Covenant Journal of Physical & Life Sciences (CJPL) Vol. 9 No. 1, June 2021
ISSN: ***print 2354 - 3574 electronics 2354 – 3485 DOI:***

An Open Access Journal Available Online

Concentrations of Selected Trace Metals in Groundwater from a Legacy oil-spill location in Rivers State, Nigeria

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Received: 09.05.2021; Accepted: 02.02.2021
Date of Publication: June 2021

***Abstract*:** This study was carried out to assess the concentrations of some selected trace metals in borehole water from a legacy oil spill location in Rivers State, Nigeria. Water samples were collected from ten (10) functional boreholes using standard techniques. The levels of the trace metals in the study area were found to be in the order of: cadmium (0.361±0.381 mg/L), > lead (0.117±0.056 mg/L) > nickel (0.042±0.0281 mg/L) > cobalt (0.010±0.009 mg/L) in the water samples. These values were above the WHO and NIS limits. The water quality parameters varied across the sampling periods (June and August); apart from Cd whose mean value was higher during the month of June, but lower during the second month. The groundwater from the community is therefore, unsafe for drinking purpose due to elevated levels of toxic metals. These findings give cause of concern, particularly as trace metals are bio accumulative in the human system and portends a serious health risk to man. In light of these findings, periodic analysis of samples from boreholes is inevitable so as to reveal contamination or pollution status of groundwater in this area and to determine the best method for water treatment. It will help in safeguarding the health of water consumers against the subsequent impact that may arise from drinking trace metals contaminated water.

Keywords: Groundwater, concentrations, Pollution, Trace metals, legacy oil-spill location, Water quality.

1.0 Introduction

The World Health Organisation [25] reported that 786 million people globally do not have access to safe drinking water. This report makes it roughly one in ten of the 7.4 billion world's population. Nigeria is not exempted from the world water crisis affecting other countries in many parts of the world. [26] reported that over 63 million Nigerians have no choice but to get water wherever they can, leading to

57 million people not having access to safe water and 25,000 children die every year from diarrhoea caused by unsafe water and poor sanitation.

Presently, it is estimated that more than 300 million people in Africa live in a water-scarce environment. By 2025, eighteen African countries are expected to experience water stress. The amount of fresh water available for each person in Africa is about one-quarter of what it was in 1950; in many countries, requirements for domestic freshwater use, sanitation, industry and agriculture cannot be met [4]. The situation might worsen due to population growth, rapid s urbanisation, increasing agriculture and industrial activities, and lack of adequate capacity to manage freshwater resources [4].

The best standard of purity is required for drinking water as the water mostly accessible is obtained from different sources like wells, streams, lakes, rivers (surface water), groundwater (boreholes) [14]. Groundwater is water located beneath the surface in soil pore spaces and in permeable geological formations. [1][23] Gave empirical figures which suggest high groundwater resources potential for Nigeria. [17] Opined that the nation's groundwater resource is abundant and of good quality, estimated at 52,000 Million Cubic Metres (MCM), with an estimate of 11,800 km3 as estimated groundwater storage in Nigeria. Groundwater includes all water found beneath the earth's surface in a saturated zone of the aquifer[8]. They are formations that contain sufficient saturated permeable materials to yield sufficient quantities of water to wells and springs [8][19]. Groundwater can be extracted utilising Hand Dug Wells (HDWs) and boreholes at various depths. A large percentage of the world population depends on groundwater as their primary source of drinking water [8][22].

