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Heavy Metals Pollution Indices and Multivariate Statistical Evaluation of Groundwater Quality of Maru town and environs

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Abstract

Investigation was carried out on the groundwater quality of Maru town and environs in terms of Heavy metals concentration using the pollution indices and multivariate statistical approaches. 29 groundwater samples were taken from dug wells and one Borehole in the area and analyzed for the presence of Heavy metals, Temperature and PH. The concentration of the analyzed metals in the groundwater arranged in decreasing order is Cr >Fe >Mn >Zn >Cu >Ni with three elements Cr, Fe and Mn had concentrations above the WHO recommended limits. Calculated Pollution indices revealed low C_d and HEI values for the area while HPI gives an overall high value, consequently translating the area into high groundwater pollution zones. Correlation analysis did not produce any significant relation between the heavy metals. However C_d, HPI and HPI were strongly positively correlated to Cr, while a strong positive and significant correlation was observed between the computed indices. The PCA and HCA performed on the heavy metals produced results that are comparable and agreed with each other; both the CA and PC obtained revealed geogenic and anthropogenic origin for the dissolved heavy metals ions in the sampled groundwater. The study have revealed chromium pollution status for the area, based on the concentration level of the Cr in the sampled groundwater, computed indexes and statistical evaluation performed on the results obtained.

1. Introduction

Water especially for drinking and domestic purposes are expected to be of high quality, and free from any form of contaminants. As groundwater moves through different geological strata in the sub-surface, it dissolves impurities of both organic and inorganic origin. Drinking is the commonest means by which the public are exposed to harmful dissolved elements, derived from natural and anthropogenic sources [1]. Although these dissolve elements constitute the micronutrients, needed metabolism and functioning by organisms, however when these dissolve elements exceeds the quantity required by these organisms it become toxic. Heavy metals are metallic elements that have relatively high density and could be toxic even at low concentrations when they accumulate within the body [2].

The sources of the heavy metals in groundwater can be a release from chemical weathering of minerals, soil leaching processes in addition to anthropogenic activities. These anthropogenic Sources include industrial and domestic effluent, landfill leachate and mining activities [3]. According to [4], metal solubility in water and soil depend on PH, metal concentration, organic carbon, ion exchange and oxidation state of mineral components as well as the redox potentials of the system. Monitoring of heavy metals concentration in drinking water especially groundwater sources is crucial as this can go a long way in remedying health implications particularly water born diseases.

To assess and evaluate the heavy metals in groundwater and surface water sources from Ota and Parts of Yobe in Nigeria respectively, [5] and [6] determined the pollution index (PI) of groundwater, which gives the ratio of individual trace elements against the baseline standard. This give information on relative pollution contributed by the individual sample analyzed. Generally, water pollution indices involve the integration of different water quality variables in a specific index which are design to represent the water quality on a regional and global scale. [7] Pointed out that water quality index represent is a simpler way of processing multiple dataset to compute the overall quality in a single dimensionless number. For heavy metal contamination assessment, the practical indices used are the Heavy metals pollution index (HPI), Heavy metal evaluation index (HEI), Degree of contamination (C_d) and Hazard index (HI). These gives a composite influence of several metals on the overall groundwater quality [8], [9], [10], [11],[12]. According to [13] and [14], the principal component analysis (PCA) and correlation matrix (CM) are useful methods for identifying common patterns in data distribution, leading to reduction of the initial dimension of data sets and facilitating their interpretation. Several studies assessed and evaluated the groundwater pollution and toxicity in different parts of Zamfara State. These studies include those of [15-19]. The findings revealed high concentrations of toxic heavy metals especially lead (Pb) which is derived mostly from the gold mining and processing activities common in these localities. This has given rise to the lead poisoning and other health problems being experience in the State.

The objectives are to investigate heavy metals concentration in groundwater of Maru, Northwestern Nigeria and assess the health risk involve in consuming such groundwater laden with these heavy metals above the set limit through the use of pollution indices of HPI, HEI and Cd. Further more to perform multivariate statistical analysis on the different heavy met so as to assess the sources of these metals in the groundwater. All these will be conducted with the aim of evaluating the toxicity and contamination levels of the heavy metals in the groundwater within the study area.

2. Materials and Methods

2.1 Location and climatic settings

The study area is in Zamfara State, Northwestern Nigeria, located between latitudes 12° 17′ and l2° 25′ and longitudes 6° 10′ and 6° 30′ and is accessible through the Gusau-Sokoto road. The area lies within the dry humid tropics climate which fluctuates annually from the north toward the southern part of the area. The Inter-tropical discontinuity line (ITD) separate the dry continental air masses from the moist monsoon masses in the south, these two are responsible for the two seasons of wet and dry that are being experienced in the area. Raining season usually commences in May and last till late September with an average of 849 mm and rainy days average of 140 days. Relative Humidity reaches 90 % and 60 % in the morning and afternoon respectively. The north-eastern dry air masses blowing from the Sahara gives rise to the dry season characterized with dry dusty Harmattan condition that begins in late October and lasted till April bringing with it high and harsh temperatures with a minimum, maximum and averages of 19-21 °C, 33-35 °C and 26-28 °C respectively, [20]. The River Sokoto which is the major river in the area cuts across the study area, flowing from the northwestern toward southwestern portion. There are Tributaries' linking up with the River Sokoto, among these is river magada (Figure 1).

