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# Elemental Composition of Sediments from Borehole Water in Abakaliki Metropolis, Ebonyi State, Nigeria

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**ABSTRACT:** Elemental composition of sediment samples (sample S1 and sample S2) from borehole water collected from Abakaliki Metropolis was evaluated using Energy Dispersive X-ray Fluorescence (ED-XRF) model 710H, 7300Si (L), 4861BM/PC. The results indicated a total of 18 elements in S1 sediment and 14 elements in S2 sediment in different concentrations expressed in weight percentage (wt.%). Fe and Mn had the highest concentration of 62.4365 ± 0.1491 wt.% and 15.2202 ± 0.0789 wt.% respectively in S1 sediment, while the concentration of Ca (82.9295 ± 0.2057 wt. %) was highest in S2 sediment. The mean concentrations of all the heavy metals found in S1 were above the WHO maximum permissible limit except for Cu and Zn, while only Mn exceeded the WHO limit in S2 sediment. These results showed that Fe, Mn and Ca were the three most abundant elements in the sediments. The presence of these elements is likely to be cause of the observed problems in borehole water in the area such as high hardness, food and fabric colouring and food sour. Therefore water samples from boreholes in Abakaliki Metropolis require treatment to make them potable and fit for domestic purposes.

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## INTRODUCTION

Underground water sourcing from boreholes and hand-dug wells are the most prevalent sources of water to residents of Abakaliki metropolis and its environs all year round. Greater number of people who reside in the area resorts to borehole water for their daily water need in view of the inconsistent supply and sometimes non availability of pipe borne water in the city. However, the poor quality of water from these boreholes orchestrated by some inherent problems usually limits the water use in terms of drinking, bathing, laundry and other purposes. In most of these boreholes, high level of salinity, hardness, turbidity and colouring of food, fabric and storage tanks have been reported (Afiukwa, 2010; Christian and Nnabo, 2015). Often times, water from some of these boreholes appear clear when collected freshly but upon standing for some hours, visible sediments settle at the bottom of the container. Ordinarily these sediments would normally be consumed by those who drink the borehole water. From literature survey, possible components of these sediments may include several solid particles of different sizes and origin suspended in the borehole water. Examples include sand, silt, chalk, carbonaceous materials, organic materials and other small solid particles of varying sizes suspended in water (Gaur *et al.*, 2005). The presence of solidified particles of calcium and magnesium when these minerals occur in the water table (aquifer) from where

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the borehole water is obtained can also bring about accumulation of sediments in water (Murad *et al.*, 2011). Sediments in the form of solid precipitates are also observed when borehole water from the area is boiled and left to stand for few hours. The problem of sediment formation in borehole water samples from Abakaliki metropolis have triggered concern on the overall quality and suitability of water from boreholes drilled in the area to serve for most domestic purposes including drinking.

In this study, analysis of the inherent elemental composition of sediments formed when samples of borehole water was left to stand for some days and sediments obtained after boiling were carried out to assess the overall quality of groundwater in the area. Although a number of studies have been done on the physical and chemical status of borehole water and other water sources in Ebonyi State (George and Paulinus, 2014; Ngele *et al.,* 2014; Christian and Nnabo, 2015; Afiukwa, 2010; Njoku *et al.,* 2015) information on the nature and composition of sediments in the borehole water are limited. To this end, this study sought to provide information on the elemental composition of sediments from borehole water in Abakaliki Metropolis, Ebonyi State, Nigeria.

## MATERIALS AND METHODS

*Sampling and Sediment Collection:* Borehole water samples were collected from five different boreholes located within Abakaliki metropolis using newly purchased and pre-washed 2-litre white plastic containers. Each of the samples was divided into two. One litre each of the samples was allowed to stand for 7 days and then carefully decanted and filtered to obtain a dark-brown residue (sediments) which aggregated at the bottom of each of the containers. Sediments from each of the samples were mixed together to obtain a composite sample. The composite sediment obtained was sun-dried for 48 h and were later oven-dried at 65 ºC until a constant weight was obtained. This was labeled S1 and kept in an airtight and sterilized polypropylene vial. The remaining one litre of each of the sample was boiled and allowed to cool for 24 hours. Deposit of white precipitate formed were filtered, dried and packaged in the same manner as in S1 sediment labeled S2.

*Sediment Sample Preparation and XRF Analysis:* Each sediment sample was pulverized to a fine powder using agate mortar and 13 mm pellet formed using a Carver model manual pelletizing machine at a pressure of 6-8 torr. Elemental composition and quantification was done using the Portable AMPTEK$^{(R)}$ Energy Dispersive X-ray Fluorescence (EDXRF) domiciled at the Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria. The pelletized sample was inserted into the sample holder of the XRF system and was bombarded by the x-ray tube at a voltage of 25 kV and current of 50 µA for 1000 counts or approximately 18 minutes in an external chamber set up. The characteristic x-ray of the sample areas were detected by the solid state Si-Li detector system. The spectrum analysis was carried out using the ADMCA and FP-CROSS Software which relates the peak area with concentration values.

