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# PRELIMINARY INVESTIGATION OF SOME TRACE METALS CONTAMINATION INDEXES IN GROUNDWATER OF JEBBA-KARA ENVIRONS, NIGERIA

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## ABSTRACTS

Hydrochemical assessment of groundwater contamination in Jebba-Kara environs with respect to some trace elements distribution profiles in the area has been established. The aim is to assess possible environmental impacts of various anthropogenic activities and the weathering of surrounding rock types on the groundwater metal distributions in the area. Inductively Couples Plasma/Mass Spectrometry (ICP/MS) technique was used for the analysis of the trace elements in the sampled water. Hydrochemical analysis results show that the average concentrations of the trace elements analyzed fall below standards except average value of Ba (0.33 ppm) that is above the prescribed limits, making the water unfit for domestic consumptions. Also, elevated values of Al (0.87 ppm) and Fe (0.77 ppm) in some of the Hand-dug wells were observed. The Contamination Factor among the trace elements ranged from low Contamination Factor to moderate Contamination Factor depicting both anthropogenic and geogenic influences on the metals profile in the groundwater. The Degree of Contamination ranged from 0.68 to 7.96 depicting low degree of metal contamination. Computed average Geo-accumulation Index (I-geo) revealed practically no contamination. However, some of the computed I-geo in the Hand-dug wells water samples show some levels of contamination with respect to Al, Ba, Fe, Cu and Sr. The average Enrichment Factor (EF) computed for the trace elements ranged from deficiency enrichment to considerable enrichment of the metals in the water samples. Majority of the trace elements significantly correlated with one another connoting same source of metal contribution (anthropogenic or/and geogenic origins).

**KEYWORDS:** hand-dug wells, trace metals, contamination factor, geo-accumulation index, enrichment factor.

## INTRODUCTION

One of the main problems the public is encountering is contamination of domestic and industrial water supply. Many industries have actually contributed to the contamination of waterways by discharging toxic metals into rivers and streams and finally get in contact with the groundwater. The toxic metals (e.g. Pb, As, Cu, Ba, and Al) also get into the environment by air emissions from smelters, industrial smokes, waste incinerators, lead in household plumbing, old house paints and industrial waste (Tijani, 2000; Tijani *et al*., 2004; Odewande and Abimbola, 2008; Makinde, 2008;

Golia *et al*., 2008; Laniyan *et al*, 2013). The level of toxicity of the trace metals depends on the type, its biological role and the type of organisms that are exposed to it (Tijani *et al*., 2006; Laniyan *et al*, 2013). Some of the types of metals linked most often to human poisoning include: lead (Pb), mercury (Hg), arsenic (As) and cadmium (Cd). In developing nations like Nigeria, two sectors (food and processing sectors) accounted for nearly half (47.9%) of total polluted wastewater discharges from the Nigerian industry in 1994 (World Bank, 1998a; Laniyan *et al*, 2013). This has being the concern of the public health since majority of Nigerians still lack access to safe drinking water.

Interestingly, groundwater accounts for about 98% of the world's fresh water and it is however fairly well distributed throughout the world (Bouwer, 2002; Laniyan *et al*, 2013). It is readily exploited for agricultural, domestic and industrial uses in many urban and rural settlements; however, the underground has come to serve as a receptor for many industrial and urban wastewaters and for solid waste disposals (World Bank, 1998a; Laniyan *et al*, 2013).

Apart from river Niger at Jebba area, groundwater is the main available source of water in the area, even the available water from river Niger has to be treated before using it for various domestic purposes. The question is how many householders could afford the cost for water treatment unless the government comes to their aid? Unfortunately, the available hand-dug wells in the area are not properly maintained by the inhabitants. They do complain that the hand-dug wells are tasty. This research has therefore led to the preliminary investigation of some of the trace elements concentrations in the hand-dug wells in the study area to evaluate their respective contamination indexes and possible source(s) of contamination.

The area of study lies within latitudes $9^o11'29''$N and $9^o07'$N, longitude $4^o48'$E and $4^o52'$E (Fig. 1) at Central Nigeria. Jebba is the seat for Nigerian Hydropower station and Paper Mill Company. The main occupations in the area are Crop farming and cattle rearing and the area hosts daily movement of heavy trucks. The area is mainly drained by River Niger at Jebba and the study area is marked by two distinct seasons, the rainy and dry seasons. The rainy season runs from April to November, while the dry season is from November to April. The annual range of rainfall in the wet season is about 1,500 mm. The average annual temperature ranges between $35^o$ C during the day and $25^o$ C at night. The area lies within the Guinea Savannah vegetation belt of Nigeria with scanty trees, shrubs and grasses because of the moderate annual rainfall in the area. The area is situated across the basement complex of Nigeria and Bida basin. The basement rocks comprise of migmatite gneiss, quartzite complex, granitoids and minor acid dykes while the sedimentary terrain consists essentially of sandstones, conglomerates and claystones of Campanian to Maastrichtian age (Okonkwo, 1992; Omotoso and Ojo, 2012; Omotoso and Ojo 2015).