2.2 Physical settings

The study area is characterized by two types of topography the plain lowland areas and elevated highlands which are mostly the hilly areas. The elevation of the area ranges from about 350 meters above sea level at the lowland areas at the northwestern portion of the area to about 580 meters above sea level on the Hilly areas at the northeast part of the area. The highest hill in the area is the Awala Hill with a height of about 580 m above sea level, other hills in the area are the Yola, and Baraba hills. Majority of these hills are watershades that give rise to several tributaries in the area that are responsible for contributing to the flow of the River Sokoto within the study area, (figure 1).

2.3 Geology of the study area

The study area lies within Maru Schist Belt of Northwestern Nigeria. The belt consists of metamorphic rocks which comprises of the phyllites, schists, slate, quartzites and gneiss. Granitoids in form of granodiorites and porphyritic granites are common intrusions within the study area (Figure 2). The N-S Pan African tectonic trend is observed to have affected the metasediments and the granitoids. Presences of laminated fine grained

sediments and ironstone formations' point to deposition under quite condition [21], whereas the dominance of iron oxides indicates an oxygen rich environment of deposition. The Maru schist belt is known to be Kibaran in age [22].

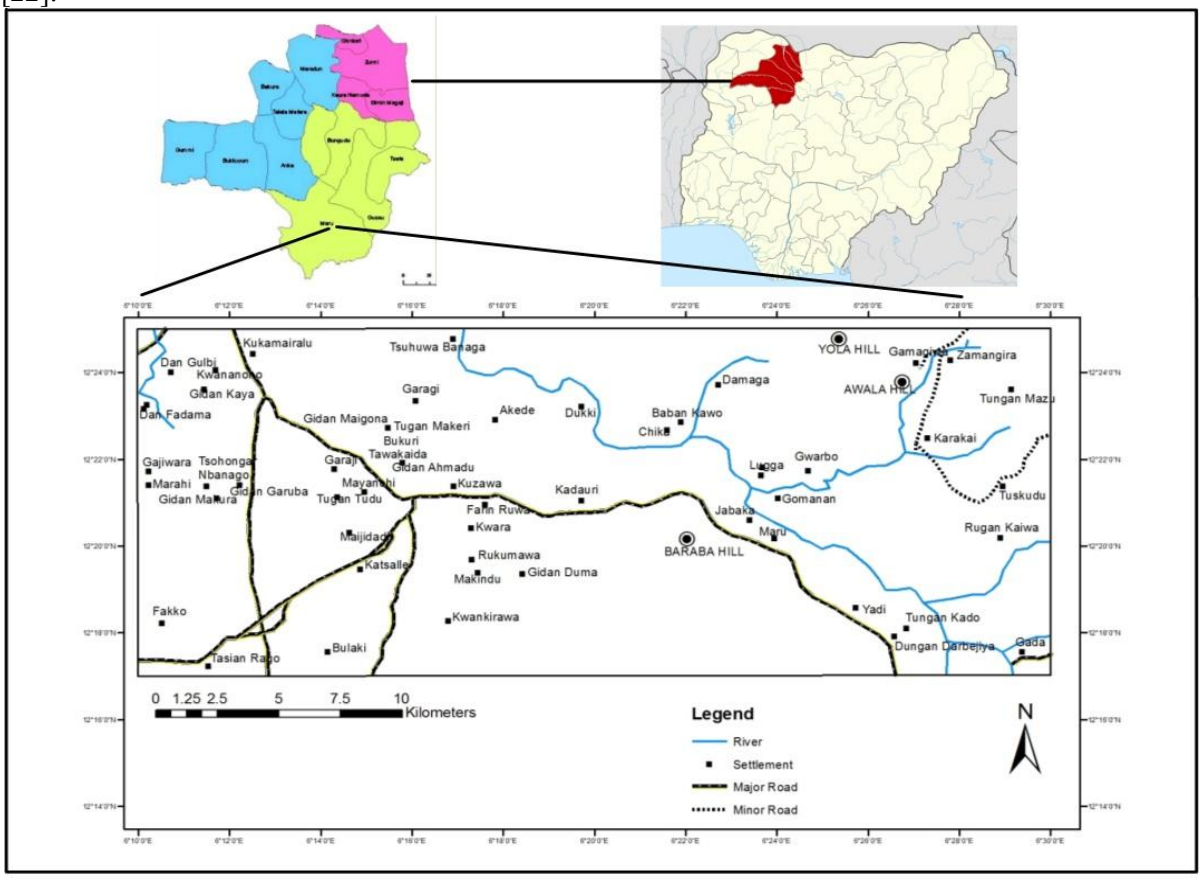

Figure 1: Location map of the study area

2.4Sampling

Twenty-nine groundwater samples were collected from one borehole and 28 hand-dug wells within the area of study, samples were collected using 1 liter plastic containers. To ensure the collection of representative water samples from the borehole and dug-wells, large quantity of water from were pumped out or bailout for at least 10 minutes to remove water from bore storage in the case of the borehole and the dug wells before sampling. This was done to obtain water coming directly from the aquifer. During the sampling, preparation and analysis the protocols outlined by [23] were followed. The containers were rinsed with the water to be sample before samples were taken. Few drops of concentrated HNO_3 were added into the water sample to reduce the pH ~2 and kept at a temperature of 4 $^{\circ}$C to stop the precipitation of important metals before the commencement of the analysis. A portable handheld digital 2 in 1 HANNA HI 98128 pH meter was used to measure the PH and Temperature of sample water in-situ at each sampling point. At each Location the coordinates was taken using a GPS, GARMIN *etrex* 10model.

