GEOCHEMICAL EVALUATION FOR HEAVY METALS IN STREAM SEDIMENTS OF KANO RIVER DRAINAGE BASIN, NORTH WESTERN NIGERIA

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Abstract

Geochemical investigation was carried out to ascertain the levels of heavy metal pollution in rivers around Kano River. Stream sediments were collected from upstream to downstream and geochemical analysis for six heavy metal elements (Cr, Co, Ni, Cu, Pb, and Mn). Heavy metal concentration in stream sediments was determined using XRF. Three pollution criteria (Contamination factor, enrichment factor and index of Geo accumulation) were used to assess the level of pollution in these sediments. Computed results revealed low contamination to considerable contamination when contamination factor was used. Most samples displayed low contamination. Application of enrichment factor reveals samples were deficient to enrichment to moderate enrichment. Index of geo accumulation reveals all samples had uncontaminated characteristics. From geochemical point of view, pollution levels within the study area were generally low but caution should be taken in areas like Wailari where significant pollution was observed.

Keywords: Pollution, Heavy Metals, Environment, Contamination and Geo accumulation

Introduction:

Our global environment now consists of numerous metals due to the crucial role played by industrial development as well as technology. From an environmental point of view, origin of these heavy metals can be attributed to numerous sources that can either be natural or anthropogenic. Analytical measurements of heavy metals in any environments are an integral component of monitoring and assessing their toxic effects. They are required for regular purpose and routine monitoring to ensure compliance with allowed levels to determine hazardous conditions. Monitoring of the contamination sediments with heavy metals is of interest due to their influence on ground and surface waters (loan Suciu *et.al* 2008). Accumulation of trace metals in sediments may become toxic to sediments dwelling organisms and fish resulting to death, reduced growth or an impaired reproduction and low species diversity (Praveeena 2007). It is of great interest to note that heavy metal may accumulate in any environment without being visible. Stream sediments recognized as important sink of heavy metals in aquatic system as well as a potential non-point source may directly affect the overlying water. Kano city is a mega city with numerous activities that can lead to accumulation of heavy metal in its surrounding rivers. Because Kano River form an integral part of Kano City, it was essential to evaluate heavy metal levels within its stream sediments, since sediment reflect long term quality situation independent of the current input (Adeyemo *et.al* 2008).

Geology of the study area:

The study area covers the present Kano and Jigawa states and lies within latitudes 10^0 45"- 12^0 30"N and longitudes 8^0 43"-10^0 10" E. The river has a total length of 1,384 Km and it is part of Lake Chad Drainage Basin. The River flows through normal non-polluted background areas of Nigeria, with exception to Kano metropolis, where from it drains most of its pollutants. Kano River flows from the foot of the Jos Plateau on the Pre-Cambrian rocks of the central Nigerian Crystalline Shield under the effluent regime. Passing through Kano Metropolis it drains its residential and industrial effluents, then, some 40 KM downstream Kano metropolis, enters the Borno basin, changes its regime into an influent one, and finally disappears in the sands and silts of the Chad Formation in the Hadejia- Nguru wetlands.

The rocks of the basement complex of Precambrian age in the western and southern part and southeast characterize the study area, which is located in present Kano and Jigawa States of Nigeria. The Quaternary Chad Formation dominates the north and northeast. A hydrogeological divide separates the two geologic domains. The basement complex consists of rocks of gneiss-migmatite and granites of the Pan-African (600±150 Ma) and older. In the southern tips and southeastern parts, i.e., Ririwai, Fagam, Dutse, Kila-Warji and Birnin Kudu the basement rocks are of the Mesozoic 'Younger Granites' series.

