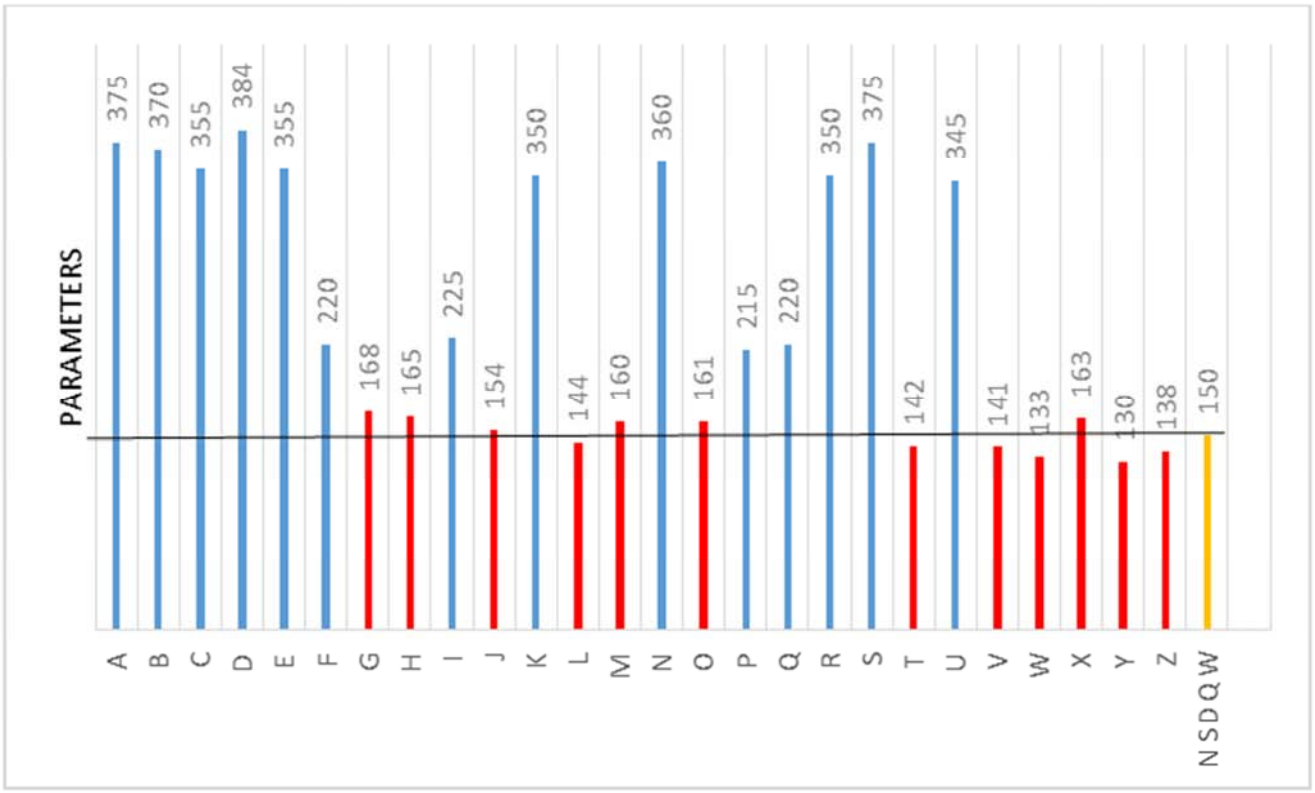

Figure 6. *Concentration of total hardness in water samples from sampled stations.*