2.5 *preparation and analysis*

To prepare the samples for analysis, 50 mills of the water sample was taken in a conical flask, 10 M Concentrated HNO_3 acid solution was added and heated on a hot plate to digest. This was allowed to cool and distilled water was added to make 50 mils volume and then filtered using a filter paper. The heavy metals Cr, Cu, Fe, Mn, Ni and Zn were analyzed using the Atomic Absorption Spectrometer AA 6300 SCHIMADZU model at the Biomass instrumental laboratory of the Centre for Energy Research, Usmanu Danfodiyo University Sokoto.

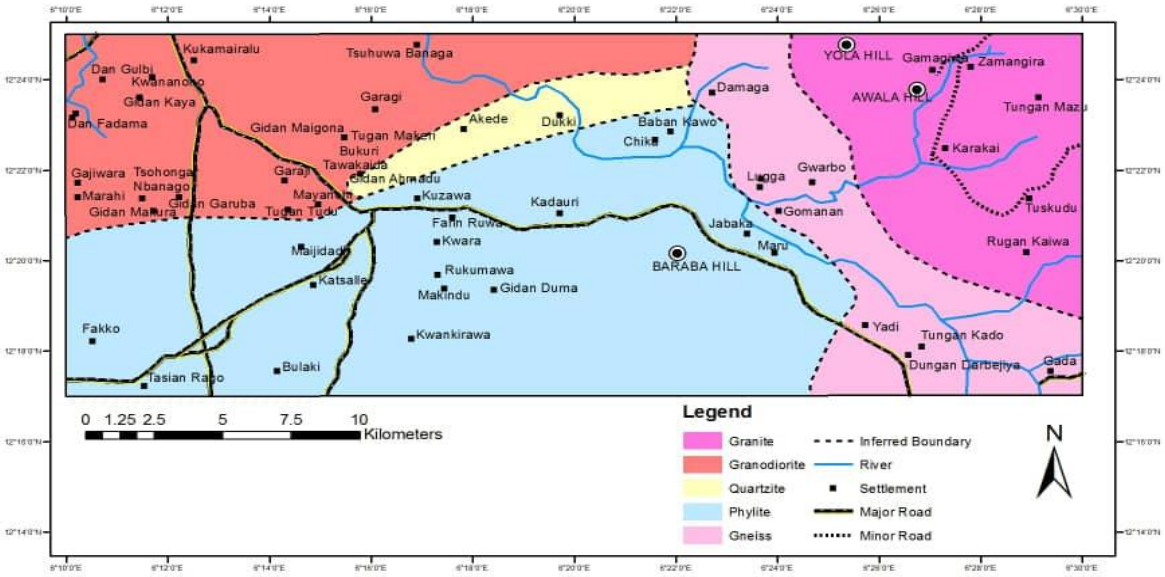

Figure 2: Geologic map of Maru and environs

2.6 Map production

The spatial distribution maps of some selected heavy metals were produced using Arch GIS 10.2 using the inverse distance Weighted method IDW. Similarly the location and geologic maps were produced using Arch GIS 10.2.

2.7 Heavy metal pollution index (HPI)

The HPI was first proposed by [24], the HPI is based on the weighted arithmetic quality mean method which is developed in two basic steps [25]. A rating scale was developed for each of the selected parameters and a weight (W_i) was allocated to it. The second step is selecting the pollution parameter on which the index is to be based on. The rating is an arbitrary value between zero and one which depends upon the importance of the individual quality consideration. It can be assessed by making value inversely proportional to the recommended standard (S_i) for corresponding parameter [6], [24], [25], [26]. The HPI model [24] is computed using the following equation:

$$\frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi}$$

Where Q_i is the sub-index of *i*th parameter

W_i is the unit weightage of the *i*th parameter and *n* is the number of parameters considered

The Q_i sub-index is calculated using the equation below:

$$Q_i = \sum_{i=1}^{n} \frac{\{Mi(-)Ii\}}{(Si-Ii)} \times 100$$

Where M_i I_i and S_i are the Heavy metal's *i*th parameter monitored, ideal and standard values respectively. The negative sign (-) is the numerical difference of the two values, the algebraic sign is ignored. For this index, the intended use is for drinking hence the critical pollution index value is 100. In this study the W_i and S_i are taken as the inverse of MAC and [27] standard, (table 1). For this study Cr, Cu, Fe, Mn, Ni, and Zn were used for the computation of the indexes.

2.8 Heavy metal evaluation index (HEI)

Like the HPI, HEI method gives you the overall quality of the water with respect to heavy metals [27], [26]. HEI is calculated from the following equation

$$HPI = \sum_{i=1}^{n} {Hc}/{Hmac}$$

H_c is the monitored value of the i^{th} parameter and H_{mac} is the minimum admissible concentration of the i^{th} parameter.

Table 1: Adopted Standard for computed indices

Heavy metal	W	S	I	MAC
Cr	0.02	50	50	50
Cu	0.001	1000	2000	1000
Fe	0.005	300	200	200
Mn	0.02	100	500	50
Ni	0.05	20	20	20
Zn	0.0002	5000	3000	5000

MAC: maximum admissible concentration/upper permissible
W: Weightage (1/MAC)
S: Standard permissible in ppb
I: Highest permissible in ppb

2.9 Contamination index (C_d)

The degree of contamination takes into consideration both the number of parameters that exceed the upper permissible limit or guide values of potentially harmful elements and the concentration exceeding these limit values [1]. To determine the degree of contamination (C_d) this is computed separately for each sample of water analyzed as the sum of water contaminant factor of the individual components exceeding the upper permissible values. Generally the C_d is a summary of the combined effects of the several quality parameters considered harmful to household water. In this study all detected values were used in computing the contaminant index, it is computed using the following :

$$C_d \sum_{i=1}^{n} Cfi$$

Cf_i = represent the contaminant factor for the *i*-th component and is calculated from the equation

$$C_{fi} = \frac{CAi}{CNi} - 1$$

Where C_{Ai} = analytical value of the *i*-th component and C_{Ni} = upper permissible concentration of the *i*-th component (N denotes the normative value).