Geology of the study area will be discussed here under three categories (Figure 3):
Basement Complex (Kano Metropolis) – Midstream Younger Granites (Ririwai area) – Upstream Chad formation – Downstream

Younger Granites (Upstream)

The Mesozoic Younger Granite complexes in the study area are part of the larger anorogenic ring complexes of Nigeria, which are made up of series of volcanic, sub-volcanic and plutonic alkaline rocks. The Younger Granites have similarity in the hydrogeological properties with the Precambrian basement complex despite the age difference. The rocks found in these complexes are basalts, rhyolites, tuffs (ignimbrites), afvedsonite - riebeckite granites, syenites, biotite granites and porphyries (as ring dykes). The Ririwai complex is important in this study as it forms the headwaters (upstream) of the Kano River.

Basement Complex

Part of the study area which is located on Basement Complex has an area of 24,471632,000 m^2 a (Garba, 2014), consists of gneiss-migmatite complex, metasediments (schists and quartzites of the schist belts) and granitic rocks of the Older Granites series (Mc Curry, 1973). Minor dykes are found within these major rocks.

Gneisses, migmatites, schists, quartzites of the basement complex ranges in age from the Liberian (c. 2,800 Ma) to the Upper Proterozoic (c. 600 Ma). The Older Granites, which intruded the gneiss-migmatite complex and the metasediments (schist belts), consist of porphyritic, medium and fine grained varieties of granites, granodiorites, syenites, diorites and gabbros are mostly products of Upper Proterozoic (Pan-African) event (750-450 Ma). There are also the minor dykes such as pegmatites, aplites and quartz vein that are either concordant with general strike or cross cut these rocks and are the youngest rocks of the basement complex.

Geology of the Kano Metropolis (Midstream)

The lithological units underlying the Kano Metropolis area, according to Magdi (1999), includes Schists, Diorites, Granodiorites, Granites, Minor intrusions (pegmatite) and Superficial deposits. Magdi (1999) describes the units as follows

The Schist is fine to medium-grained rocks of argillaceous to arenaceous character, and also usually found in association with diorites boulders. The diorites are dark greenish-grey and medium-fine grained in texture. Their outcrops are rounded to sub rounded boulders, and they both occur in schist and granodiorites. Granodiorites are porphyritic with phenocrysts of plagioclase often recognized in field outcrops and hand specimen.

Granites are two types and varied in age, i.e. the porphyritic granites and medium grained granites. The porphyritic are most abundant in colour of pink to light, also white rocky or pink phenocrysts of feldspars is responsible for their variations. Whereas the medium grained granites are equiangular and vary in colour from light to pink. They are highly jointed and mostly covered by laterites found along the valleys of Challawa and Kano Rivers.

Minor intrusive rocks include dykes and veins of aplites, quartz and pegmatites found to be intruding the major rocks. Superficial deposits result from weathering, erosion and deposition resulting in the formation of products like laterites, alluvial deposits, soils and clays (Fig. 2).

Chad Basin (Downstream)

The Chad basin locally known as the Bornu Basin is one of Nigerian inland basins occupying the North Eastern part of Nigeria. It represents about one tenth of the total areas extent of the chad Basin. The Chad Basin belongs to African Phanerozoic Sedimentary basin whose origin is related to dynamic process of plate divergence. Sedimentary sequence of the Chad Basin consists of clays, iron stones and Sandstones of Cretaceous age, which may be more than seven hundred meters thick (Baber 1965). Beds are generally low lying, flat lying and slope gently North East ward. In Ascending order, the litho-stratigaphic units consists of clay, lower ironstone, Yellow sandstone, greyish sandstone, upper iron stone and unconsolidated sand.

Materials and Methods:

Field work was carried out for 4 days. During fieldwork, streams sediments were collected from the active part of the river. As a precaution, care was taken to avoid sampling organic particles alongside stream, sediments. A plastic device was used in sampling to avoid metal contamination. After sampling, fresh sediments were put in a polythene bag and taken to the lab. In the lab, samples were aired dried. Air drying was followed by pulverization of samples. After pulverization, samples were analysed geochemically using the XRF method. Statistical and geochemical interpretation methods were used to ascertain the level of heavy metal pollution in these sediments.