Table 2. *Heavy metal concentration of Water Samples.*

SAMPLED STATIONS	Pb (mg/l)	Cd (mg/l)	Cu (mg/l)	Cr (mg/l)	Ni (mg/l)	Zn (mg/l)	Fe (mg/l)
A	0.01	N.D	0.03	N.D	0.01	0.01	0.01
B	0.02	N.D	0.03	0.01	0.01	0.01	0.01
C	0.04	0.01	0.02	N.D	0.02	N.D	0.03
D	0.05	N.D	0.04	0.08	N.D	N.D	0.03
E	N.D	N.D	0.01	0.01	0.03	N.D	0.03
F	N.D	N.D	0.07	0.06	0.01	N.D	0.05
G	N.D	N.D	0.01	N.D	0.01	N.D	N.D
H	N.D	N.D	N.D	N.D	N.D	N.D	N.D
I	N.D	N.D	N.D	0.05	N.D	N.D	N.D
J	0.01	0.01	0.08	N.D	0.03	N.D	N.D
K	0.01	N.D	N.D	0.03	0.01	0.01	0.03
L	0.03	N.D	N.D	0.03	N.D	0.01	0.03
M	0.01	N.D	N.D	N.D	N.D	N.D	0.03
N	0.01	0.01	0.08	0.03	N.D	N.D	0.03
O	0.04	N.D	0.02	N.D	N.D	0.01	0.03
P	N.D	N.D	N.D	0.01	N.D	N.D	0.02
Q	N.D	N.D	0.03	N.D	N.D	N.D	0.02
R	0.01	0.01	0.02	N.D	N.D	0.01	0.02
S	0.03	0.01	0.04	N.D	0.02	0.01	0.02
T	N.D	N.D	0.01	N.D	0.01	0.01	0.05
U	N.D	N.D	N.D	0.01	N.D	N.D	0.01
V	N.D	N.D	0.01	N.D	N.D	N.D	0.01
W	0.02	N.D	N.D	0.04	N.D	N.D	0.07
X	0.02	N.D	N.D	0.05	N.D	N.D	0.01
Y	0.01	N.D	N.D	0.03	0.05	N.D	0.15
Z	0.01	N.D	0.02	0.03	N.D	N.D	0.17
NSDQW [18]	0.01	0.003	1.00	0.05	0.02	3.00	0.30

N.B: Pb- Lead, Cr- Chromium, Cd- Cadmium, Fe- Iron, Zn- Zinc, Cu- Copper, Ni- Nickel, N.D- Not detected, NSDQW – Nigerian Standard for Drinking Water Quality.

