Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.9, 2015

Evaluation of Physicochemical Properties, Mineral and Heavy Metal Content of Drinking Water Samples in Two Communities in South-East, Nigeria: A Puplic Health Implication

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Abstract

The aim of this study is to evaluate the physicochemical properties, mineral and heavy metal content of drinking water sources in two communities in South-East, Nigeria and discuss its public health implication. The water samples were collected from two wells and two streams respectively in the two communities (Ishiagu and Ugwuaji). The physicochemical parameters, minerals and heavy metal content were analyzed using standard methods. The total acidity, total suspended solid (TSS), biochemical oxygen demand (BOD), nitrate, phosphorous, arsenate, mercury, lead, and cadmium were above both Federal Environmental Protection Agency (FEPA) and United States Environmental Protection Agency (US EPA) standards for drinking water while iron was only above EPA standards. Ishiagu stream had significantly ($p<0.05$) higher level of most of the physicochemical parameters, minerals and heavy metals followed by Ugwuaji well then, Ishiagu well and Ugwuaji stream had the lowest. The result shows an indication of minerals and heavy metals contamination of the water sources of both communities. Therefore, it is suggested that these water sources are not good for drinking due to the possible health hazards that may arise from the consumption heavy metal and mineral contaminated water.

Keywords: Water, minerals, heavy metals, health hazards, physicochemical parameters.

1. Introduction

Pollution is the introduction of contaminants into a natural environment that causes instability, disorder, harm or discomfort to the ecosystem i.e. physical systems or living organisms. The components of pollution, can be either foreign substances/energies or naturally occurring contaminants (Spengler *et al*, 1993). Different types of pollution exist globally. These include: air, light, noise, water, and soil pollution among others (Newton, 2008). Water pollution is the contamination of water bodies (e.g. lakes, rivers, oceans and groundwater). Water pollution occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds. Water pollution affects plants and organisms living in these bodies of water. In almost all cases, the effect is damaging not only to individual species and populations, but also to the natural biological communities and consumers (Spengler *et al*, 1993).

Water is typically referred to as polluted when it is impaired by anthropogenic contaminants and either does not support human use or undergoes a marked shift in its ability to support its constituent biotic communities, such as fish. Natural phenomena such as volcanoes, algae blooms, storms, earthquakes, and industrial activities such as mining also cause major changes in water quality and the ecological status of water ((Nwaedozie, 2000, Habashi, 1992, Newton, 2008). The type of activities prevalent in any given environment determines the type of contamination in that area. Soil in a particular area may have been sinks for many hazardous wastes, organic wastes sewage and several other waste types generated from different human activities. In most cases, large ponds and heaps of wastes are left in the trail of excavations for minerals and rains wash the waste heaps into the surrounding water bodies and farmlands, the ponds overflow their banks resulting in pollution even outside the area of production. A typical example is seen in Pb or Zn mining fields of Ishiagu, Ebonyi State in Nigeria.

Due to mining of lead in Ishiagu community of Ebonyi State, and stone crushing activities going on in the area and Ugwuaji community of Enugu State, it is now important that studies are done in these areas to determine the possible presence of contaminants and their possible health effects on living organisms in both areas. This work then aims at establishing the level of pollution in Ishiagu and Ugwuaji in relation to the water health or quality.

2. Materials and methods

2.1Sampling Site

Ishiagu is a town in Ivo Local Government Area of Ebonyi State, Nigeria located on the plains of the south eastern savannah belt. The geographical coordinates are $5^0 56^1$N and $7^0 34^1$E. Ugwuaji is in Enugu South Local Government Area of Enugu State and a satellite town in Enugu urban. It is located within latitude 6.24^0 N and 6.30^0 N and longitude 7.27^0 E and 7.32^0 E. Ishiagu has quarry/crush industries while Ugwuaji community had manual stone crush and the major occupation of both communities are stone crush work and farming. Both communities depend on hand-dug wells and streams waters for drinking and domestic purposes (Akubugwo et al., 2012; Enele et al., 2012).