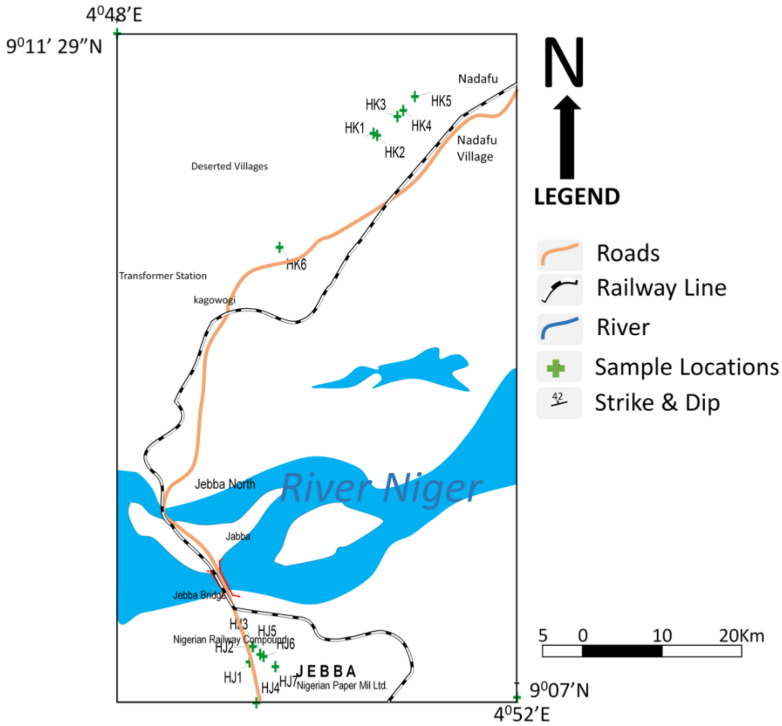


**Figure 1:** The study area showing sampling points

## METHODOLOGY

Thirteen hand-dug wells were sampled in January, 2015. 6ml white water bottle containers were used for water sampling. The containers were rinsed by the water to be put in them and filled to the brim. Concentrated nitric acid was added and covered immediately to prevent air tight. The reason for acidification is to prevent the precipitation of the needed cations from the water. In other words, it will maintain the cations in solution prior to laboratory analysis. The water samples were further sent to the Laboratory for analysis. Inductively Coupled plasma/ Mass Spectrometry (ICP/MS) method was used for the analysis of the trace elements. The Hydrochemical analysis was carried out in ACME laboratory in Canada.

## RESULTS AND DISCUSSION

### Trace elements concentration in the ground water phase

The results of the Hydrochemical analysis of the trace elements together with the statistical summary are presented in Table 1. Al ranged from 0.014 to 0.873 ppm (average=0.10 ppm; stdev=0.23 ppm, variance=0.06 ppm). All the hand-dug wells have values below the prescribed limits of WHO and NSDWQ except hand-dug well HJ1 at Jebba having value of 0.87 ppm. Unfortunately some of the inhabitants do consume this source of water without any prior treatment (Table 1).

Al causes potential neuro-generative disorder in man.

**Table 1:** measured concentrations of the trace metals along side with their respective statistical summary and WHO standards