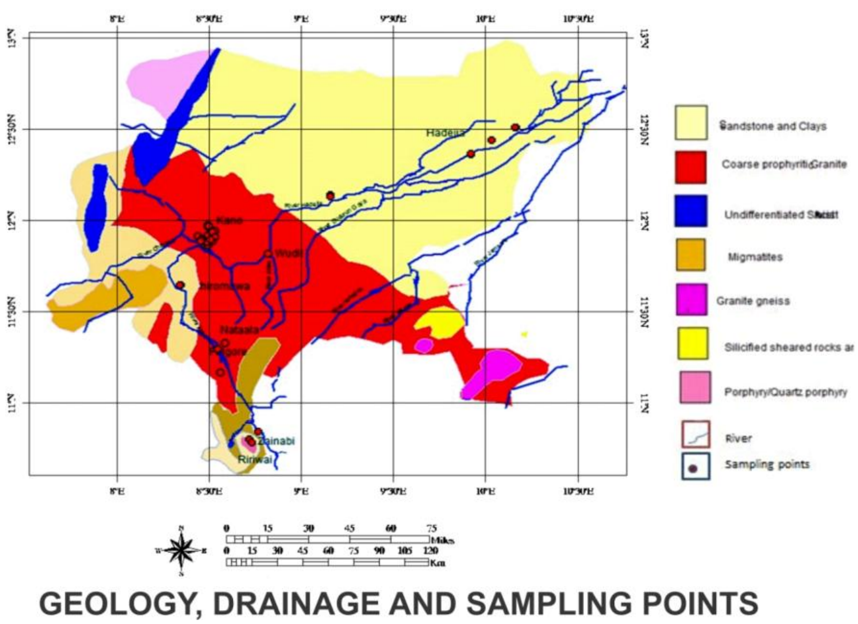

Figure 1. Map of Geology the Study Area (After GSN, 2004).

Results:

Geochemical analysis was performed for seven elements (Cr, Co, Ni, Cu, Zn, Pb and Mn). For twelve locations. Elemental concentrations for these elements are presented on Table 1.

Table 1: Elemental Concentrations in Heavy metals of stream sediment of the Study Area

Sample Loc.	Cr	Co	Ni	Zn	Cu	Pb	Mn
Nata'ala	16.69	4.05	9.91	26.15	9.47	7.37	210.53
Kwari Chiromawa	24.44	0	8.93	11.63	23.94	21.32	242.27
Kano River	28.98	4.74	7.94	5.29	19.98	45.76	217.13
Tatsawarki	142.29	8.91	8.64	33.78	7.63	17.01	184.27
Wailari	378.18	20.36	17.72	11.24	32.15	23.14	484.14
Yandanko	5.83	6.79	8.68	29.05	8.65	14.52	197.38
Wudil	47.12	7.91	8.58	26.85	9.88	13.72	181.73
Majiyawa	6.03	7.85	9.03	11.22	36.65	21.31	219.61
Hadiyau	32.04	5.9	9.63	22.6	6.61	10.94	484.7
Turabu	17.98	4.34	9.13	21.08	13.6	21.52	241.21
Max.	378.18	20.36	17.72	33.78	36.65	45.76	484.7
Min.	5.83	0	7.94	5.29	6.61	7.37	181.73
Mean	69.958	7.085	9.819	19.889	16.856	19.661	266.297
SD.	115.32	5.32	2.83	9.46	10.84	10.53	116.76