2.9.1 Multivariate statistical analysis

All multivariate analysis was performed using SPSS 21 for Windows. The PCA was used to reduce data and then extracted data were used to analyze the relationship between the analyzed heavy metals in the water samples and the likely possible sources of these metals in the water [28] and [29]. The cluster analysis CA was employed to classify the heavy metals on the basis of their similarities based on their chemical properties [29]. While the Hierarechiecal agglomerative cluster analysis provides intuitive similarity relationship between any one sample and data set using the dendogram which gives a visual of the clustering process. Finally the correlation coefficient matrix was used to measure how the variance picture of each constituent can be explained by its relationship with each other. Depending on the co-variance of the analyzed parameters, the multivariate technique was used to predict the origin of the analyzed metallic ions in the analyzed groundwater samples.

3. Results and discussion

3.1 Physicochemical analysis

The result of the physicochemical analysis is presented in Table 2 and the descriptive statistics in Table 3. For the 29 groundwater samples analyzed, temperature measured ranges between 25.20 and 28.7 ^{0}C. Recorded PH values ranges between 6.33 and 8.65, both outcomes of temperature and PH values falls within the accepted ranges set by both [27] and [30] as given in table 3. Measured PH for the water in this study revealed weakly acidic to slightly alkaline water. Heavy metals concentration in the groundwater revealed that 17 water samples, equivalent to 58.6 % have chromium concentration that exceed the [27] and [30] set minimum limit of 50 µg /l. Iron and manganese, have concentrations above the recommended limits of [28] and [30] in 7 locations each, this constituted 24.14 % of the samples analyzed, however Mn have concentration above the [27](400µg/l) limit in 5 samples (17.24 %) while all seven samples have concentrations of Mn above the [30] standard (200µg/l). The remaining heavy metals Cu, Ni and Zn analyzed have their concentrations far below the set limits for both

[27] and [30] in all the water samples (Tables 2 and 3). The order of dominance in term of concentration of heavy metals in the analyzed groundwater is Cr >Fe >Mn >Zn >Cu >Ni. The spatial distribution maps of Cr, Fe and Mn are shown in (Figures 3a, 3b and 3c) respectively.

Table 2: Descriptive statistic of the Heavy metals in groundwater of the study area

Parameter	Minimum	Maximum	Mean	Std. Deviation	Variance	Standards	
						WHO (2011)	NSDWQ (2007)
TEMP. °C	25.2	28.7	28.330	.6736	.454	6.5-8.5	6.5-8.5
PH	6.33	8.65	6.74	1.92568	3.708	30-32	Ambient
Cr (µg/l)	.00	990	184.75	257.64974	66383.390	50	50
Cu(µg/l)	0	330	41.79	75.504	5700.884	2000	1000
Fe(µg/l)	0	460	170.79	125.114	15653.599	300	300
Mn(µg/l)	0	870	141.69	227.280	51656.079	400	200
Ni(µg/l)	.0	5.6	.193	1.0399	1.081	70	20
Zn(µg/l)	12	87	46.59	15.539	241.466	3000	3000

WHO: World health organization
NSDWQ: Nigerian standard for drinking water quality

Table 3: Concentrations of analyzed Heavy metals in groundwater

S/N	Community	Latitude	Longitude	Temp ℃	pH	Cr µg/l	Cu µg/l	Fe µg/l	Mn µg/l	Ni µg/l	Zn µg/l
1	Satto Gidan Gona	12 21 31.5	6 27 31.9	27.6	6.65	150	24	320	180	5.6	37
2	Gidan goji	12 23 58.7	6 28 5.1	25.2	7.55	230	BDL	350	380	BDL	39
3	Rugan tudu	12 22 42.2	6 23 13.1	28.2	8.65	180	BDL	390	530	BDL	42
4	Chika	12 20 06	6 21 32.3	NM	NM	160	BDL	320	720	BDL	61
5	Tsola	12 21 05	6 22 23	28.4	7.15	290	BDL	120	870	BDL	52
6	Mayanchi	12 21 46.6	6 04 43	27.9	7.27	340	16	360	70	BDL	57
7	Gobro	12 24 10.6	6 25 1.8	28.6	7.43	380	BDL	460	110	BDL	87
8	Gamagiwa	12 23 19.5	6 26 50.9	28.5	7.05	560	BDL	420	41	BDL	56
9	Dukki	12 23 50.6	6 19 46.5	28.5	7.85	0.74	BDL	95	10	BDL	57
10	Baichi	12 23 8.7	6 22 50	28.6	7.14	850	BDL	73	44	BDL	42
11	Danfaru	12 23 55.1	6 22 45.1	28.4	7.10	BDL	BDL	160	6	BDL	55
12	Ekuka	12 22 14.9	6 22 47.3	28.5	7.20	BDL	56	140	18	BDL	46
13	Gavagi S yaki	12 17 57.4	6 15 51.1	28.6	6.89	86	330	99	BDL	BDL	85
14	Zango Kabai	12 20 34.9	6 23 36.6	28.5	7.28	340	270	150	110	BDL	49
15	Gomonan	12 20 34.9	6 24 16.3	28.5	7.01	450	62	103	48	BDL	47
16	Maitsani	12 19 25	6 12 06	28.4	7.14	990	65	120	61	BDL	54
17	Gidan Barti	12 22 55	6 11 26	28.4	7.18	130	BDL	55	26	BDL	46
18	Kabibo	12 24 21	6 11 47	NM	NM	BDL	37	120	38	BDL	58
19	Karakai	12 22 36.1	6 27 0.6	28.7	7.08	58	40	130	72	BDL	23
20	Gobro II	12 21 37.7	6 25 03.1	28.3	6.33	56	7	120	BDL	BDL	42
21	Tungar bore	12 23 37.7	6 10 53.9	28.2	6.98	BDL	57	130	BDL	BDL	42
22	Tudun fulani	12 20 37.8	6 27 42.1	28.7	6.85	11	25	130	9	BDL	30
23	Gada	12 17 34.6	6 28 06.3	28.7	6.74	8	65	160	BDL	BDL	31
24	Garagi	12 22 20	6 15 50	28.6	7.76	75	BDL	81	BDL	BDL	35
25	Jidda	12 23 00	6 15 32	28.6	8.50	BDL	30	55	320	BDL	38
26	Baragi	12 22 20	6 15 33	28.5	7.16	BDL	30	30	380	BDL	47
27	Kudauli	12 20 45	6 19 36.8	28.7	6.94	BDL	18	92	31	BDL	46
28	Lugga	12 21 35.6	6 23 31.6	28.4	7.21	13	40	BDL	35	BDL	35
29	Gidan F Gobro	12 21 43.2	6 24 37.4	28.7	7.23	BDL	40	170	BDL	BDL	12

