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Trace Metals in Surface and Subsurface Water in Kaduna South Industrial Area North-Central Nigeria

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Abstract: This study discusses the analysis of trace elements constituents in parts of Kaduna South industrial area of the Basement Complex of North-Central Nigeria which is necessary to ensure that objectionable elements like Cr, As and Pb whose ingestion in high doses can have serious consequences on the health of the populace, are not significant in the water. In line with this, 22 water samples were obtained, three from boreholes, eleven from surface water and 8 from hand-dug wells and analysed for the presence of 19 trace metals in the study area. The trace metals concentration levels were compared with the regulation. K, Ca, Mn, Zn and Cu were within the maximum contaminant level (mcl) accounting for 23.62% while V, Cr, Fe, Co, Ni, Ga, As, Se, Pb, Br, Rb, Sr, Zr and Mo, whose concentration level exceed the maximum contaminant level (mcl) accounting for 73.68% of the total contaminants. The high percentage of trace metals that exceed the maximum contaminant level suggests that the water within the study area may be classified as been highly polluted and thus unfit for drinking especially regard to Arsenic, Lead and Chromium content. Domestic and industrial waste should be properly disposed and recycled. The government industrial regulating bodies should make conscientious effort to control, regulate and educate the industries and the populace on indiscriminate waste disposal from domestic and industries within the study area.

Key words: Trace metals, surface water, boreholes, hand-dug wells, maximum contaminant level

INTRODUCTION

Water is the most important single commodity in human civilization but it is also responsible for most diseases and deaths in the developing countries due to contamination. The quality of water depends upon the major and minor elements constituents, which also depend on the quality of the sources of water and the distribution (Oteze, 1990). Lack of proper waste disposal in an environment has been recognized as one of the major sources of anthropogenic pollution/contamination in many urban cities of the developing countries (Uduezue, 2004).

In many cases, solid wastes are dumped directly on the land, in shallow excavations as well as along the rivers and stream channels. These waste decay and like liquid waste, infiltrate into the subsurface water source. The study area have a lot of industries which include; textiles, petrochemicals, iron and steel, breweries, fertilizer plants, flour mills, automobile, glass industries, food and beverage industries etc. Thus high amount of solid, liquid and gaseous waste are dumped or discharged into the environment. These wastes contain trace metals like Arsenic, Chromium, Lead, Selenium, etc, which are objectionable because their ingestion in high doses can have serious health effects. Some even at low doses can be very hazardous (Wikipedia, 2005).

The purpose of this study is to ascertain that a potent health related danger in the presence of toxic trace metals as a result of industrial and domestic activities within the study area is not being overlooked. Also, to ascertain the trace metals present and their level of occurrence and compare with the (WHO, 2004; EPA, 2005) standard and other regulating bodies. This study will also educate the government and the people on the health implication of these wastes and proffer possible solutions.

Literature review: Trace metals are defined as metals in extremely small quantities almost at the molecular level that reside in or are present in animal and plant cells and tissues. They are a necessary part of good nutrition (Wikipedia, 2005). Adriano (2001), said that some of these trace metals like mg, Zn, etc are essential at low concentrations while others like As, Pb, Cd, etc are toxic even at relatively low concentrations.