Evaluation of geochemical data reveals that Cr has a maximum of 378.18 ppm as observed in Wailri compared with the one with minimum of 5.83ppm observed at Zainabi. A mean value of 69.958 ppm and a standard deviation of 115.32ppm was observed for Cr. Co had a maximum of 20.36 ppm observed at Wailari and a minimum of 0 ppm at Kwari Chiromawa with Mean and standard deviation of 7.085 ppm and 5.32 ppm. Ni had a maximum of 17.72 ppm at Wailari with a minimum of 7.94 pp at Kano River and a mean and standard deviation of 9.819ppm and 2.83ppm. Zn had a maximum of 33.78 ppm at Tatsawarki, a minimum of 5.29 ppm at Kano river and a mean and standard deviation of 19.889 ppm and 9.46 ppm. Cu had a maximum of 36.5ppm at Majiyawa, a minimum of 6.61ppm at Hadiyau and a mean and standard deviation of 16.856 ppm and 10.84ppm. Pb had a maximum of 45.76 ppm at Kano River, a minimum of 7.37 ppm observed at Nata'ala. Mean and standard deviation was 19.661ppm and 10.53. Mn had a maximum of 484 ppm at Hadiyau, a Minimum of 181 at Wudil, A mean value of 266.29 ppm and standard deviation of 116.76.

Correlation Analysis:

Inter elemental relationship existing between heavy metals for stream sediments was studied with the aid of a dendrogram. From dendrogram analysis, it was observed that a close correlation existed between Cr and Ni as they have similar linkage distances. Cr and Ni were are more correlated to Co than the rest of the elements. Cu correlates more with Cr, Ni, Co, Mn than pb and Zn. Zn is the least and most correlating element (Figure 2). Figure 2: Dendrogram Showing Elemental Relationship for Heavy Metals in Stream Sediment.

Evaluation of Heavy Metal Pollution: Several criteria were used to evaluate pollution levels of heavy metals within these stream sediments. These include.

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Contamination Factor:

Contamination factor can be defined as the concentration of an element in a sample relative to the background concentration

It is evaluated using the following formula.

$$C_F = C_s / C_{bg}$$

From the calculated contamination value,
Contamination Factor < 1 = Low contamination
Contamination Factor 1≤ C ≥ 3 = Moderate contamination
Contamination Factor 3 ≤ C≥ 6 = Considerable Contamination
Contamination Factor ≥ 6 = Very High Contamination

Contamination factor was calculated for heavy metals in stream sediments (Table 2).

Table 2: Contamination Factors for different heavy Metals in stream Sediments

Sample Loc.	Cr	Co	Ni	Zn	Cu	Pb	Mn
Nataala Kwari	0.185444	0.213158	0.145735	0.275263	0.210444	0.3685	0.247682
Chiromawa	0.271556	0	0.131324	0.122421	0.532	1.066	0.285024
Kano River	0.322	0.249474	0.116765	0.055684	0.444	2.288	0.255447
Tatsawari	1.581	0.468947	0.127059	0.355579	0.169556	0.8505	0.216788
Wailari	4.202	1.071579	0.260588	0.118316	0.714444	1.157	0.569576
Yandanko	0.064778	0.357368	0.127647	0.305789	0.192222	0.726	0.232212
Wudil	0.523556	0.416316	0.126176	0.282632	0.219556	0.686	0.2138
Majiyawa	0.067	0.413158	0.132794	0.118105	0.814444	1.0655	0.258365
Hadiyau	0.356	0.310526	0.141618	0.237895	0.146889	0.547	0.570235
Turabu	0.199778	0.228421	0.134265	0.221895	0.302222	1.076	0.283776

From contamination factor table 2 above it can be observed that no element with very high contamination factor. Sediments from Wailari had considerable contamination in Cr. Also Cr displayed moderate contamination for samples around Tatsawarki. Co had moderate contamination for samples around Wailari. Moderate contamination was observed for Pb in samples around Chiromawa, Kano River, Wailairi. Majiyawa and Turabu. Ni, Zn, Cu and Mn displayed low contamination for all samples (Figure 3).