*Data Analysis:* Simple descriptive statistics (standard error of the mean) was used to analyze the raw data obtained.

## RESULTS AND DISCUSSION

Tables 1 and 2 shows the elemental compositions of the sediment samples (S1 and S2) in weight percentage (wt %). Formation of sediments in water is an indication of the presence of suspended or dissolved solids which can settle at the bottom of the water container over time. Sediments in water negatively impart water quality because sediments are known to be substrates for metallic substances which can accumulate over time. This calls for periodic evaluation of the composition of water sediments especially when such water appears very clean upon collection but forms sediments on standing. This implies that those who usually consume this type of water immediately after fetching are bound to ingest a lot of toxic metals which are hidden in the as dissolved solids. It is based on the above premise and also considering some of the identified problems of borehole water in Abakaliki such as colouring, high hardness, food souring among others that this study investigated the elemental composition of sediments obtained from borehole water samples from the area to find out elements that are responsible for the identified problems. A total of 18 elements were found in sample S1 (Table 1) and 14 elements in S2 (Table 2) in different concentrations. A holistic look at the entire result indicated that the concentration of Fe was highest (62.4365 ± 0.1491 wt. %) in S1 which is the sediments obtained before boiling, while Ca (82.9295 ± 0.2057) had the highest concentration in the sediment obtained after boiling (S2). The high level of Fe in S1 suggests why the borehole water imparts brownish colouration on the surface of most overhead storage tanks readily seen in different areas within Abakaliki metropolis. The brownish colour shows the oxidation of the soluble $Fe^{2+}$ in the water to insoluble $Fe^{3+}$ on exposure to the surface of the tanks. The elevated concentration of Ca which in the sediments obtained after boiling explains why most borehole water in Abakaliki metropolis is hard. Formation of scum which hardens after boiling to form scales inside kettles, boilers or pots used frequently in boiling the borehole water is an indication of hardness and its persistence on standing shows it is permanent hardness.

**Table 1**: Mean concentration of Elements in S1 Sediment Sample (wt. %)

| Elements | Conc. Value | Conc. Error (± SE) | WHO (mg/L) (2011) |
|---|---|---|---|
| Nb | 0.0139 | ±0.0035 | - |
| Zr | 0.0446 | ±0.0053 | - |
| K | 3.0219 | ±0.0851 | - |
| Ca | 6.2840 | ±0.0988 | - |
| Ti | 1.9189 | ±0.0368 | - |
| V | 0.3532 | ±0.0130 | - |
| Cr | 0.2210 | ±0.0091 | 0.05 |
| Mn | 15.2202 | ±0.0789 | 0.05 |
| Fe | 62.4365 | ±0.1491 | 0.3 |
| Ni | 0.1167 | ±0.0079 | 0.07 |
| Cu | 0.1906 | ±0.0092 | 2.0 |
| Zn | 0.1722 | ±0.0082 | 3-5.0 |
| Rb | 0.0431 | ±0.0041 | - |
| Sr | 0.1480 | ±0.0079 | - |
| Pb | 0.3426 | ±0.0197 | 0.01 |
| Th | 0.1133 | ±0.0105 | - |
| U | 0.0977 | ±0.0114 | - |
| Cd | 5.6940 | ±0.1820 | 0.003 |
| Bi | 0.1418 | ±0.0116 | - |

*± SE = Standard error of the mean (n = 3); WHO = World Health Organization permissible guideline values for drinking water quality*

**Table 2**: Mean concentration of Elements in S2 Sediment Sample (wt. %)

| Elements | Conc. Value | Conc. Error (± SE) | WHO (mg/L) (2011) |
|---|---|---|---|
| P | 6.0732 | ±0.3275 | - |
| S | 4.1590 | ±0.1567 | - |
| Cl | 1.7964 | ±0.0656 | - |
| K | 3.8910 | ±0.0479 | - |
| Ca | 82.9295 | ±0.2057 | - |
| Ti | 0.0928 | ±0.0072 | - |
| V | 0.0097 | ±0.0019 | - |
| Cr | 0.0037 | ±0.0010 | 0.05 |
| Mn | 0.4060 | ±0.0086 | 0.05 |
| Fe | 0.2541 | ±0.0059 | 0.3 |
| Cu | 0.0286 | ±0.0015 | 2.0 |
| Zn | 0.0712 | ±0.0022 | 3-5.0 |
| Ga | 0.0087 | ±0.0007 | - |
| Sr | 0.2761 | ±0.0044 | - |

*± SE = Standard error of the mean (n = 3); WHO = World Health Organization permissible guideline values for drinking water quality*