2.2 Sample Collection and Analysis

Exactly 2000mls of water samples were collected from 8 different water bodies (4 from Ishiagu and 4 from Ugwuaji), using labeled clean plastic cans. Two wells and two streams from Ishiagu were used for the experiment and in the same vain two well and three streams from Ugwuaji were also used. The portion of the water samples for metal analysis were treated with 1ml of Hydrochloric acid (HCl) in 500ml sample to arrest microbial activities while the remaining portion for non-metal analysis were freshly refrigerated in a cooler packed with ice blocks to avoid microbial action that may affect their concentration.

The physicochemical parameters were determined based on AOAC Official Methods (1973) as reprinted by Williams (2011) and these physicochemical parameters include pH, total acidity, total alkalinity, total solid (TS), total dissolved solid (TDS), total suspended solid (TSS), dissolved oxygen (DO), chemical oxygen demand (COD) and biological oxygen demand (BOD). Sulphate, chloride, nitrate and phosphate were also determined based on AOAC Official Method (1973) as reprinted by Williams (2011). The minerals (copper, manganese, magnesium, calcium and iron) were determined using Atomic Absorption Spectrophotometer (AAS) after acidic digestion (Williams, 2011)

2.3 Statistical Analysis

All the tested parameters were subjected to statistical analysis. Statistical analysis was done by one-way analysis of variance (ANOVA), Turkey's Studentized Range (HSD) and mean were compared by the SAS System.

3. Results

Table 1 represents the physicochemical properties of waters sources from Ishiagu and Ugwuaji communities with the Federal Environmental Protection Agency (FEPA, 1991) and United States Environmental Protection Agency (US EPA, 2009) standards for drinking water. The pH level of Ugwuaji stream and well were slightly below FEPA and EPA standards while Ishiagu stream and well had a pH level within both standards. Ugwuaji stream and well pH were also significantly ($p<0.05$) lower than Ishiagu stream and well. Ishiagu stream and well had total acidity above EPA standard while Ugwuaji stream and well were exactly at the stipulated standard of EPA but, both streams and wells total acidity were not significantly ($p<0.05$) different when compared together. The total alkalinity of Ishiagu well was significantly higher than Ugwuaji well and Ishiagu steam and both Ugwuaji well and Ishiagu stream were significantly higher than Ugwuaji stream at $p<0.05$. The total alkalinity of all the water samples was within EPA standard. The TS, TDS, DO and COD levels were below FEPA and EPA standards except DO which was slightly above FEPA standard.

The TS, TDS, DO and COD levels ranged from 240.00±14.64mg/l to 420.00±17.18mg/l, from 160.00±16.46mg/l to 320.00±31.36mg/l, from 4.81±0.02mg/l to 5.90±0.17mg/l and from 9.67±1.04mg/l to 48.67±13.63mg/l respectively. TSS levels were higher than FEPA and EPA standards and Ugwuaji stream TSS level was significantly ($p<0.05$) higher than the other water sources. The BOD level of all the water sources were above FEPA and EPA standards except Ugwaji stream and Ishiagu well which were below FEPA standard and, Ishiagu well BOD level was significantly $p<0.05$) lower than the other water sources.

Table 2 shows the mineral levels of water sources in Ishiagu and Ugwuaji communities measured in mg/l. Copper, magnesium, calcium, iron, manganese, sulphate and chloride were observed lower than FEPA and EPA standards while nitrate and phosphorous levels were higher than FEPA and EPA standards. However, when the mineral level in the different water sources were compared it was found that Ishiagu stream had significantly ($p<0.05$) high level of Mn and Cl^-; Ishiagu well had significantly $p<0.05$ high level of Cu, Ca and Mn; Ugwuaji well had highest level of Mg and NO_3^- compared to water from other sources while Ugwuaji stream was not found to have very high concentration of any of the minerals. Sulphate was not detected in all the water samples, Mn was not also detected in Ugwuaji well water and phosphorous was not found in Ugwuaji stream and well water samples.