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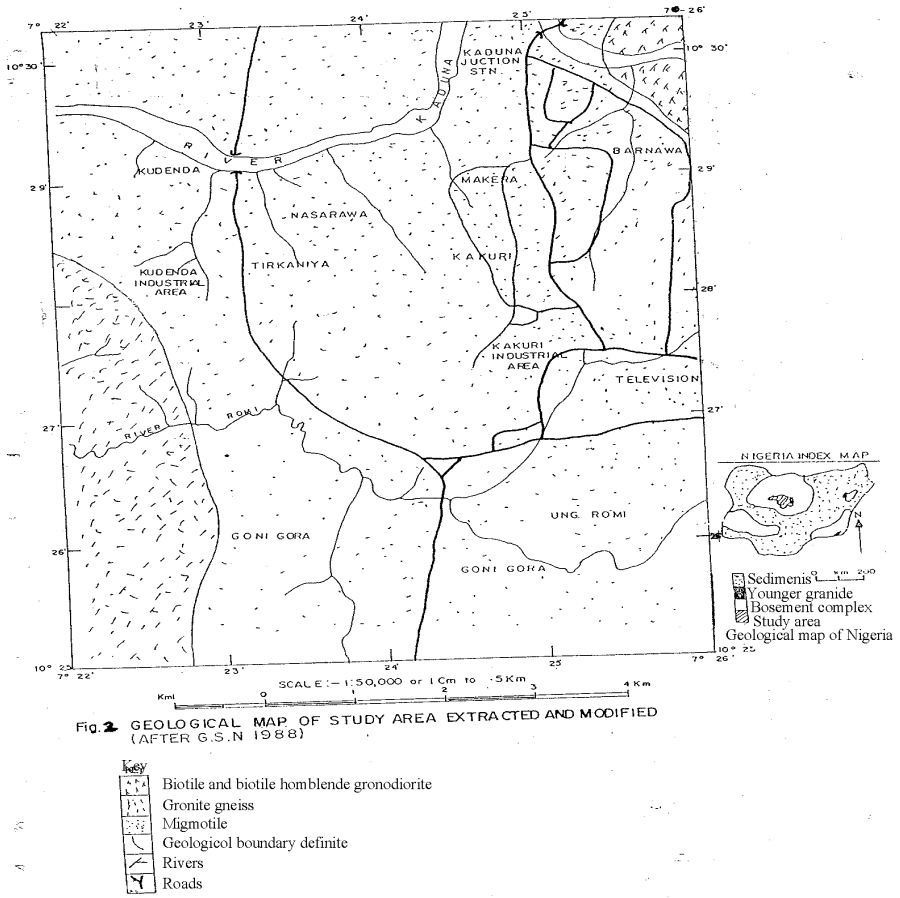

Fig. 1: Geological map of study aera extracted and modified (After G.S.N, 1988)

Russ (1957), Olugboye (1975) and Ajibade (1976) stated that the area is underlain by the crystalline Basement Complex composed mainly of metamorphic rocks. The major rivers include River Kaduna, Rigasa and Romi rivers. The study area lies in the North central part Nigeria, on latitudes 10°25'N and 10°30'N and longitudes 7°22 and 7°26'E and accessible by networks of major and minor roads with a total area coverage of 63.55 km^2 (Fig. 1).

Mbonu (1992) carried out a study of the hydrogeology of basement rocks of North Central Nigeria. His work concentrated on the groundwater quality and reported that 91% of sampled water points both surface and groundwater sources have nitrates concentration less than 45 mg L^{-1}. Jatau and Ajodo (2005) carried out some preliminary assessment of groundwater quality of some shallow wells around Kaduna metropolis revealed that the water are dominated by alkaline earths elements. The water was slightly acidic with high hydrocarbonate ion and low percentage of sulphate and chloride ion. Jatau *et al.* (2006) in their preliminary geo-environmental studies of parts of Kaduna North metropolis stated that some wells were slightly acidic, high iron concentration is wells in Kurminmashi, vegetable analysis indicate high concentration of nitrates. They further stated that the microbial analyses obtained from both ground and surface water samples contain Coli-form bacteria. *Escheria coil* (*E. coil*) was found in almost all the water and soil samples in parts of Kaduna North metropolis. They stated that leaches from waste came into contact with the ground water through dilution and weathering processes.

Farr (2001), stated that the body needs iron to fight bacterial infection but that above the recommended limit, iron may damage the cells in the liver and heart. Conterminal transport processes are advection, diffusion and may be responsible for groundwater pollution (Robinson and Stokes, 1959). The X-ray fluorescence (XRF) is electromagnetic radiations whose wavelengths are useful for trace elements detection and lie in the 0.1-10 A range (Oteze, 1990; Bertin, 1997). They are generated when a stream of high energy elections strike a material and then a quantum of energy is released which is characteristic for each element (Nnanedu, 1989).