| Sample ID | mean, ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Al | Ba | Co | Cu | Fe | Mn | Sr | Zn | Pb | As |
| HJ1 | 0.873 | 0.06638 | 0.00053 | 0.0039 | 0.767 | 0.16237 | 0.04741 | 0.0195 | 0.0038 | BDL |
| HJ2 | 0.019 | 0.16389 | 0.00006 | 0.0014 | BDL | 0.00155 | 0.13729 | 0.0035 | 0.0002 | BDL |
| HJ3 | 0.022 | 0.10245 | 0.00008 | 0.0019 | 0.024 | 0.00341 | 0.09983 | 0.0079 | 0.0003 | BDL |
| HJ4 | 0.031 | 0.16118 | 0.00027 | 0.0037 | BDL | 0.07156 | 0.38444 | 0.008 | 0.0003 | 0.0014 |
| HJ5 | 0.046 | 0.04294 | 0.00055 | 0.0021 | BDL | 0.17336 | 0.45629 | 0.0148 | 0.0005 | 0.0007 |
| HJ6 | 0.035 | 0.19729 | 0.00027 | 0.0039 | 0.098 | 0.03912 | 0.61547 | 0.4085 | 0.0018 | 0.0006 |
| HJ7 | 0.025 | 0.03239 | 0.00035 | 0.0022 | BDL | 0.02324 | 0.27595 | 0.0095 | 0.0007 | 0.0008 |
| HK1 | 0.123 | 0.87183 | 0.00802 | 0.0021 | 0.109 | 0.04404 | 0.31848 | 0.0111 | 0.0016 | BDL |
| HK2 | 0.022 | 1.05616 | 0.00055 | 0.0088 | 0.029 | 0.00733 | 1.56896 | 0.0301 | 0.0006 | 0.001 |
| HK3 | 0.015 | 0.17589 | 0.00123 | 0.0043 | 0.017 | 0.00429 | 0.11433 | 0.0071 | 0.0004 | BDL |
| HK4 | 0.018 | 0.1691 | 0.00301 | 0.0078 | 0.011 | 0.00536 | 0.06307 | 0.0066 | 0.0009 | BDL |
| HK5 | 0.036 | 0.11452 | 0.00085 | 0.0057 | 0.019 | 0.00369 | 0.04689 | 0.0039 | 0.0008 | BDL |
| HK6 | 0.014 | 1.12863 | 0.00005 | 0.0013 | BDL | 0.00521 | 2.2949 | 0.0092 | 0.0003 | BDL |
| **average** | **0.098385** | **0.329435** | **0.001217** | **0.003777** | **0.13425** | **0.041887** | **0.494101** | **0.041515** | **0.00093846** | **0.0009** |
| **min** | **0.014** | **0.03239** | **0.00005** | **0.0013** | **0.011** | **0.00155** | **0.04689** | **0.0035** | **0.0002** | **0.0006** |
| **max** | **0.873** | **1.12863** | **0.00802** | **0.0088** | **0.767** | **0.17336** | **2.2949** | **0.4085** | **0.0038** | **0.0014** |
| **stdev** | **0.234471** | **0.400075** | **0.00219** | **0.002395** | **0.258506** | **0.059788** | **0.678056** | **0.110498** | **0.00099208** | **0.00031623** |
| **Variance** | **0.054977** | **0.16006** | **4.79E-06** | **5.74E-06** | **0.066825** | **0.003575** | **0.45976** | **0.01221** | **9.8423E-07** | **0.0000001** |
| **WHO, 1993** | 0.2 | 0.3 | - | 2 | 0.3 | 0.5 | - | 3 | 0.01 | 0.01 |

***BDL= below detection limit***

Ba ranged from 0.03 to 1.13 ppm (average=0.33 ppm; stdev. =0.4 ppm; variance=0.16 ppm). On the average the value is above the prescribed limits of WHO and NSDWQ. Hand-dug wells HK1, HK2 and HK6 have Ba values above the prescribed limit. Barium does enhance an increase in blood pressure, gastrointestinal problems, muscle weakness and influence the nervous and circulatory system. Cu ranged from 0.0013 to 0.009 ppm (average=0.004 ppm; stdev. =0.002 ppm; variance=$5.7*10^{-6}$). The values are generally below the prescribed standards of WHO and NSDWQ. Fe ranged from 0.011 ppm in Hand-dug well HK4 to 0.77 ppm in Hand-dug well HJ1 (average=0.13 ppm; stdev. =0.26 ppm; variance=0.07 ppm). On the average, the value is below the prescribed limit of WHO and NSDWQ. However, Hand-dug well HJ1 only has its concentration above the prescribed limit. Furthermore, Mn ranged from 0.0016 to 0.17 ppm (average=0.04 ppm; stdev. =0.06 ppm; variance=0.004 ppm). All the values fall below prescribed standards. Zn ranged from 0.0035 to 0.41 ppm (average=0.042 ppm; stdev. =0.11 ppm; variance=0.01 ppm). Pb ranged from 0.0002 to 0.0038 ppm (average=0.0009 ppm; stdev. =0.001 ppm; variance=$10^{-7}$ ppm). All the values appeared to fall below the prescribed limit. As ranged from 0.0006 to 0.0014 ppm (average=0.0009 ppm; stdev. =0.0003 ppm; variance=$10^{-8}$ ppm). Most of the Hand-dug wells fall below the detection limit for As and the traces detected in remaining wells are below the prescribed limits.