The heavy metal levels of water sources in ishiagu and Ugwuaji communities measured in mg/l are as shown in table 3. The mean levels of Zn and Hg were lower than FEPA and EPA standard in all the samples while the mean levels of As and Pb were higher than FEPA and EPA standards in all the samples and the mean

Cd level were lower than FEPA standard but higher than EPA standards in all the samples. Ugwuaji stream was found to have significantly ($p<0.05$) lower level of Zn and Hg while Ishiagu well had significantly ($p<0.05$) lower level of As, Cd, Hg and Pb compared to other water sources and Ugwuaji stream also had significantly ($p<0.05$) higher level of As compared to other water sources.

Discussion

Pollution has posed a major challenge in our environment, affecting the drinking water sources as well as the farm land for agriculture in Nigeria and beyond. This research has thrown some light on the possible pollutants in Ishiagu and Ugwuaji drinking water sources. The FEPA (1991) and EPA (2009) recommended values for pH in water are 6-9 and 6-8.5, respectively. Since these pH values were not so much higher than the recommended values, it will not adversely affect the living organisms in the water bodies. The enzymes and other proteins of the aquatic organisms in the water which have an optimum pH ranges will also not be inactivated or denatured. Hence, water organisms within this pH range will survive in these water bodies (Gregory *et al.*, 2005). The significantly ($p<0.05$) high pH level of Ishiagu stream and well than Ugwuaji stream and well waters could possibly be as a result of deposit of alkaline containing minerals on Ishiagu soil, which could eventually be leached into the water bodies (Aroh *et al.*, 2007). The acidity of all the water samples in Ishiagu and Ugwuaji were within the EPA standard and the acidity of the water samples did not differ significantly ($p<0.05$). This observed result could be as a result of moderate amount of acidic carbonate ($H_2CO_3^-$ and HCO_3^-) containing minerals being washed into the soil. Due to the moderate acidity of the water sources, fresh water organisms (such as snail and earthworm) will survive in all the water sources (APHA, 1992). The moderate alkalinity levels of all the water samples could be because high alkaline minerals leached into the water bodies form the large heaps of wastes usually left in the trail of excavations for minerals.

The presence of high level of total solid (TS), total dissolved solids (TDS) and total suspended solids (TSS) in water sources shows that materials are carried in suspended form by the water body and suggests that the water is polluted. High level of total solid in the water bodies might be as a result of deposit of soluble (such as in borax, kornelite, potassium alum and nitratine) or insoluble (such as clay, pyrite) minerals in the underground soil which in turn gets into the underground water (APHA, 1992). The high levels of TS and TSS in the steams of Ishiagu and Ugwuaji could affect the amount of light that enters the streams and will therefore affect the survival of plants and photosynthetic bacterial in the streams. The high level of TDS could be attributed to the fact that moderate amount of soluble anions and cations were present in the water samples (APHA, 1992). Both Ishiagu and Ugwuaji stream had higher level of TS, TDS and TSS compared to the wells and it could be as a result of leached minerals and other particles from the excavated mine into the stream, bearing in mind that streams are usually wide open while wells has small mouth and are closed some times by the owners.

High values of chemical oxygen demand (COD) and biochemical oxygen demand (BOD) is an indication of polluted water and signifies the presence of organic, inorganic and oxygen demanding pollutants in the water bodies. The COD values of all the water samples were within the standards and this could be due to the presence of low quantity of oxygen demanding pollutants (Amadi *et al*., 2006, Akan *et al*., 2008) or because the usage of oxygen by the organisms during decomposition in the water bodies is balanced. The mean dissolved oxygen (DO) level of all water samples were within the FEPA and EPA standards in all water samples and this shows that the water samples have moderate DO that could support the activities of the aquatic organisms in the water bodies (APHA, 1992). Mean BOD levels in all the water samples were higher than EPA and FEPA standard except Ugwuaji stream and Ishiagu well that were within FEPA standard. The high level of BOD could be attributed to high level of organic pollutant in the water samples and it implies that the water samples are polluted and not good for drinking purposes. No odour was found in all the water samples. This could be possibly because of low concentration of causing matter such as decaying plants or animal (Axel, 2010).