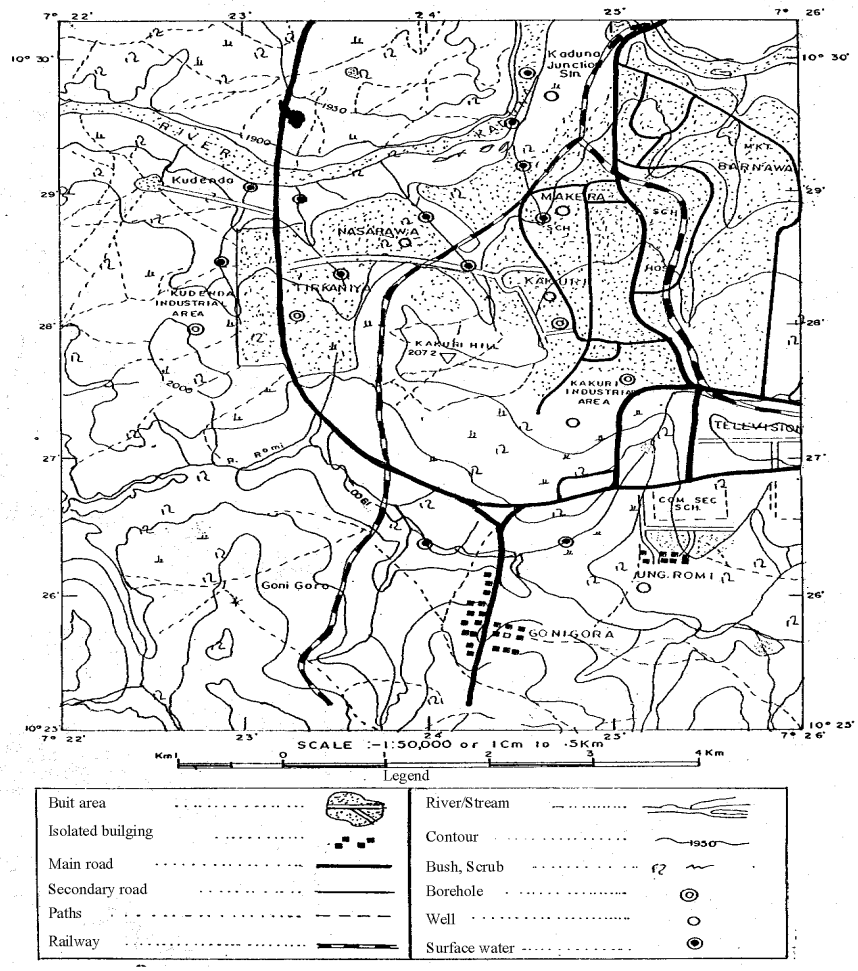

Fig. 2: Map of study area extracted and modified after Northern Nigerian survey, Kadund (1965-1988 showing sampling points)

MATERIALS AND METHODS

The water samples were collected from three boreholes, 8 hand-dug wells and 6 surface water points. Twenty-two water samples were collected in total from 8 locations within the study area (Fig. 2). Spectro-chemical analyses of these samples were done at the centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria. Samples from surface water were collected 1 km apart. The water samples were each colleted in 500 mL plastic containers which were rinsed three times. They were all collected in one day in the first week of August, 2006 during the rainy season and preserved in the refrigerator before been taken for analysis. The XRF method was used for the analysis.

RESULTS AND DISCUSSION

Table 1 shows the concentration in mgl of each of the 19 trace metals in the 22 water samples analyzed and their corresponding (WHO, 2004) and other relevant standards. The average concentration of each trace metals for borehole samples with their corresponding (WHO, 2004) and other standards revealed that in the Kakuri area, the average concentration of the following trace metals (V, Cr, Fe, Co, Ni, Ga, As, Pb, Br, Sr and Zr) exceed the maximum contaminant level of (WHO, 2004) and other regulating standards while K, Ca, Mn, Cu, Zn, Rb and Mo are below the regulating standards. The concentration of selenium was found to be at the border.

The average concentration of each trace metal for only hand-dug well samples shows that in the Railway