Groundwater has various advantages over surface water as it is not exposed to water pollutants associated with surface waters. In view of this, the World Health Organization recommends that drinking water supplies be well analysed based on their contamination or pollution level [14]. Very few people in small towns have access to a safe water supply. Only about 5 percent from small towns, get water from protected ground sources through boreholes [14]. The WHO had stated that it is not sufficient merely to have access to water in adequate quantities, the water also needed to be of adequate quality to maintain good health [2]. Such water must be free from toxic biological, physiological and chemical contaminations. The widespread reports on pollutants in groundwater have increased in recent years and have resulted in increased public concern on the quality of groundwater. The importance of potable water, both for domestic and industrial uses, has created a public health concern for water quality analysis [14]. Groundwater bodies are prone to contamination from anthropogenic and natural activities [16]. Boreholes, though more protected due to inherent chemical constituents of permeable rocks through which the water flows, can limit the quality of the water as they may have dissolved impurities that came from rock and sand strata through which the water flowed or passed. The seepage of waste buried underground such as pit toilets or leachate from fertiliser applications and debris from erosion can produce harmful effects on groundwater quality, especially in Ebubu, a legacy oil spill location in Rivers State with potential high flooding risk and the residents are primarily farmers. This study was carried out to determine the levels of trace metals contamination of ten different functional boreholes spatially distributed in Ebubu community to assess the portability and usability of their borehole water as a domestic water supply. Ebubu is chosen for this research as it is considered a crude oil overburdened site owning to previous oil-spill record in that area [4]. The result and findings of this research shall provide information on the effect of crude oil spill on groundwater even after years of its spillage.

2.0 Materials and Methods

2.1 Sample Collection

Groundwater samples were collected from the different sampling locations within the Ebubu community were transported in an ice cooler to Fugro international Laboratory, Port Harcourt, Rivers state. Trace metals were determined in accordance with APHA 3111B, 3112B, 3114B, 3030B and ASTM D3859 [5]. Samples of groundwater obtained from Ebubu Eleme were digested and subjected to an atomic absorption spectrometer (Perkin Elmer 3100 model) for metals analyses. The concentrations of lead (Pb), Cadium (Cd), nickel (Ni) and cobalt (Co) were analysed. SPSS version 22 was used for statistical analysis and the data were presented as mean.

Trace metal contents were calculated as follows.

Metal concentrations (mg/L)

$$= \frac{C \times Y}{X}$$

Where C = Concentration of metal determined from calibration curve (mg/l)

Y = Final volume made-up (ml)

X = Volume of sample (ml)

3.0 Results

These metals were present in all the sampled boreholes, though their values varied. These metals are often characteristic of municipal landfill leachates and can be harmful to health [25]. The average value of nickel present in groundwater was 0.042 mg/L in groundwater. This value is higher than the [25], and [15] prescribed limit. The minimum value was obtained in BH5 and maximum in BH10. Nickel was, however not detected at BH6, BH7 and BH8 (Table 1). The distribution of nickel in groundwater is presented in Figure 1. Water samples from boreholes (BH6, BH7 and BH8) had the same distribution pattern as their values were below the detection limit. Similarly, in the month of June, Ni level was below the detection level in BH5. Water samples from BH10 had the highest level of nickel for both June and August (sampling periods) followed by water from BH2. The presence of nickel is an indicator of the presence of pollution from petroleum product [9]. This finding is similar to that of [6] who in their study had values above the WHO limit within the Niger

Delta area. However, this finding is at variance with [2] who had values lower than the [25] limit within the Niger Delta area. Nickel can result in lung, liver and kidney damage. In high quantities, Ni can also cause cancer, respiratory failure, birth defects, allergies, dermatitis, eczema, nervous system and heart failure [13].

Lead from this study had a mean value of 0.117 mg/L within the study area. This value is above both the [25] and the [15] limits of 0.01 mg/L. These findings confirm an earlier work by [6] who had recorded a mean value of 2.8 mg/L in groundwater within this region, an indication of possible lead pollution with the study area. The distribution pattern of Pb in groundwater from Ebubu community is presented Figure 2 indicates that water samples from boreholes (BH1 to BH8) had the same pattern of distribution as their values in the month of June were more than in the month of August. The reverse case was observed for BH9 and BH10, where the values in the month of August were higher than in the month of June. Although BH9 and BH10 are 768.56m and 929.96m away from the legacy spill site (Table 1, Figure 5), this could be due to more ionic dilution within the aquifer during the month of August. The peak value of lead content was recorded for BH2 first sampling. Lead in drinking water could have significant medical effects on renal functions [3]. Other symptoms of acute lead poisoning are headache, irritability, and abdominal pain [12].