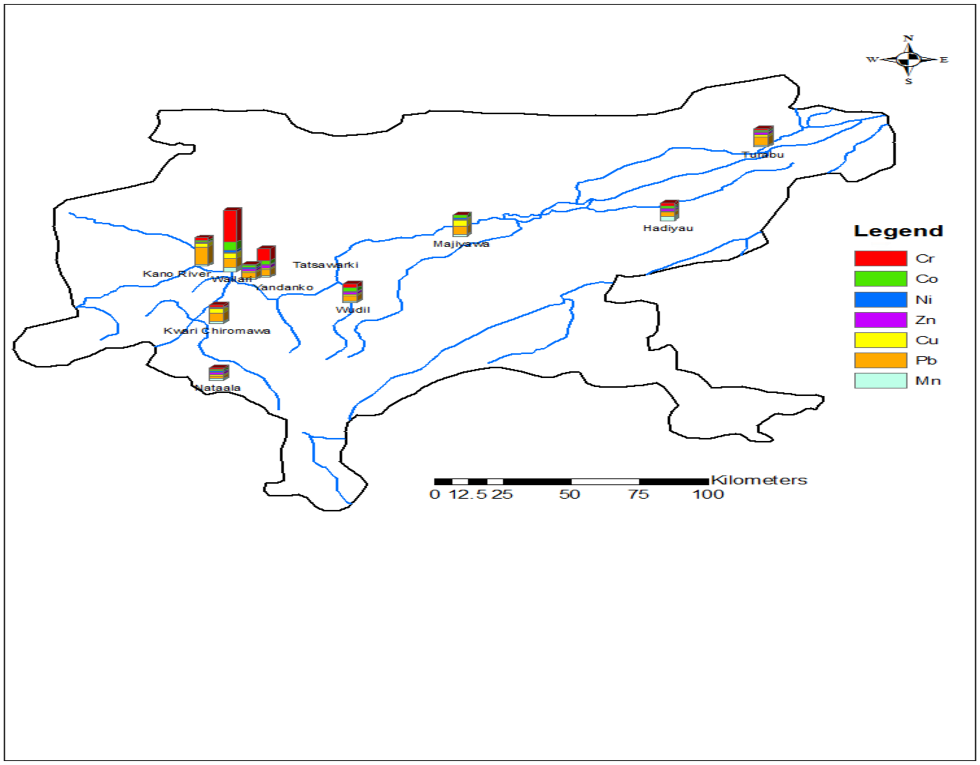

Figure 3: Contamination Factor for different elements across different areas

Enrichment Factor:

Pollution level assessment for heavy metals was calculated using Enrichment method technique by comparing the concentration of heavy metal of interest to a reference element. In this study, Mn was taken to be the reference element due to its high immobility. Enrichment factor was computed using the following formula.

$$\mathbf{EF = \frac{(C_s/e)}{(C_n/e)}}$$

From the calculated enrichment factors,

EF < 2 = Deficient to mineral enrichment
EF = 2-5 = Moderate Enrichment
EF = 5-20 = Significant Enrichment
EF = 20 – 40 = Very high Enrichment
EF > 40 = Extremely high enrichment

Enrichment factors for samples in heavy metals were calculated and are presented below.

Table 3: Enrichment Factors for Heavy Metals in Stream Sediments

Sample Location	Cr	Co	Ni	Zn	Cu	Pb	Mn
Nataala	0.185444	0.213158	0.145735	0.275263	0.4735	0.3685	0.247682
Kwari Chiromawa	0.271556	0	0.131324	0.122421	1.197	1.066	0.285024
Kano River	0.322	0.249474	0.116765	0.055684	0.999	2.288	0.255447
Tatsawarki	1.581	0.468947	0.127059	0.355579	0.3815	0.8505	0.216788
Wailari	4.202	1.071579	0.260588	0.118316	1.6075	1.157	0.569576
Yandanko	0.064778	0.357368	0.127647	0.305789	0.4325	0.726	0.232212
Wudil	0.523556	0.416316	0.126176	0.282632	0.494	0.686	0.2138
Majiyawa	0.067	0.413158	0.132794	0.118105	1.8325	1.0655	0.258365
Hadiyau	0.356	0.310526	0.141618	0.237895	0.3305	0.547	0.570235
Turabu	0.199778	0.228421	0.134265	0.221895	0.68	1.076	0.283776

From data analysis, no sampled had significant to extremely high enrichment. One sample observed at Wailari had moderate enrichment for Cr (Figure 4). Most samples were deficient to mineral enrichment.