The significantly ($p<0.05$) high presence of Cu in ugwuaji well, Ishiagu well and stream than Ugwuaji stream might be due to erosion and leaching from natural deposits among other factors (Smith et al., 2003). Possible sources of magnesium in the water sources are due to deposits of magnesite, dolomite among other salts in the area. These salts can be washed or leached from the soil and subsequently ends up in water (Housecroft *et al.*, 2008). The Mg level in Ugwuaji well was significantly ($P<0.05$) higher than that of other samples. Low concentration of calcium in the water sources could be attributed to soft water. They might also be due to low present of calcium chloride and magnesium chloride in the soil around the water. It could also be attributed to low accumulation of bones of dead animals in the water beds as this is also a source of calcium in a water body. Up to 75mg/L of calcium was recommended by EPA probably because calcium is a major mineral used in mineralization of bones and shells (Tordoff, 2011). High level of iron when compared with EPA standard as was observed in this study is in agreement with the study carried out on surface water of Bompai-Jakara Drainage Basin, Kano State, Northern Nigeria by Imam (2012). High values of iron in the water samples might result from leaching of natural deposits into the water bodies (Nam, 2007). Mean manganese levels were within the FEPA standard in all the samples but, the manganese level Ishiagu Stream and well were significantly ($p<0.05$) higher than the other water sources. The possible sources of manganese in the Ishiagu water samples might be as a result of industrial activities in the area. The presence of manganese results in bitter taste in water, dark scales in pipe, black staining of laundry among others (Takeda, 2003).

Nitrate (NO_3^-) levels were significantly ($p<0.05$) higher than FEPA and EPA standards in all the samples and Ugwuaji well had the highest level of nitrates. High levels of nitrate in the water bodies might be due to acid rains or organic residues (e.g. fertilizer, decaying plant, manures) (Bruning-Fan *et al.*, 1993). Nitrate concentration higher than 10mg/l is dangerous to pregnant women and poses a serious health threat to infants less than three to six months of age because of its ability to cause methaemoglobinaemia or blue baby syndrome in which blood loses its ability to carry sufficient oxygen (Burkart and Kolpin, 1993). The phosphorus levels in Ishiagu steam and well were above FEPA and EPA standard, while phosphorous was not found in Ugwuaji. Traces of phosphates increase the tendency of growth of troublesome algae in the water and their presence in the water sources may be attributed to agricultural activities (Ikem et al., 2002). Phosphorus is an essential component of ATP, DNA and phospholipids (Nelson *et al.*, 2000). However, higher level of nitrate and phosphorous may be due to high degree of organic pollution, eutrophication, agricultural activities, use of detergents in the water sources and /or very close to the water sources which could be wash into the water by erosion or leaching.

Mean arsenic levels were higher than FEPA and EPA standards in all the water samples. However, zero amount of arsenic was recommended by EPA probably because of its toxic health effects such as inhibition of the enzyme pyruvate dehydrogenase, the enzyme that convert pyruvate to acetyl CoA and this could lead to coma and subsequently death. The possible sources of arsenic in the water sources are its natural deposits on earth crust (Baccarelli et al, 2009). The mean Cadmium levels were within FEPA standard but higher than EPA standard except Ugwuaji well where cadmium was not detected. Cadmium is naturally present in water at small quantities. They are released from car exhaust into the environment and they find their way into water. Once in air it spreads with the wind and settles into the ground or surface water as dust. Cadmium has no benefit on the human system (Wiltman, 2002) and the toxic effect of cadmium include renal dysfunction, obstructive lung disease, cadmium pneumonitis, bone defects, mayocardic dysfunction, renal effect and pulmonary effect (Duruibe et al., 2007). The mean mercury (Hg) levels were within the FEPA standard but above EPA standard in the water samples. Mercury occurs naturally in the earth crust and rocks, and gets into the water bodies through weathering and leaching. Mercury level in the environment should be controlled by government regulations because of its toxicity to the brain, heart, kidneys, lungs and immune system of all ages (Mayell, 2007).