*Heavy Metal Concentration in S1 and S2 Sediments:* From Tables 1 and 2, the mean concentrations of all the heavy metals found in S1 were above the WHO maximum permissible limit except for Cu and Zn. Three of the heavy metals namely Fe, Mn and Cd were found in exceptionally very high concentration in S1 sediment indicating that Fe, Mn and Cd were the three most abundant heavy metals in the sediments from borehole water in Abakaliki Metropolis. In Table 2, only Mn exceeded the WHO limit, while Cr, Fe, Cu and Zn were within the WHO permissible limits. The trend in the mean concentration of heavy metals in S2 sediment indicated the order: Mn > Fe > Zn > Cu > Cr. This trend further indicated that Mn and Fe are abundant in sediments obtained before and after boiling the borehole water. The foregoing observations explains why borehole water from the area colours food materials cooked with it and also stains fabric, dishes or glassware constantly washed with it since Fe and Mn are transition elements capable of developing coloured complexes. When found in larger concentrations, manganese can as well give water a bitter and metallic taste, while both Fe and Mn can affect the flavour and colour of food substances and water (Tukura *et al.*, 2012). Iron will cause reddish-brown staining of laundry, dishes, utensils and even glassware while manganese acts in a similar way but causes a brownish-black stain (Brian, 2014).

*Concentration of Hardness causing ions in the Sediments:* In Tables 1 and 2, the concentration of Ca in S2 sediment was about 13 times higher than S1 sediment. This is because most of the calcium salts in the water were in solution (i.e. dissolved) at room temperature while at high temperature, it precipitates out as carbonates as observed in S2 sediment. The elevated concentration of Ca found in the sediment obtained after boiling the water samples was because the dissolved calcium ions precipitated out as solid calcium carbonate ($CaCO_3$) upon boiling (McGowan, 2000). The high concentration values of Ca in S1 and S2 explains why borehole water in the area is very hard because $Ca^{2+}$ ion is a known hardness cation (Miroslav and Vladimir, 1999). The elevated amount of calcium in the sediments can also be attributed to the fact that the accessible water (aquifer zones) in Abakaliki area is located within the weathered and fractured zones of the Asu River shale which contains large deposits of limestone and sandstones (Ofoegbu and Amajor, 1987; Ezeh and Anike, 2009) as well as deposits of dolomite ($CaCO_3.MgCO_3$) and gypsum ($CaSO_4.2H_2O$) (Afiukwa, 2010).

*Other Elements of Interest in the Sediments:* The presence of K in S1 (3.0219 ± 0.0851) and S2 (3.8910 ± 0.0479) and Cl (1.7964 ± 0.0656) in S2 sediment in relatively lower concentrations is suggestive of the fact that the borehole water samples used in this study is not saline even though some borehole water in Abakaliki metropolis has been reported to be highly saline (Ngele *et al.*, 2014; Christian and Nnabo, 2015). The high level of phosphorous (P) found in S2 (6.0723 ± ±0.3275 wt.%) may be due to the nature and composition of rock minerals present in the area where the boreholes were drilled. Corroborating the above, Afiukwa (2011), had reported high level of $PO_4^{3-}$ across nine LGA of Ebonyi State with about 82 and 93

% in excess of the WHO value (0.1 mg/L) in ground and surface water. Aghamelu, Ezeh and Obasi, (2013) have reported that phosphorous is among the mineral deposits present at high levels in aquifers within the Abakaliki area in particular and Ebonyi State at large. The introduction of phosphorus in form of phosphates in aquatic environment is a major cause of eutrophication (Rao, 2014). Sulphur in natural water brings about a suphorous stinking odor and can also impart hardness when it combines with Ca, Mg or Fe to form $CaSO_4.2H_2O$ or $MgSO_4$ (Sawyer, McCarty and Parkin, 2000). When sulphur gets into groundwater, naturally occurring bacteria can reduce the organic sulphite ores and produce odorous hydrogen sulphide gas. The concentration of sulphur in S2 sediment was 4.1590 ± 0.1567 wt.%. The odor usually perceived in some borehole water from Abakaliki area may be partly attributed to the presence of sulphur in the water. Like other minerals, sulphur can leave stains in plumbing fixtures such as sinks and toilets while clothing washed in water that is high in sulphur may also become stained. Drinking water that contains sulphur does not pose any health risk, but it can be unappetizing.

*Conclusion:* The results of the XRF analysis of borehole sediments samples indicated the presence of several elements some of which are most likely the cause of observed hardness, odour and colour in borehole water from Abakaliki metropolis. Fe, Mn, Ca and S were clearly identified as some of the culprit elements responsible for the poor quality of most boreholes in Abakaliki area of Ebonyi State. Further studies should be carried out on the treatment of the water against these elements to enhance maximum use of the boreholes.

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