BDL: Below detection limit **NA**: Not measured

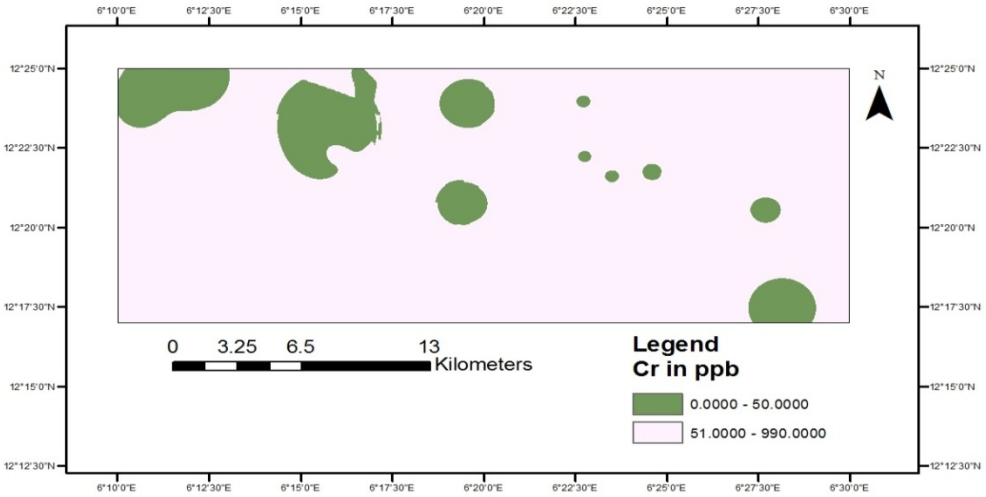

Figure 3: Spatial distribution map of Chromium in the area of study

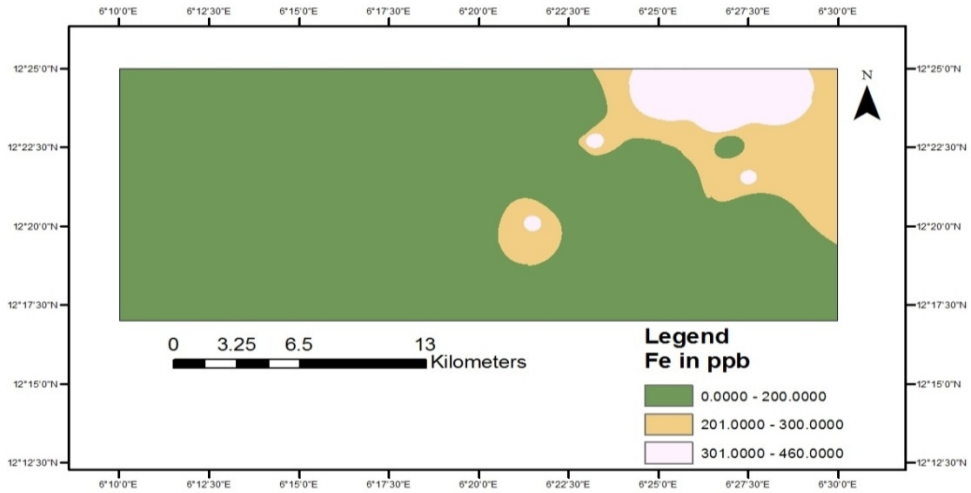

Figure 4: Spatial distribution map of Iron in the area of study

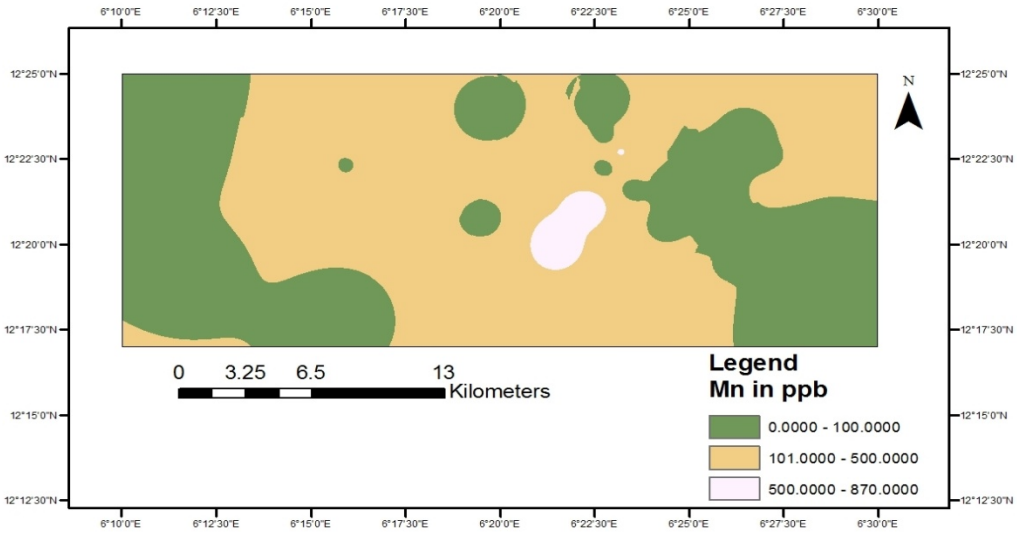

Figure 5: Spatial distribution map of Manganese in the area of study

3.2 Evaluation of heavy metals pollution indexes

The computed indexes for this research are presented in Table 4. The Calculated values of the contamination index which is also the degree of contamination has a mean value of -1.216 which is far below the value of 1, this value of C_d average in this research revealed the area to have low contamination in terms of the heavy metals. In this study the grouping by [1] and [26] was adopted, which are: low (C_d < 1) medium (C_d 1-3) and high (C_d >3).

Table 4: Computed Pollution indexes for the area of study

SAMPLE NO	Cd	HEI	HPI
1	-1.31	4.56	2853
2	0.57	6.57	3756
3	0.51	5.97	2714
4	0.76	5.76	2306
5	1.96	7.96	5013
6	2.2	8.17	6062
7	3.35	9.35	6897
8	6.7	12.7	10645
9	-5.65	0.35	1055
10	13.2	17.3	16662
11	-5.47	0.53	20.06
12	-5.32	0.68	2.93
13	-3.74	2.26	781
14	0.6	6.6	627
15	3.44	9.44	8346
16	14.4	20.4	19572
17	-3.2	2.85	196
18	-5.7	0.3	3.05
19	-4.3	1.73	18.7
20	-4.5	1.33	131.3
21	-5.6	0.42	5.9
22	-5.36	0.64	842
23	-5.3	0.7	877
24	-4.2	1.81	521
25	-3.55	0.65	19.25
26	-5.1	0.9	17.45
27	-3.64	0.4	10.42
28	-5.64	0.36	806
29	-5.4	0.62	3.91
Minimum	**-5.7**	**0.3**	**2.93**
Maximum	**14.4**	**20.4**	**19572**
Mean	**-1.2169**	**4.5279**	**3129.792**

Only 5 samples which represent 17.24% of the total analyzed sample have C_d values that are above the maximum value of 3 indicating high contamination in these samples. Samples 5 and 6 have C_d values 1.96 and 2.20 which are within the class of medium contamination and covers just 6.89 % of the total samples. The remaining 22 samples have their computed C_d values below 1 which indicate a low contamination statue for these groundwater samples, and this covers 75.86 % of the area. The results of the computed C_d for the different locations in this study are comparable with values obtained elsewhere by [31] and [32].This revealed that greater percent of the area are with no threat of contamination in terms of the dissolved heavy toxic metals in

the groundwater. Computed heavy metal evaluation index (HEI) for this study gives a mean of 4.5297 with minimum and maximum values of 0.3 and 20.4 respectively. Adopting the procedure used by [26], the computed values of HEI were divided into 3 classes using a multiple of the mean value. The three classes demarcated are HEI < 5 low, HEI 5-20 medium and HEI > 20 high. Based on these, 18 locations which represent 62.07 % of all the locations had low HEI values, while 10 locations covering 34.48 % of the sample water falls within the medium class. Only 1 location had high HEI value in this study.

Calculated Heavy metal pollution index had a mean of 3129.8 with a range of 2.93- 1957.2, which compared positively with the result obtained elsewhere with the findings of [3]. Based on the values obtained in this study a new grouping was proposed for this index based on the mean of this study: HPI < 90 low, HPI 90 -150 medium, HPI >150 high. From this classification 9 locations have low HPI values this is equivalent to 31.03 % of the samples taken. The medium class had only a sample with a HPI value of 131.3, while a total of 19 samples fall within the high class of HPI representing 65.52 % of the locations studied, Table 5. The high values of the pollution indices obtained in this research were contributed mainly by Cr, Fe and Mn whose values exceeded the [27] set limits for drinking water.