Cadmium had a mean level of 0.361 mg/L in this study (Table 1). This value is above the permissible limit of 0.003 mg/L prescribed by both the [25][15]. Distribution pattern of cadmium in groundwater is presented in Figure 3. Water samples from boreholes (BH1 to BH9) have more levels of cadmium in the month of June than in the month of August (the second sampling period). However, in BH10 cadmium was below detection level during the month of August. However, this finding is at variance with [24] submission in their study conducted on water bodies around Warri refinery area in Nigeria, when they reported nil for cadmium. However, cadmium has health effects like hypertension, cancer, cardiovascular diseases and other kidney related effects [21].

The mean value of cobalt (Co) observed in this study was 0.010 mg/L. This is above the WHO value of 0.0038 mg/L. This finding collaborates with [6] report that revealed a mean value of 0.60 mg/L within the same area. The distribution pattern of cobalt in groundwater samples is presented in Figure 4. Cobalt was below detection limit in four boreholes (BH4, BH5, BH6 and BH8) in June, and BH10 only in August. However, cobalt was detected in six boreholes (BH1, BH2, BH3, BH7, BH9, and BH10) in June and nine boreholes (BH1, BH2, BH3, BH4, BH5, BH6, BH7, BH8 and BH9) in August. The presence of Co is an indicator of the presence of pollution from petroleum product [9]. Cobalt, when ingested, could lead to vomiting, abdominal pain, allergic reactions in the skin, asthma, inflammation and fibrosis of the lung [25]. Generally, the higher contents of toxic metals recorded in this study indicate higher metal accumulation and this is similar to the findings of [10] within the same region.

Nickel, lead, and cobalt had higher mean values of 0.098±0.168; and 0.088±0.085 and 0.011±0.008 respectively (Table 2) during the month of August than during the month of June, while cadmium had higher mean value in August 0.106±0.009. Lower values during the month of August may be due to more ionic dilution within the water aquifer because of increase rainfall and is in agreement with the findings of [11] within the Niger Delta area, they also added that the sampling period variations in the levels of the trace metals could be attributed to the difference in individual metals solubility, pH, leaching by acid rain during the wet season and topography of the area. Toxic metals trend in groundwater samples is in the order Cd (0.106±0.009) >Pb (0.061±0.001) > Ni (0.048±0.023) > Co (0.004±0.001) for the month of June (first sampling), and Ni (0.098±0.168) > Pb (0.088±0.085) > Cd (0.082±0.058)>Co (0.011±0.008) for the month of August (second sampling) (Table 2). It was also observed that both Cd and Pb had higher values than the [25][15] permissible limits during both sampling periods. While the value for Ni was only higher than the [25] limits for the month of August. Co was within range for both sampling period.

Also, the correlation analysis computed for the four toxic metals (Table 3) indicates that there is a strong positive relationship between cobalt and lead(0.603), indicating a possible common source of contamination to the sampled groundwater possibly the legacy oil spill site within the area of study. A positive relationship is revealed between lead and Nickel (0.500), and a weak positive correlation (0.137) between cobalt and cadmium (Table 3). There was, however, a negative correlation between nickel and cadmium (-0.523), and between nickel and cobalt (-0.036), indicating that they do not have the same source of pollution [7].