**Contamination Factor (CF) and Degree of Contamination of Groundwater Samples**

Contamination Factor computed for Al ranged from 0.07 in Hand-dug well HK6 (low contamination factor) to 4.37 in Hand-dug well HJ1 (considerable contamination factor). On the average, contamination factor of 0.49 is determined which is of low contamination. Most of the CF computed for Al in the Hand-dug wells fall below one (1). This depicts geogenic source for Al into the Hand-dug wells except Hand-dug well HJ1 having CF of 4.37 with high influence of anthropogenic activity on the well leading to Al contribution into the well (Tijani *et al.,* 2007).

Hand-dug wells HK1, HK2 and HK6 have contamination factor greater than 1 which depict anthropogenic source (Tijani *et al.,* 2007). Others have low contamination factor for Ba, lower than 1 which connotes geogenic Barium metal contribution into the wells. The average CF for Ba in the wells is 1.1 which depicts anthropogenic contribution of Ba into the Hand-dug wells.

Furthermore, the Contamination Factor determined for Co ranged from 0.01 to 0.8 (average=0.12) depicting contribution from weathering of granitic and meta-sedimentary rocks in the study area (Tijani *et al.,* 2007). The CF calculated for Cu ranged from 0.007 in sample HJ2 to 0.004 in sample HK2 (average=0.0019) which signifies low contamination factor. This also revealed activities of weathering of rock types in the area leading to the dissolution of Cu into the groundwater phase. This also depicts lower influence of anthropogenic contribution in the study area. The rock types observed in the study area include: granite, granite gneiss, quartzite and biotite schist (Okonkwo, 1992).

CF factor computed for Fe ranged from 0.04 in Hand-dug well HK4 to 2.56 in Hand-dug well HJ1 (average=0.45). This depicts CF ranging from low contamination factor to moderate contamination factor. This connotes influence of weathering activities in the area leading to the contribution of Fe into the water phase except Hand-dug well HJ1 that has moderate contamination factor of 2.56 due to various anthropogenic activities in the area. The CF computed for Mn also ranged from 0.003 in Hand-dug well HJ2 to 0.35 in Hand-dug well HJ5. This denotes low CF by the influence of weathering of rock types and dissolution of Mn ion into the groundwater phase.

Contamination Factor computed for Sr ranged from 0.05 in Hand-dug well HJ1 to 2.29 in Hand-dug well HK6 (low contamination to moderate contamination factor). The source of Sr is no doubt from the weathering and dissolution of the rock types minerals in the study area as depicted by CF of <1 except Hand-dug wells HK2 (CF=1.57) and HK6 (CF=2.29) which depict influence of anthropogenic activities in the area. The CF computed for Zn in the groundwater ranged from 0.00117 in Hand-dug well HJ2 to 0.136 in Hand-dug well HJ6 (i.e. low contamination factor) which are of geogenic source of Zn ions dissolution into the groundwater phase.

Contamination Factor computed for Pb ranged from 0.02 in Hand-dug well HJ2 to 0.38 in Hand-dug well HJ1 which are of low contamination factor. The source of lead (Pb) ion contribution is from the weathering of rocks forming minerals in the area. The contamination Factor computed for As ranged from 0.06 in Hand-dug well HJ6 to 0.14 in Hand-dug well HJ4 which are of low contamination factor. Hand-dug wells HJ1, HJ2, HJ3, HK1, HK3, HK4, HK5 and HK6 are below detection limit for As concentration. The addition of the contamination factors of all the elements in each of the sample gives the degree of contamination. The Degree of Contamination in the groundwater samples ranged from 0.68 to 7.96 (average=2.71) which fall within low degree of contamination.

***Index of Geo-accumulation (I-geo):*** The computed I-geo for Al in the Hand-dug wells ranged from practically uncontaminated (-4.4) in Hand-dug well HK6 to moderately contaminated (1.5) in Hand-dug well HJ1. The extent of contamination in Hand-dug well HJ1 by the influence of anthropogenic activities in the area is also confirmed by the computed Contamination Factor for Al in the same water sample. Barium ranged from -3.796 in Hand-dug well HJ7 to 1.327 in Hand-dug well HK6 (i.e. from practically uncontaminated to moderately contaminate). In addition, Hand-dug well HK1 with I-geo of 0.95 and Hand-dug well HK2 with I-geo of 1.23 indicate uncontaminated to moderately contaminated and moderately contaminated respectively.