Table 1: Geochemical analysis results of the study area

S/N	Trace Metal	B/H-1 Kakuri UNTL Qtrs	B/H-2 Kudenda	B/H-3 Kakuri Barrack	WELL-1 Kakiuri 1	WELL-2 Makera	WELL-3 Railway Qtrs.	WELL-4 Nassarawa	WELL-5 Trikania	WELL-6 U/Romi	WELL-7 Kakuri Ind. Area II	WELL-8 Kakuri Ind. Area III
1	Le	2.01	1.34	1.57	2.47	3.00	3.19	2.45	2.15	2.21	2.03	3.01
2	Ca	1.49	1.39	1.18	2.13	2.78	3.64	2.03	1.91	1.78	1.71	2.08
3	V	0.43	0.29	0.32	0.58	0.68	0.74	0.56	0.49	0.61	0.58	0.57
4	Cr	0.38	0.27	0.34	0.51	0.52	0.57	0.49	0.48	0.44	0.44	0.44
5	Mn	0.22	0.17	0.19	0.39	0.49	0.43	0.42	0.45	0.31	0.43	0.43
6	Fe	0.41+	0.34+	0.93+	0.74+		0.50+		0.63+	0.50+	0.77+	
		0.09	0.12	0.10	0.15	0.35	0.17	0.29	0.35	0.13	0.13	0.15
7	Co	0.18	0.14	0.20	0.23	0.28	0.32	0.23	0.24	0.23	0.28	0.25
8	Ni	0.12	0.09	0.10	0.20	0.31	0.25	0.19	0.16	0.21	0.17	0.18
9	Cu	0.10	0.07	0.10	0.17	0.23	0.19	0.14	0.13	0.14	0.19	0.16
10	Zn	0.08	0.06	0.07	0.13	0.25	0.16	0.12	0.12	0.12	0.14	0.20
11	Ga	0.09	0.06	0.06	0.12	0.14	0.21	0.11	0.12	0.11	0.11	0.14
12	As	0.11	0.06	0.07	0.15	0.18	0.18	0.19	0.12	0.12	0.12	0.15
13	Se	0.05	0.04	0.05	0.08	0.14	0.13	0.08	0.11	0.07	0.08	0.11
14	Pb	0.15	0.09	0.01	0.22	0.25	0.26	0.28	0.17	0.17	0.17	0.21
15	Br	0.04	0.03	0.03	0.06	0.11	0.10	0.09	0.06	0.06	0.06	0.07
16	Rb	0.04	0.03	0.03	0.07	0.08	0.09	0.06	0.05	0.06	0.05	0.07
17	Sr	0.03	0.03	0.03	0.06	0.08	0.07	0.06	0.05	0.06	0.07	0.06
18	Zr	0.03	0.02	0.02	-	-	-	-	-	-	-	-
19	Mo	0.03	0.02	0.02	0.04	0.05	0.06	0.44	0.04	0.04	0.04	0.05

S/N	Trace Metal	S/W-1 Makera	S/W-2 R. Kaduna I	S/W-3 R. Kaduna II	S/W-4 Nassarawa I	S/W-5 Nassarawa II	S/W-6 Kudenda I	S/W-7 Kudenda II	S/W-8 Trikania I	S/W-9 Trikania II	S/W-10 River Romi I	S/W-11 River Romi II	WHO Standard (Mg L^{-1})
1	Le	2.88	2.86	2.18	3.08	2.88	3.00	2.25	2.45	2.78	2.82	2.88	200
2	Ca	2.42	1.81	2.16	1.75	2.64	2.25	1.90	1.78	2.25	1.96	2.48	200
3	V	1.00	0.49	0.55	0.51	0.79	0.84	0.69	0.70	0.63	0.53	0.68	0.05
4	Cr	0.73	0.57	0.39	0.39	0.63	0.56	0.40	0.43	0.50	0.38	0.64	0.10
5	Mn	0.48	0.40	0.33	0.34	0.46	0.46	0.36	0.43	0.41	0.30	0.43	0.50
6	Fe	0.74+		0.50+			0.34+				0.52+		
		0.34	0.13	0.28	0.12	0.38	0.38	0.12	0.25	0.33	0.26	0.17	0.30
7	Co	0.30	0.23	0.25	0.21	0.28	0.41	0.23	0.32	0.27	0.23	0.30	0.001
8	Ni	0.24	0.17	0.16	0.16	0.25	0.26	0.22	0.16	0.22	0.16	0.26	0.02
9	Cu	0.21	0.51	0.16	0.14	0.20	0.20	0.14	0.14	0.18	0.17	0.22	1.30
10	Zn	0.18	0.14	0.11	0.17	0.16	0.21	0.16	0.11	0.18	0.12	0.16	15
11	Ga	0.15	0.10	0.10	0.11	0.17	0.16	0.10	0.11	0.13	0.11	0.17	0.009
12	As	0.22	0.13	0.17	0.13	0.27	0.19	0.13	0.14	0.17	0.13	0.21	0.10
13	Se	0.11	0.07	0.08	0.07	0.10	0.11	0.07	0.07	0.10	0.09	0.11	0.05
					0.20+								
14	Pb	0.31	0.21	0.24	0.10	0.39	0.27	0.19	0.20	0.26	0.17	0.30	0.015
							0.10+						
15	Br	0.09	0.07	0.06	0.07	0.11	0.04	0.08	0.08	0.09	0.06	0.10	0.005
16	Rb	0.12	0.06	0.05	0.08	0.08	0.08	0.06	0.05	0.07	0.06	0.09	0.054
17	Sr	0.09	0.05	0.07	0.05	0.07	0.08	0.05	0.05	0.07	0.05	0.11	0.005
18	Zr	-	-	-	-	-	-	-	-	-	-	-	0.002
19	Mo	0.06	0.04	0.04	0.04	0.05	0.05	0.04	0.04	0.04	0.06	0.06	0.07