Table 1: Mean Distribution of Toxic metals of the Analysed Groundwater Samples

Sample Locations												
Parameters	**BH1**	**BH2**	**BH3**	**BH4**	**BH5**	**BH6**	**BH7**	**BH8**	**BH9**	**BH10**	**Mean**	**WHO (2006)**	**NIS (2007)**
Ni	0.04	0.08	0.05	0.03	0.003	BDL	BDL	BDL	0.013	0.20	0.042±0.0281	0.07	0.02
Cd	0.68	0.30	0.38	0.27	0.42	0.54	0.35	0.42	0.20	0.05	0.361±0.381	0.003	0.003
Pb	0.11	0.18	0.09	0.09	0.10	0.11	0.09	0.12	0.15	0.13	0.117±0.056	0.01	0.01
Co	0.01	0.02	0.01	0.005	0.01	0.004	0.01	0.0075	0.02	0.003	0.010±0.009	0.0038	NS

*BDL= Below Detection Limit *NS= Not Stated

Table 2: Summary of Toxic metals in borehole water in Ebubu during sampling

		Month of Collection	
Parameters	Variable	June (BH1-BH10)	August (BH1-BH10)

Nickel	Mean	0.048±0.023	0.098±0.168
	Range	BDL-0.08	BDL-0.005
Cadmium	Mean	0.106±0.009	0.082±0.058
	Range	0.09-1.25	0-0.08
Lead	Mean	0.061±0.001	0.088±0.085
	Range	0.06-0.31	0.055-0.21
Cobalt	Mean	0.004±0.001	0.011±0.008
	Range	BDL-0.003	0.00-0.02