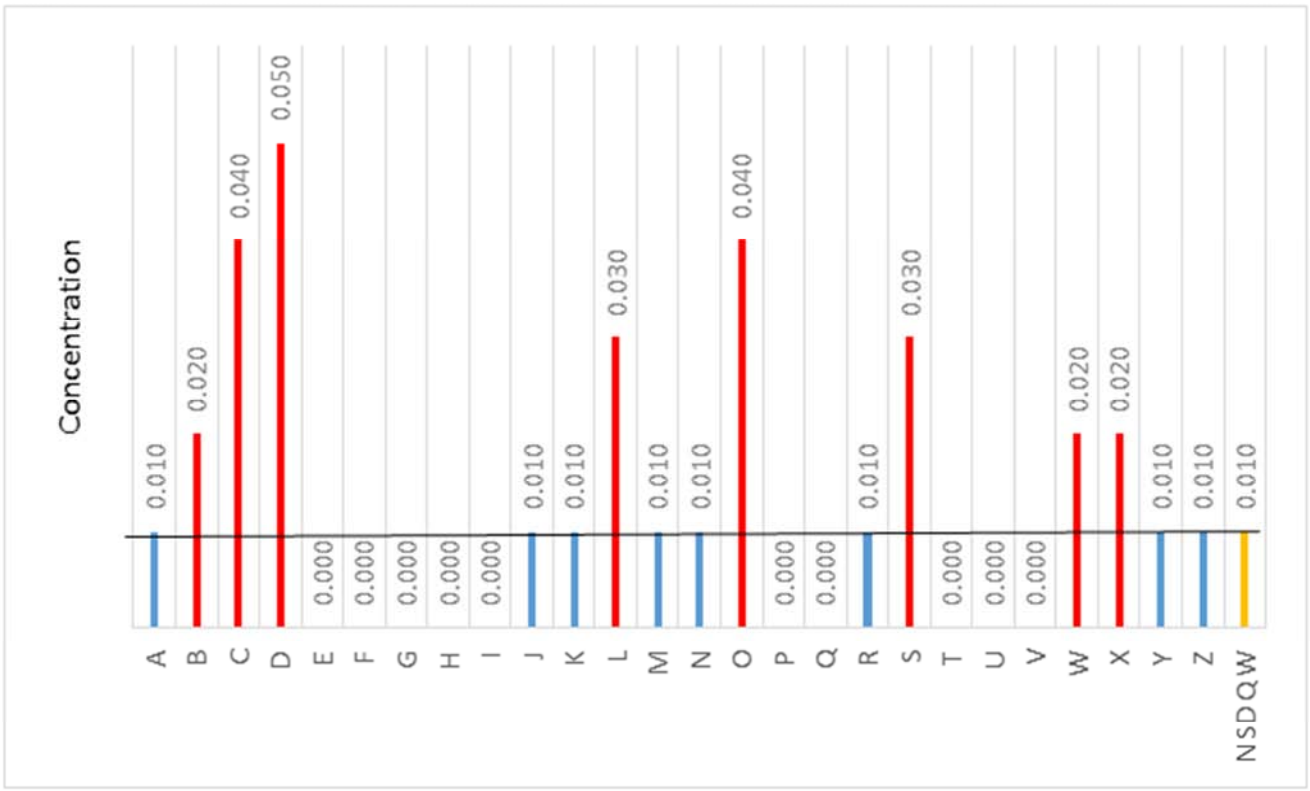

Figure 7. *Concentration of lead in water samples from sampled stations.*

Figure 8. *Concentration of cadmium of water samples from sampled stations.*

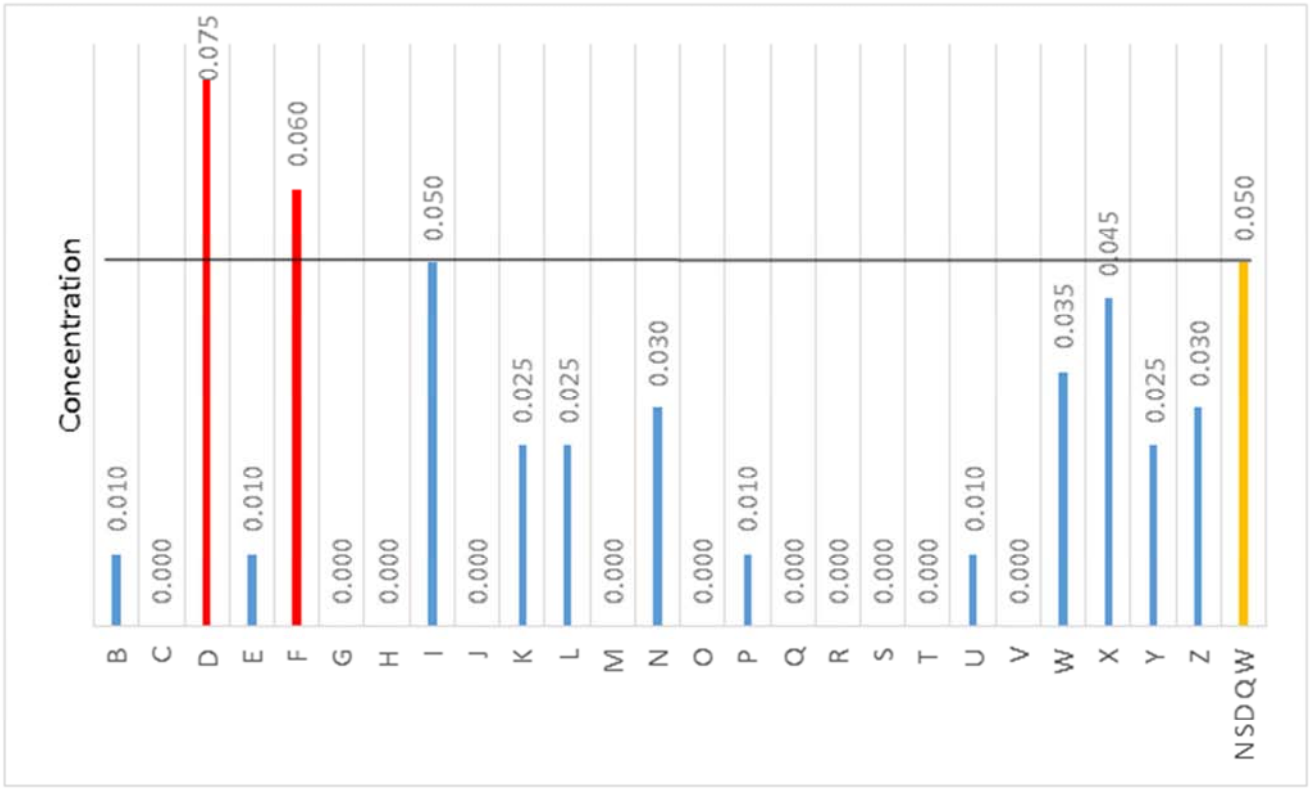

Figure 9. *Concentration of chromium in water samples from sampled stations.*

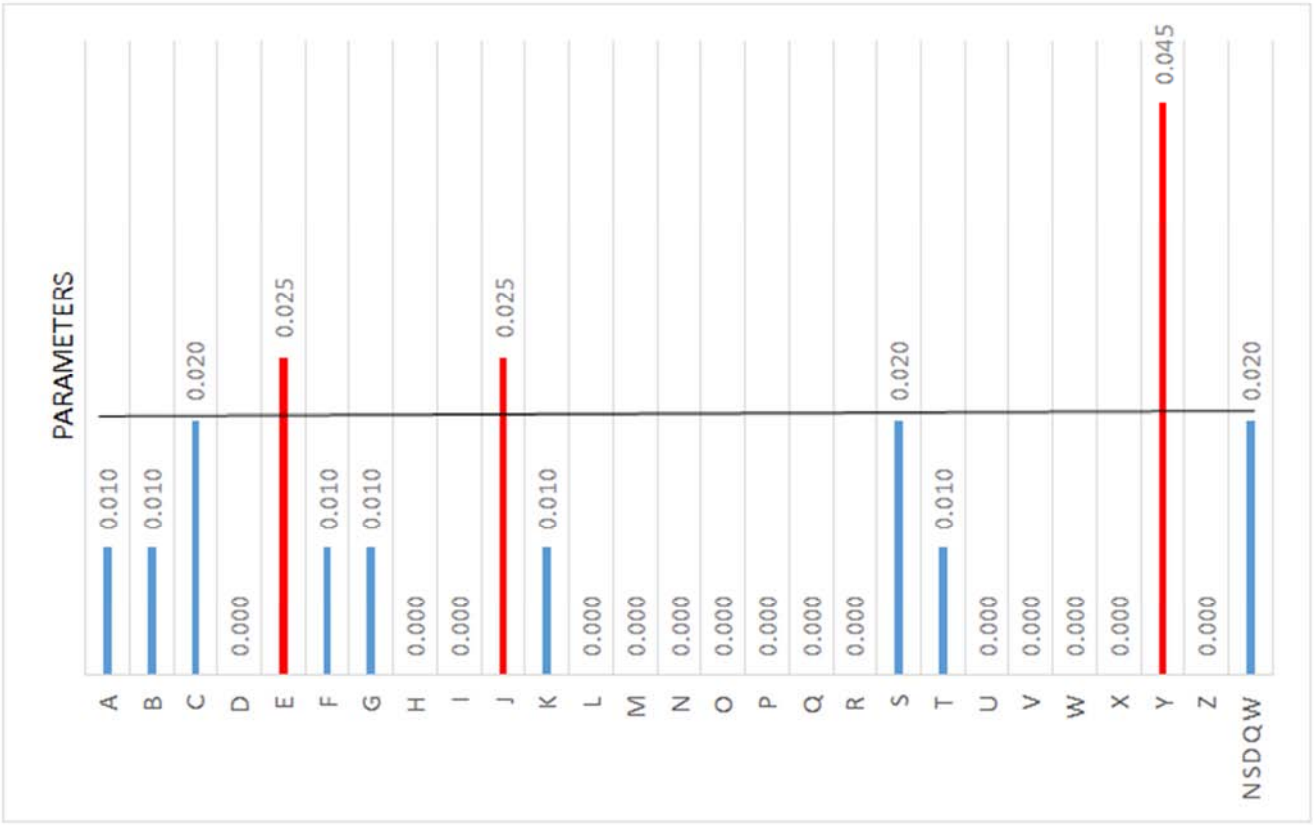

Figure 10. *Concentration of nickel in water samples from sampled stations.*

4. Discussion

4.1. Physico-chemical Assessment of Water Samples at Sampled Stations

The basic hydrographic parameters, the temperature measured across all samples were ambient, while the average turbidity values showed only 19% of the samples fell within the acceptable threshold value of 5 NTU [18], 58% were slightly higher than the acceptable standard falling with a range of 5.4 – 5.9, while 23% had values higher than 8.2 (Samples G, H, J, M, O, X). Similar findings were observed in Chen *et al.,* [17] where high turbidity values were recorded indicating possible high concentration of hydrocarbon and other pollutants but this showed that the concentration of ammonia, turbidity and nutrients concentration decreased with