*All units are in Mg L^{-1}, *B/H: Borehole; SW: Surface water; Qtrs: Quarters

quarters area the concentration level of the following trace metals (V, Cr, Fe, Co, Ni, Ga, As, Se, Pb, Br, Rb and Sr) exceed the maximum contaminant level while K, Ca, Mn, Cu, Zn and Mo are below the recommended standard. The average concentrations of each trace metal for only surface water samples revealed that in the Nasarawa area the following trace metal (V, Cr, Fe, Co, ni, Ga, As, Se, Ph, Br, Rb and S) exceed the maximum containment level while (K, Ca, Mn, Cu, Zn and Mo) are below the maximum containment level. The results also show that the hand-dug well and surface water samples are more contaminated compared to the borehole samples. This may be attributed to the depth at which the boreholes were sunk and casing/screens which offer more protection against contaminants.

Chromium: The concentration ranges from 0.41-0.63 mg L^{-1}. This is much higher than the maximum standard of 0.10 mg L^{-1} (EPA, 2005) revealed that the common source of chromium contaminant in drinking water is through the discharge from steel and pulp mills while the potential health effect as a result of continuous exposure to crisis allergic dermatitis. It is also carcinogenic when inhaled (EPA, 2005).

Table 2: Average contaminant concentration in all the locatioins sampled (mg L^{-1})

S/N	Location	Contaminants K	Ca	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	As	Se	Pb	Br	Rb	Sr	Zr	Mo
1	Kakuri	2.15	1.66	0.48	0.41	0.32	0.67	0.22	0.15	0.14	0.12	0.10	0.12	0.07	0.14	0.05	0.05	0.05	0.03	0.04
2	Kudenda	1.99	1.80	0.53	0.38	0.29	0.35	0.23	0.17	0.12	0.13	0.10	0.11	0.07	0.06	0.06	0.05	0.05	0.02	0.04
3	Makera	2.94	2.60	0.84	0.63	0.49	0.35	0.29	0.28	0.22	0.22	0.15	0.20	0.13	0.28	0.10	0.10	0.09	-	0.06
4	Railway Qtrs	3.19	3.64	0.74	0.57	0.43	0.50	0.32	0.25	0.19	0.16	0.21	0.18	0.13	0.26	0.10	0.09	0.07	-	0.06
5	Nassarawa	2.72	2.13	0.61	0.50	0.41	0.37	0.24	0.20	0.16	0.15	0.13	0.20	0.09	0.29	0.09	0.07	0.06	-	0.26
6	Trikania	2.39	1.97	0.58	0.48	0.44	0.32	0.27	0.17	0.15	0.14	0.12	0.14	0.10	0.20	0.08	0.09	0.06	-	0.04
7	Ungwan Romi	2.53	2.00	0.61	0.48	0.34	0.51	0.25	0.21	0.17	0.13	0.13	0.15	0.09	0.21	0.07	0.07	0.07	-	0.05
8	R. Kaduna	2.52	1.99	0.52	0.48	0.37	0.51	0.24	0.17	0.34	0.13	0.16	0.15	0.08	0.23	0.07	0.06	0.06	-	0.04
	Average	2.21	2.22	0.61	0.49	0.39	0.45	0.26	0.19	0.19	0.15	0.04	0.16	0.10	0.21	0.08	0.07	0.06	0.03	0.07
	Standard (MCL)	200	200	0.05	0.10	0.50	0.30	0.001	0.02	1.30	15	0.009	0.10	.05	0.015	0.005	0.054	0.005	0.002	0.07

Iron: The concentration ranges between 0.32-0.67 mg L^{-1} whereas the WHO (2004) standard is 0.30 mg L^{-1}. The body needs iron to fight bacterial infection, however excessive iron can damage the cells of the gastrointestinal tract and may also damage the cells in the heart and liver (Adriano, 2001).