Computed I-geo values for Co, Cu, Mn, Zn, Pb and As indicate practically uncontaminated in all the Hand-dug wells. However, I-geo for Fe ranged from practically uncontaminated (-5.35) in Hand-dug well HK4 to uncontaminated to moderately contaminated (0.77) in Hand-dug well HJ1. Likewise, the computed I-geo for Sr ranged from practically uncontaminated (-5) in Hand-dug well HK5 to uncontaminated to moderately contaminated in Hand-dug well HK2 and HK6 respectively (0.06 and 0.61).

**Enrichment Factor (EF)**

It is a measure of geochemical trends used for making comparisons between areas (Sinex and Helz, 1981; Hasan *et al.*, 2013). A value of unity (i.e. one) connotes neither enrichment nor depletion relative to the World Health Organization Drinking water standard (Laniyan *et al* 2013).

The EF computed for Al in all the Hand-dug wells water ranged from deficiency to minimal enrichment (0.536) in Hand-dug well HJ6 to moderate enrichment (2.84) in Hand-dug well HK5. The degree of their enrichment are brought about by the weathering and dissolution of rock types present in the area except for Hand-dug well HJ1 which is more influenced by anthropogenic activities in the area.

The computed values for EF of Barium in the groundwater samples ranged from deficiency to minimal enrichment (EF=0.087) in

Hand-dug well HJ1 to very high enrichment (EF=36) in Hand-dug well HK2. Enrichment Factor calculated for Co in the groundwater samples ranged from deficiency to minimal enrichment (0.021) in Hand-dug well HJ1 to significant enrichment in Hand-dug well HK4. Likewise, the EF computed for Sr ranged from deficiency to minimal enrichment (0.019) in Hand-dug well HJ1 to significant enrichment in Hand-dug well HK2. Pb ranged from deficiency to minimal enrichment to moderate enrichment and As, Zn and Mn fall within the range of deficiency to minimal enrichment.

**Correlation matrix between trace elements of groundwater samples:**

The correlation matrix was computed to search the relationship between the trace elements. Elements that showed significant correlations with Al are: Fe(r=1.00), Mn(r=0.63) and Pb(r=0.90). Ba significantly correlated with Co(r=0.33), Sr(r=0.83) and As (r=0.21). Co also significantly correlated with As (r=0.27). Mn significantly correlated with Pb (r=0.55). About 60% of the trace elements of the water samples were significantly correlated with one another, hence it could be said that their source was both from anthropogenic and geogenic influences on the groundwater.

## CONCLUSION

From the Hydrochemical analysis and evaluation of the data, the following conclusions are drawn:

1. The metal average concentrations in the Ground water phase are within the prescribed limits of WHO and NSDWQ standards except the individual concentration of hand-dug wells HJ1 having concentration of Al to be 0.87 ppm; hand-dug wells HK2 and HK6 having concentrations of Ba to be 1.06 ppm and 1.13 ppm respectively; hand-dug wells HK1, HK3 and HK4 having concentrations of Co to be 0.008 ppm, 0.0012 ppm and 0.003 ppm respectively; hand-dug well HJ1, with concentration of Fe to be 0.77 ppm; hand-dug wells HK2 and HK6 having concentration of Sr to be 1.57 and 2.29 ppm respectively. Excess Al and Ba in the body cause health related diseases like potential neuro-degenerative disorders and hypertension respectively.
2. The average Contaminated Factor of the metals ranged from low (0.001, as in Cu and Zn) to considerable contamination factor (4.37, as in Al) which depicts both geogenic and anthropogenic input of metals into the Ground water phase.
3. The Degree of Contamination ranged from 0.68 to 7.96 indicating low degree of contamination of the trace elements in the samples.
4. The average Geo-accumulation Index indicates practically no contamination. However, some individual hand-dug wells indicate certain extent of contamination induced by anthropogenic activities and weathering of rock types in the area.
5. The average enrichment factor of the metals ranged from 0.032 in Cu to 10.32 in Ba (i.e. deficiency to minimal enrichment and significant enrichment) indicating Ba is significantly enriched in the hand-dug wells of the area with respect to Fe normalization.

The results from correlation matrix computed for the trace elements show that 60% of the trace elements significantly correlated with one another confirming their sources from both anthropogenic and geogenic.

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