time as natural attenuation and organic decomposition took place in the hydrocarbon polluted zones, hence the significant high values in this study might be attributed to the release of pollutants into the environment which brought about the objectionable values.

The conductivity measured in µS/cm were also below the threshold value of 1000 µS/cm indicating resistivity but significant anomalies were observed in some samples (G, H, J, M, O, X) with low conductivity values in the range of 202 – 218. According to Atekwana *et al.*, [19], it was observed that hydraulic conductivity in an aquifer contaminated with hydrocarbon is lowered (possibly by the high resistivity property of hydrocarbons) and increases with time as attenuation processes sets in or influx of ionic elements in the environmental media. Inferring, some or all of these stations might have possibly contaminated the water sources around them.

Total dissolved solids (TDS) measured in mg/l across all samples ranged from 94.3 – 565 where 54% of the samples had values higher than the permissible limit of 500 mg/l. TDS comprises of inorganic substances and small amounts of organic compounds that are dissolved in water [20, 21].

4.2. Heavy Metals Concentration

The health risk impacts of heavy metals even at low concentrations make it a required assessment for water quality determination [22, 26, 30]. Hence the exact idea of water quality was determined when concentrations of these elements were compared to the NSDWQ [18].

Across all samples as shown on Table 2, the result revealed that Pb, Cd, Cr and Ni all had high concentrations when compared to the NSDWQ [18] acceptable limits in some of the samples while Cu, Zn and Fe across all samples had concentration within the National permissible limit for drinking water standard.

Lead (Pb) were undetected in samples E, F, G, H, I, P, Q, T, U, V, however, low concentrations the same as the NSDWQ standards (0.01mg/l) were detected in samples A, J, K, M, N, Y, Z while the higher values (0.02 – 0.05 mg/l) were detected in samples B, C, D, L, O, S, W, X. (Figure 7). This observation corroborates the findings by [33] that Pb concentrations were found in groundwater and could be released into the environment from anthropogenic sources related to handling of petroleum products or mechanic workshops.