Copper: Its concentration level of between 0.12-0.34 mg L^{-1} is below the (WHO, 2004) standard of 1.30 mg L^{-1}. Although the water is fit for drinking but all Cu compounds, unless otherwise known should be treated as if they were toxic because of its ability to accept and donate single electrons as it changes oxidation state (Farr, 2001). Common sources of contaminating drinking water are from the corrosion of household plumbing systems and erosion of natural deposits. Long term exposure may lead to liver or kidney damage (EPA, 2005).

Arsenic: The concentration level is between 0.11-0.18 mg L^{-1}. This is higher than the allowable limit of 0.10 mg L^{-1}. The potential health from over exposure effect is skin damage of problems with circulatory systems. It may also increase the risk of getting cancer while the common source of contamination in drinking water are run off from glass and electronics production wastes and erosion of natural deposits (EPA, 2005).

Selenium: It occurs between 0.07-0.13 mg L^{-1} and is above the WHO (2004) standard of 0.05 mg L^{-1}. Over exposure may lead to hair or finger nail loss, numbness in fingers or toes, circulatory problem while the common source of contamination of drinking water is discharge from petroleum refineries and mines and also erosion of natural deposits (Solovov, 1987; EPA, 2005).

Lead: The concentration range is between 0.06-0.29 mg L^{-1}. It exceeds the WHO (2004) allowable standard 0.15 mg L^{-1} and constant exposure may lead to delays in physical or mental development in infants and children while adults may have kidney problems and high blood pressure. Lead contaminates water from the corrosion of household plumbing systems and erosion of natural deposits (EPA, 2005).

Bromine: The concentration level is between 0.05-0.10 mg L^{-1}, which exceeds the Ontario (2000) regulation of 0.005 mg L^{-1}. Therefore, the water may be considered hazardous to health from a long term exposure.

Strontium: The concentration level of between 0.005-0.09 mg L^{-1}, is higher than the Ontario (2000) allowable limit of 0.005 mg L^{-1}. Continuous exposure to untreated water may poise a serious health hazard.

Nickel: The concentration range is between 0.15-0.28 mg L^{-1}, which exceeds the WHO (2004) standard 0.02 mg L^{-1}, which also stated that Ni concentration beyond the allowable limit may cause dermatitis (insensitivity in people).

Vanadium: The concentration levels vary from 0.48-0.84 mg L^{-1}. This therefore exceed the maximum contaminant level of 0.05 mg L^{-1}. Accumulation of this metal due to continuous exposure may cause a serious health set-back.

Zinc: The concentration level is between 0.12-0.16 mg L^{-1} which is below the WHO (2004) standard of 15 mg L^{-1}. However, signs of Zn deficiency include hair loss, wasting of body tissues and eventually death while too much of it suppresses Cu and Fe absorption (Farr, 2001).

Table 2 also shows that Kudenda area has the least concentration of As that is 0.11 mg L^{-1} while Nasarawa has the highest concentration of this highly toxic metal. Also Kakuri area is the least contaminated with Pb while Nasarawa again tops the area most contaminated with Pb. A close scrutiny of Table 2 shows that 14 trace metals exceed the maximum contaminated level of WHO (2004), EPA (2005), ICBWA (2003) and Ontario (2000) standards while only 5 trace metals are within the allowable standards. Their percentages are calculated thus:

Trace metals concentration above recommended standards (Fig. 3):

$$14_{/19} \times 100 = \underline{73.68\%}$$

Trace metal concentration below the recommended standard:

$$5/19 \times 100 = \underline{26.32\%.}$$

Figure 3 shows a Pie-chart reflecting the percentage concentration of trace metals.

Figure 4 and 5 show bar chart and graphical representation respectively of the concentration of trace metals in the study area.