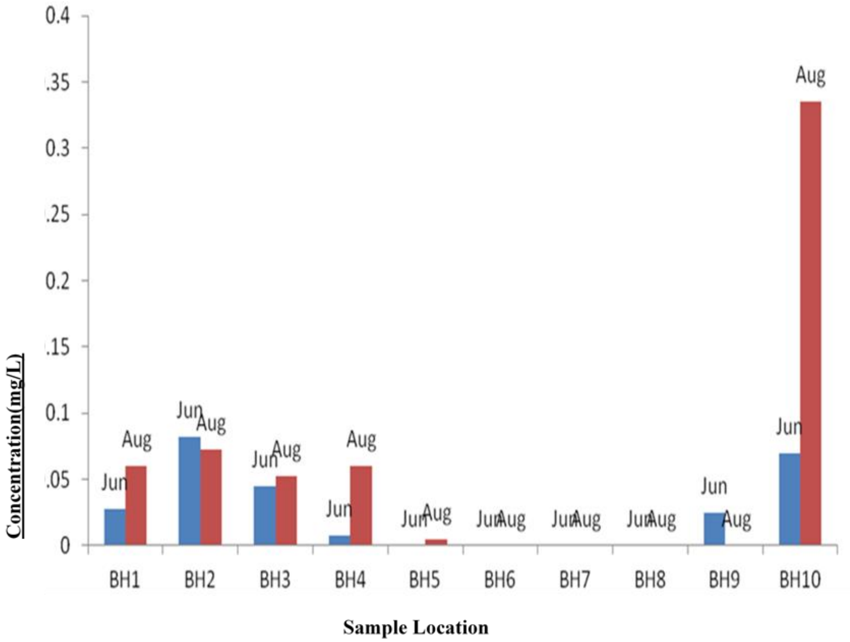

Figure .1: Distribution of Nickel in boreholes from Ebubu-Eleme

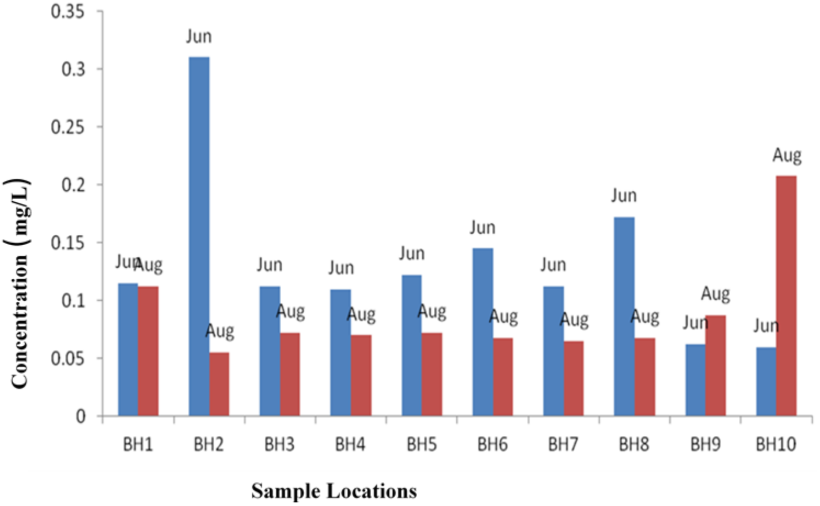

Figure 2: Distribution of lead in boreholes from Ebubu-Eleme.

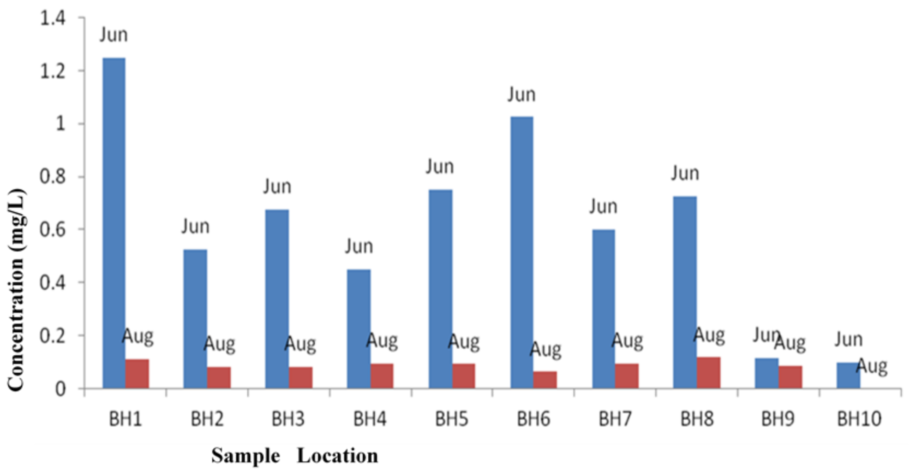

Figure 3: Monthly Distribution of Cadmium in boreholes from Ebubu-Eleme.

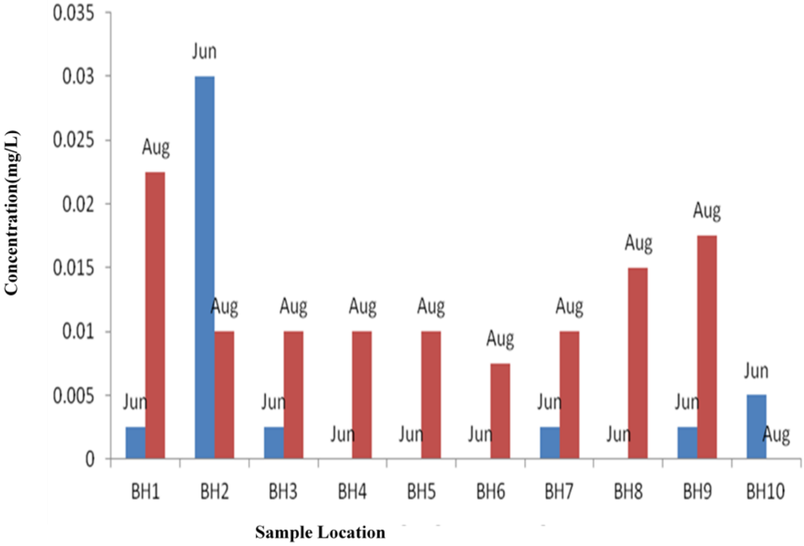

Figure 4: Monthly Distribution of Co in boreholes from Ebubu-Eleme.