Cadmium (Cd) were undetected in samples A, B, D, E, F, G, H, I, K, L, M, O, P, Q, T, U, V, W, X, Y, Z, while the higher concentrations than the NSDQW [18] permissible limit value (0.003mg/l) were detected in samples B, C, D, L, O, S, W, X with values of 0.01mg/l (Figure 8). In comparison to the study where groundwater quality was also measured at close proximity to petrol stations and mechanic workshops in Calabar metropolis, Nigeria [33], concentrations of Cd in the present study where detected were also higher than the permissible limits which suggests the identified stations possibly operates a mechanic workshop within its vicinity too as reported that Cd are associated with batteries [34].

Chromium (Cr) were undetected in samples A, C, G, H, J, M, O, Q, R, S, T, V, however, lower concentrations below and also the same as the NSDWQ standards (0.05mg/l) were detected in samples B, E, I, K, L, N, P, U, W, X, Y, Z while the higher values (0.060 & 0.075 mg/l) were detected in samples F and D respectively (Figure 9). In comparison to the study where groundwater quality was also measured at close proximity to petrol stations and mechanic workshops in Calabar metropolis, Nigeria [33], concentrations of Cr in the present study were lower and mostly within the permissible limits. A possible source of Cr is from anticorrosive chemicals [34].

Nickel (Ni) were undetected in samples D, H, I, L, M, N, O, P, Q, R, U, V, W, X, Z however, lower concentrations and the same as the NSDWQ standards (0.02mg/l) were detected in samples A, B, C, F, G, K, S, T while the higher values (0.025 – 0.045 mg/l) were detected in samples E, J and Y (Figure 10). The values of Ni in this study were lower and 88% fell within the permissible limits unlike when compared to Nganje, Edet & Ekwere, [33] where all the value were higher than the referenced data.

Although, heavy metals are naturally existing in the earth media but major sources of contaminants are through anthropogenic sources [22]. Sources of the prominent compounds with high concentrations from this study such as Pb, Ni, Cd and Cr include electroplating industries, detergents and refined petroleum products, metallic materials, automobiles parts, stainless steel, galvanized pipes and piping networks, wastewater etc. [23 -25]. Hence, the introduction of these compounds could be due to leaching, runoffs and underground flow of percolated water from the surrounding stations into the groundwater system.

4.3. Possible Health Risk from the Pollutants Identified

The physical parameters mentioned above e.g. turbidity, TDS, TH might not significantly in itself pose a health risk but render the water aesthetically unappealing [18, 27]. Turbidity which is the presence of finely suspended or colloidal particles can inhibit the chemical reaction of treatments on pathogens by shielding them hereby indirectly promoting water-related diseases [21, 28]. Total dissolved

solid (TDS) are majorly inorganic salts dissolved in water, limited information is available on its possible health effects but considered unappealing to consumers when content is high in drinking water as it influences the odour and taste [21, 29]. Total hardness- an indication of the presence of magnesium and calcium also poses no health risk normally but could be detrimental for people with kidney diseases [27].

Unlike the physical parameters, the heavy metals found in the samples with high concentrations are majorly toxic elements and poses great health effects even at low concentrations. Lead (Pb) has been reported to cause health defects such as brain damage, cancer, brain tumours, neonatal defects, anaemia, central and peripheral nervous system breakdown [18, 21, 22]. Nickel (Ni) at high concentration can cause DNA damage, decrease body weight, skin eczemas (water-washed infection), and noted as possibly carcinogenic [21, 22, 27]. Cadmium (Cd) is known to cause damage to the kidney, bones in both young and old, also responsible for bronchitis, anaemia [18, 21, 22]. Chromium (Cr) at high level of exposure can damage the liver and kidney, skin ulceration and also affect the central nervous system [21, 22].

5. Conclusion

Based on the findings, the low conductivity (high resistivity) characteristics across all samples, with high turbidity, high concentrations of lead, cadmium, chromium, and nickel at significant levels revealed the possibility of groundwater contamination from underground storage tanks and other related activities in these filling stations, which depicts that the untreated continuously use of these water sources and uncontrolled activities of these filling stations poses health risk to the consumers and people around them.

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