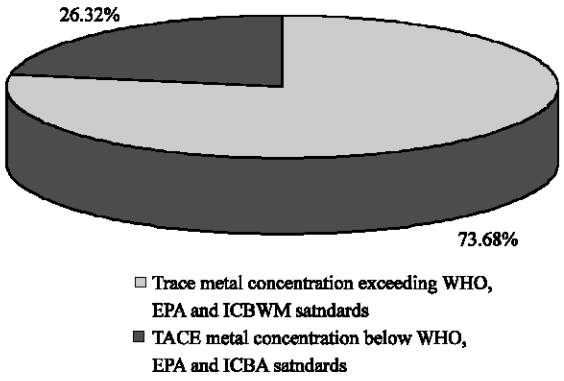

Fig. 3: Pie chart reflecting the percentage concentration of trace metals

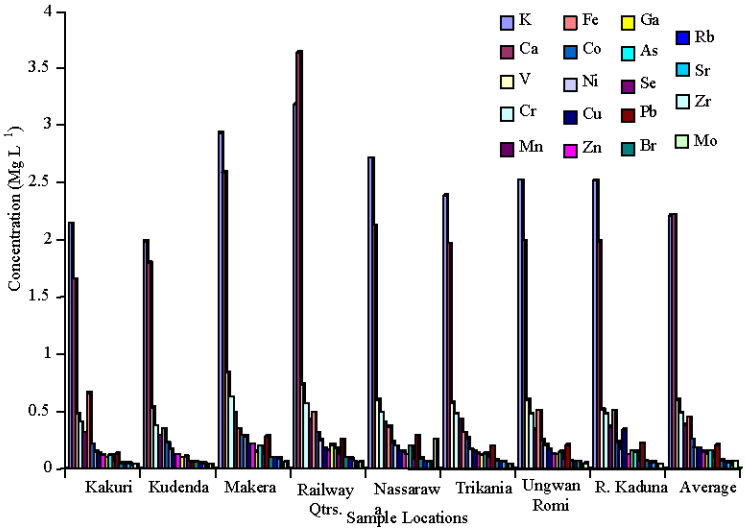

Fig. 4: Bar chart showing average contaminant concentration in all the location sampled (mg L^{-1})

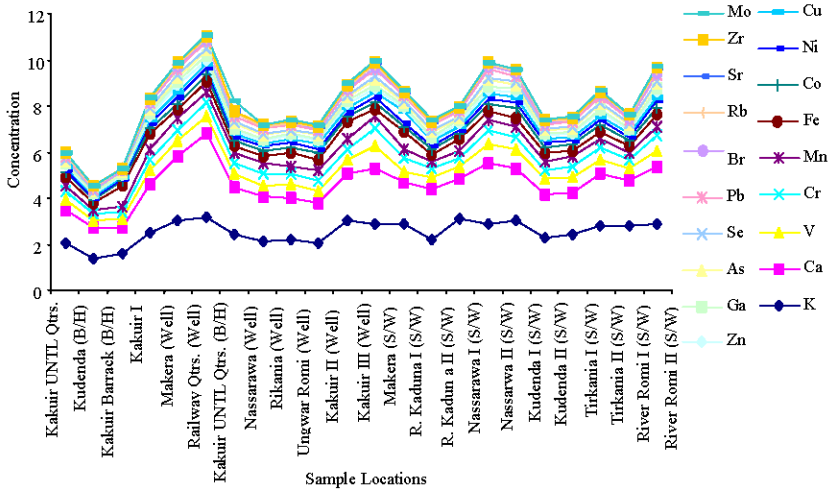

Fig. 5: Graphical representation showing contaminant concentration level at the sampling points of the study area

CONCLUSION

The borehole samples poise the least health hazards while the surface water samples poise the most dangerous, with respect to As and Pb content, the water in Kudenda area seems to be the most favourable as these metals are just slightly above the allowable limit while Makera and Nasarawa areas top the areas with the least favourable water as a result of the high rate of As and Pb contamination. However, due to the high percentage of trace metals that exceed the maximum contaminant level, the water within the study area is classified as been highly polluted and thus unfit for drinking. This may be due to the contamination from run-off and infiltration from the surrounding environment which may be usual occurrence during the rainy season.

However, some may also be attributed to sewage and domestic waste but the bulk of the trace metals are likely to be by-products of industrial activities and their concentration levels can only be as a result of industrial wastes pollution since the geologic of the study area does not indicate any source of natural deposit.

RECOMMENDATIONS

It is recommended that domestic waster should be properly disposed and recycled. Public health workers should launch a serious campaign against indiscriminate domestic and industrial disposal/pollution. Waste disposal trucks should be provided in strategic areas to collect solid waste. Industrial wastes should be properly treated and possibly recycled. Finally, the government and all regulating agencies should regulate environmental pollution conscientiously to prevent an outbreak of epidemic in these areas. It is also recommended that since this study was undertaken in raining season similar appraisal be undertaken within the same localities in the study are to evaluate seasonal changes of these trace metals.

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