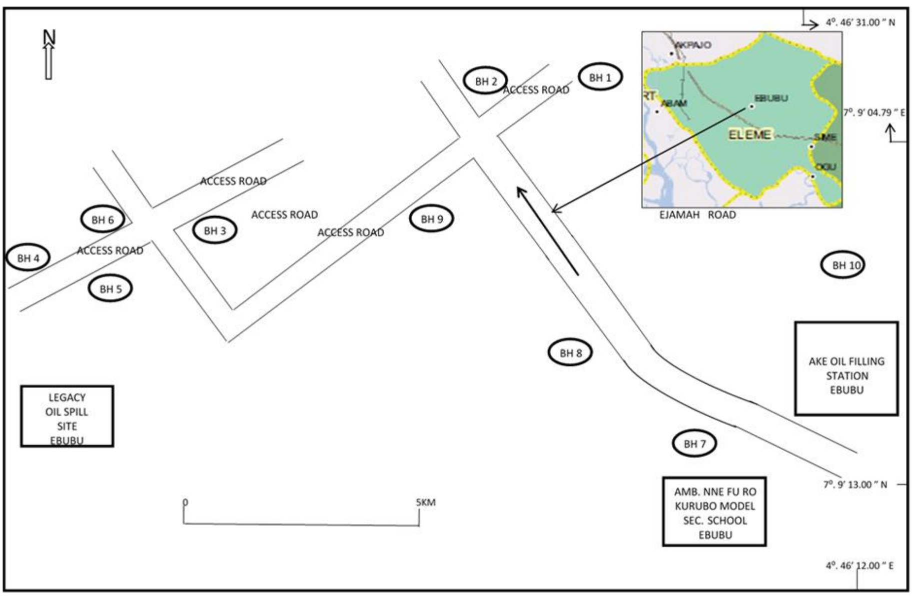

Figure 5: Ebubu Town showing the sampling points

5.0 Conclusion

Standard analytical protocols were used to assess the quality of groundwater in Ebubu town, a legacy oil spill location in Rivers State, Nigeria. The ground water samples were analysed for toxic metal contents/level. Use a better statistical tool were used for data analysis.

The mean values of toxic metals examined: Nickel (0.042 mg/L), Cadmium (0.361 mg/L), Lead (0.117 mg/L) and cobalt (0.010 mg/L) exceeded the [30] regulatory limit of 0.07 mg/L; 0.361 mg/L; 0.01 mg/L and 0.0038 mg/L respectively. These values also exceeded the permissible limit prescribed by [16].

The toxic metals levels examined also varied across the sampling periods; apart from Cd whose mean value was higher during the month of June, but lower in August, all other toxic metals (Ni, Pb, and Co). Also, the correlation analysis computed for the toxic metals suggests that there is a strong positive relationship between cobalt and lead (0.603), indicating a possible common source of contamination to the sampled groundwater possibly the legacy oil spill site within the area of study. A positive relationship between lead and Nickel (0.500) was established, while cobalt and cadmium show a weak positive correlation (0.137). There was, however, a negative correlation between nickel and cadmium (-0.523) and between nickel and cobalt (-0.036), indicating that they do not have the same source of pollution.

The total mean level of cadmium (0.361 mg/L) was observed to be the highest of all trace metals under study. The mean concentrations of nickel, cadmium, lead, and cobalt in the water samples were higher than the [25] limits for drinking water. The sampled boreholes water were therefore not suitable for human consumption, but may be adequate for domestic processes. These findings give cause of concern, particularly as trace metals are bio accumulative in the human system and portends a serious health risk to man.

In light of these findings, periodic analysis of samples from boreholes is inevitable so as to reveal contamination or pollution status of groundwater in this area and to determine the best method for water treatment. This will help in safeguarding the health of water consumers against the subsequent impact that may arise from drinking trace metals contaminated water, as industrialisation and population are on the increase in Ebubu town.

Acknowledgement

The authors appreciate the University of Uyo for the conducive environment provided for this research

6.0 References

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