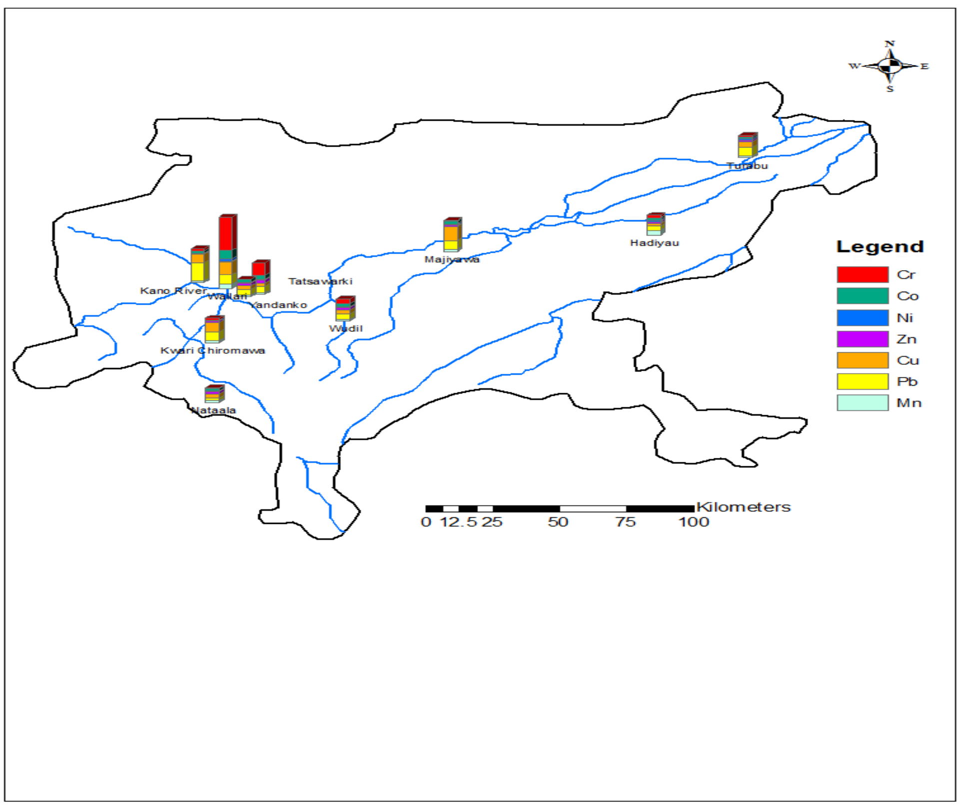

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Figure 4: Enrichment Factor for different elements across different study area

Index of Geo-Accumulation:

Assessment of pollution of heavy metals was carried out using Index of geo accumulation. Index of geo-accumulation was calculated using the following formula.

$$I_{geo} = \log_2 C_s / 1.5Bn$$

From the calculated values,

Igeo < 0 = Uncontaminated
Igeo = 0 -1 = Uncontaminated to slightly contaminated
Igeo = 1-2 = Moderately contaminated
Igeo = 2-3 = Moderately to highly contaminated
Igeo = 3-4 = Highly contaminated
Igeo = 4-5 = highly contaminated to very highly contaminated
Igeo > 5 = Very / Strongly Contaminated

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Table 4: Index of geo-accumulation for heavy metals is presented below