The correlation matrix performed between the Heavy metals and the calculated pollution indices revealed for the metal only a single negative correlation at ($p > 0.05$, $r = -.409$) between Fe and Temperature. However there is a strong significant positive correlation at ($p > 0.01$ between C_d and Cr of ($r = .985$), while HEI is positively correlated with Cr at ($p > 0.01$) of ($r > .991$), table 6. HPI is strongly and significantly correlated with Cr, at ($p > 0.01$) of ($r = .969$). This correlation is an indication that Cr loading has contributed significantly to the heavy metals concentration in the different samples analyzed than the other metals and also they are responsible for the high level or values of the Cd, HEI and HPI obtained in this study for the different locations in the area. Consequently this indicates that there is chromium pollution in the groundwater. Table 5 also shows that there is a strong positive and significant correlation between the indices, Cd is related to HEI and HPI at ($p >0.01$) of r =.994 and $r = .961$ respectively. Similarly HPI is significantly related to HEI at ($p >0.01$) of $r= .964$.

Table 5: Groundwater quality classification based on adopted and modified pollution indices classes

Index method used	Class source	Classes	Degree of Pollution	No. of samples	% of samples in each class
Cd	Adopted	< 1 1-3 >3	Low Medium High	22 2 5	78.86 6.89 17.24
HEI	Modified	<5 5-20 >20	Low Medium High	18 10 1	62.07 34.48 3.45
HPI	Modified	<90 90-150 >150	Low Medium High	9 1 19	31.03 3.45 65.25

3.3 Statistical evaluations

The principal component analysis performed on the groundwater physicochemical parameters used the varimax rotation with Kaiser Normalization, which consider only the Eigen values that exceeded 1, table 7. The scree plot, figure 6a was plotted to also demarcate the Eigen values that are greater than 1, in the plot these represent the straight line segment that contain the first three points that comes before the elbow or bend and horizontal portion of the plot. Also the factors were plotted in rotated space to show the relationship between the heavy metals and if possible to show those with common sources, figure 6b. Three factors were extracted for the Eigen values of more than 1 this made up 60.789 % of the total variance. The first component accounted for 20.590 % of the total variance and was strongly positively loaded with Fe, and Mn, while Temp was strongly negatively loaded; their sources could be from leaching from rocks and oxidation process induced by rain or percolating water. The second component explained 19.163% the total variance and strongly loaded with Zn, Cr and Cu, the sources of which are either natural from geogenic through weathering and leaching of minerals from rocks or anthropogenic through burning of materials or automobiles releasing combustible material into the air. The third component is strongly negatively loaded with Ni and weakly positively loaded with Mn and Zn explained 17.036 % of the variance. Sources of the elements are mainly from geogenic in nature with little anthropogenic origin traceable to agrochemicals or automobiles combustion and bush burning activities.

Table 6 : Correlations between Heavy metals and between Heavy metals and pollution indices analyzed and evaluated in the groundwater from the area of study

	TEMP	PH	Cr	Cu	Fe	Mn	Ni	Zn	Cd	HEI	HPI
TEMP	1										
PH	-.090	1									
Cr	-.057	.100	1								
Cu	.157	.040	.003	1							
Fe	**-.409***	-.069	.243	-.211	1						
Mn	-.300	-.195	.044	-.211	.261	1					
Ni	-.216	-.009	-.026	-.045	.229	.032	1				
Zn	.047	-.221	.257	.286	.298	.100	-.119	1			
C_d	-.095	.070	**.985****	-.063	.320	.167	-.003	.271	1		
HEI	-.113	.076	**.991****	-.045	.340	.150	.001	.283	**.994****	1	
HPI	-.045	.095	**.969****	-.122	.226	.019	-.011	.231	**.961****	**.964****	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 7: Varimax rotated Principal component analysis sampled groundwater

Parameter	PC1	PC2	PC3
R-mode			
Temp	-.690	.054	.279
PH	.447	-.235	.692
Cr	.267	.605	.055
Cu	-.441	.524	.036
Fe	.729	.345	-.194
Mn	.642	-.181	.325
Ni	.267	-.036	-.777
Zn	.105	.826	.233
Eigen values	1.967	1.533	1.363
% Variance	24.590	19.163	17.036
Cumulative	24.590	43.753	60.789