Sample Location	Cr	Co	Ni	Zn	Cu	Pb	Mn
Nataala	0.031	0.071	0.0324	0.033	0.051	0.096055	0.006053
Kwari	0.034	0	0.031	0.025	0.073	0.147138	0.006212
Chiromawa							
Kano River	0.036	0.079	0.029	0.017	0.069	0.183867	0.006088
Tatsawarki	0.051	0.111	0.031	0.036	0.047	0.136277	0.005902
Wailari	0.063	0.153	0.041	0.025	0.080	0.151077	0.006996
Yandanko	0.018	0.097	0.031	0.034	0.049	0.128666	0.00598
Wudil	0.041	0.105	0.030	0.033	0.053	0.12594	0.005887
Majiyawa	0.019	0.104	0.031	0.025	0.083	0.147115	0.006101
Hadiyau	0.037	0.089	0.032	0.032	0.043	0.115051	0.006997
Turabu	0.031	0.074	0.031	0.031	0.060	0.147587	0.006207

Resultant analysis from index of geo-accumulation computations reveals that all samples had an index of geo-accumulation value of 0 to one (0-1) thus they were uncontaminated to slightly contaminated (Figure 5).

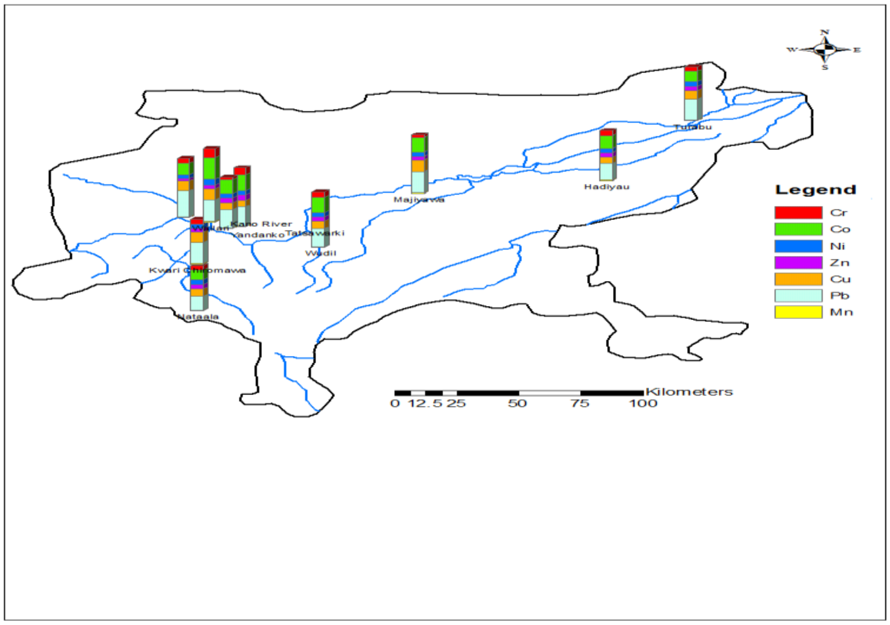

figure 5: index of geo-accumulation for different elements across different locations

Discussion and Conclusion:

Quantification of heavy metals pollution have been effectively used in determining pollution level within the study area. Three methods of quantification was used in this research. Contamination factor, enrichment factor and index of geo-accumulation. Application of contamination factor reveals considerable contamination for Cr at Wailari. Moderate contamination for Cr was observed at Tatsawari. For Pb pollution, five areas reveals moderate contamination for Pb. Highest contamination factors for Cr, Co, Ni, Pb was observed at Wailari, and highest contamination factor for Zn, Cu and Mn at Tatsawari, Majiyawa and Hadiyau. Highest enrichment factor for Cr and Ni was observed at Wailari, highest enrichment factor for Co, Zn, Cu, Pb and Mn was observed at Wudil, Tatsawarki, Majiyawa, Kano River and Hadiyau. From enrichment factor, one sample (Wailari) displayed moderate enrichment, while the rest were deficient to enrichment. Data from index of geo-accumulation reveals all samples were uncontaminated to slightly contaminated with highest observations for Cr, Co and Ni at Wailari, highest geo-accumulation for Zn, Cu, Pb and Ma at Tatsawark, Majiyawa, Kano River and Hadiyau. From geochemical computations, it can be concluded that pollution levels throughout the study area are generally low. But precautions should be taken in places like Wailari increasingly observed to have fairly strong indications of pollution.

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