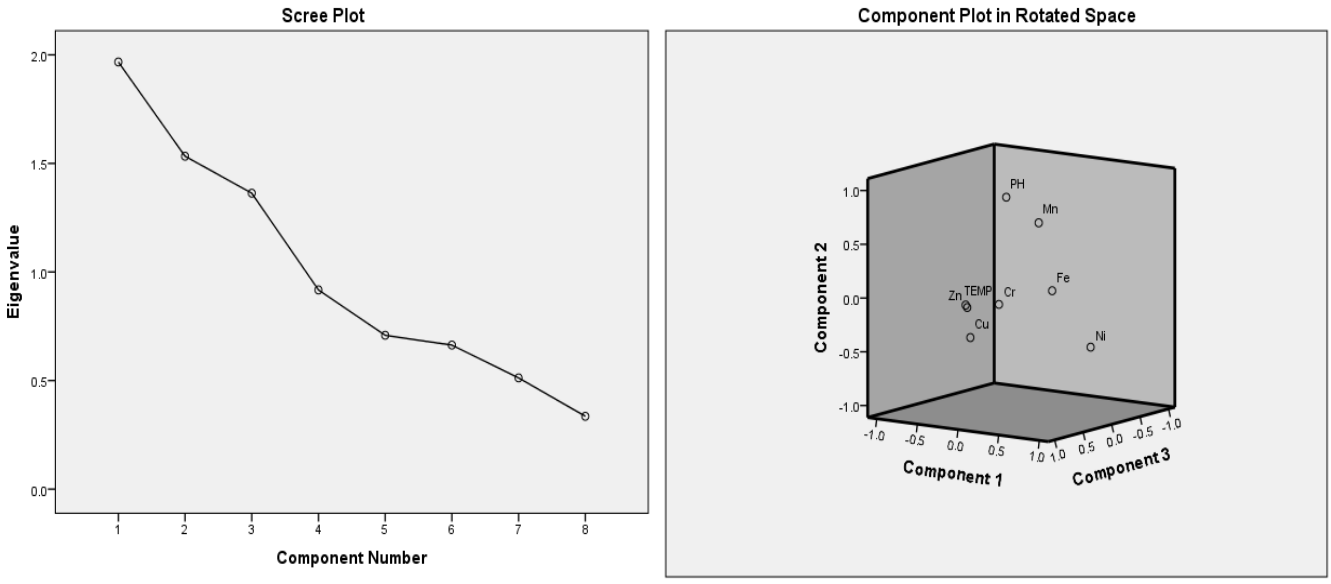

Figure 6a and 6b: Scree plot and factor plot in rotated space

The R- Mode Hierarchical Cluster Analysis HCA was used to determine the relationship between the heavy metals in the groundwater in the study area by grouping them based on their spatial similarities and differences. Parameters in the same group might have originated from the same source. The R-mode CA produced 3 clusters, this are demarcated in the dendogram, figure 7.

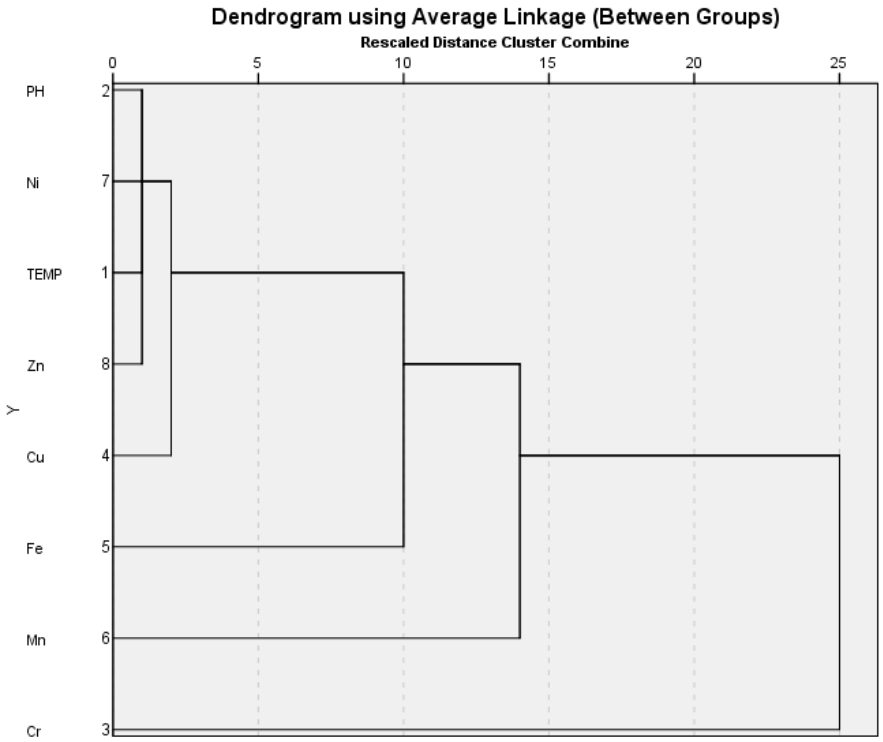

Figure 7: Dendogram for the physicochemical parameters in groundwater

Cluster 1 contain only Cr this corresponds with PC 2. Cr appeared as the only member in this cluster because it has the highest number of samples with concentration that are above the maximum standard limit than any other metal that was analyzed. Sources of Cr were both geogenic and anthropogenic traced to automobiles exhaust, leaching from residential refused dump site and weathering of minerals and leaching from soil respectively. Cluster 2 consisted of Mn, Fe, and Cu and this group agreed with PC 1, concentrations of the metals in this group is attributed to weathered mineral leaching and oxidation process as well as fossil fuel burning, the use of fertilizers that contain phosphate, could be the possible source for metals in this group**.** Cluster 3 contained Zn, Temp, Ni and PH which is comparable to PC 3 which is the weakest of the three clusters and the one with least concentration of heavy metals in it, for this group there is a strong indication of a natural source from geogenic material decomposition and burning of substances containing these metals.

4. Conclusion

The groundwater of Maru town and its environs was analysed and evaluated for its Heavy metal concentration and pollution statue, out of all the metals detected and evaluated Cr had concentration above the required and permissible limit of 50µg/l in 17 locations out of the 29 samples, representing 58.62 % of total samples analyzed. This level indicated chromium groundwater pollution in these locations. The consumption of water with this elevated concentration levels of chromium could result in health problems in individual taking such polluted water. The calculated pollution index that includes $C_{d,}$ HEI and HPI gives a low value for 75.56 % and 62.07 % for the $C_{d,}$ and HEI. The HPI was dominantly of high class with 65.52 % of the locations falling in this category; hence this indicated the groundwater in the area to be polluted. Among the indices, HEI is preferred as an assessment method for heavy metal pollution because its gives a better result compared to Cd and HPI. Multivariate treatment of the result revealed a good correlation between the PCA, and HCA, which showed geogenic and anthropogenic sources of the Heavy metals to be the products of weathering of rocks and minerals and automobiles exhaust, burning and leaching from dump sites and agrochemical on farm lands within the area of study. Also the CA grouping agreed with PCA in terms of significance and contribution of the different metals in terms of loading and concentration in the different locations within the study area.

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