The mean Pb levels were significantly higher than FEPA and EPA standard. The presence of lead in water samples from Ishiagu could be as a result of deposit of lead in the area, which was leached into the water bodies (Eugene, 2010). High level of lead in waters from Ugwuaji might be due to wearing-away of materials containing lead into the water bodies (Nriagu, 2000). The acceptable FEPA (1991) and EPA (2009) levels of lead in water are 0.01mg/L and zero mg/L, respectively, because of its toxicity in the body by inhibiting porphobilinogen synthase and ferochelatase, preventing both porphobilinogen formation and incorporation of iron into protoporphyrin (ix), the final step in heme synthesis. It also acts as calcium analog, interfering with ion channels during nerve conduction. It is toxic to many organs and tissues including the heart, bones, intestine, kidney, reproductive and nervous system (Nriagu, 2000). Due to high levels of lead in the water, the water is not good for drinking or cooking but could be used for laundry. Mean zinc (Zn) levels in all the water samples were within FEPA and EPA standards and it may be because much of the zinc in the soil are not been leached into the water bodies (Broadly et al, 2007). Zinc has been reported to have the same signs of toxicity as lead and could be mistaken diagnosed as lead poisoning (McCluggage, 1991).

4. Conclusion

In conclusion, the research shows that the drinking water sources from both Ishiagu and Ugwuaji are heavily polluted with heavy metals. These could pose great challenge to the health of the villagers and those that eat food crops produced in areas. To check possible risk of these heavy metals clean-up methods such as bioremediation could be used by the government to reduce the heavy metal pollution. Since the water sources were also affected, the water sources could be used for washing or industrial uses other than drinking. Moreover, ion exchange could be used to reduce the level of heavy metal pollution in the water bodies.

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Table 1. Physicochemical properties of water sources in Ishiagu and Ugwuaji communities

Parameters	Ishiagu stream	Ugwuaji stream	Ishiagu well	Ugwuaji well	FEPA (1991)	EPA (2009)
pH	7.50±0.89[c]	5.80±0.00[a]	6.80±0.40[b]	5.80±0.00[a]	6.00-9.00	6.00-8.50
Total acidity (mg/l)	66.67±8.87[a]	50.00±0.00[a]	83.33±8.87[a]	50.00±0.00[a]	NA	50.00
Total alkalinity (mg/l)	108.33±16.06[b]	50.00±0.00[a]	175.00±19.19[c]	100.00±0.00[b]	NA	30.00-500.00
TS (mg/)	420.00±17.18[b]	480.00±22.92[b]	340.00±12.11[a]	240.00±14.64[a]	NA	500.00
TDS (mg/l)	320.00±31.36[b]	220.00±16.46[a]	176.67±26.86[a]	160.00±16.46[a]	2000.00	500.00
TSS (mg/l)	100.00±14.64[a]	260.00±25.83[b]	94.33±16.20[a]	80.00±15.68[a]	30.00	80.00
DO (mg/l)	5.84±0.73[a]	5.90±0.12[a]	4.81±0.02[a]	5.90±0.17[a]	5.00	6.00-8.00
COD (mg/l)	48.67±13.63[b]	43.00±3.61[b]	9.67±1.04[a]	48.00±2.65[b]	80.00	250.00
BOD (mg/l)	54.50±3.31[b]	48.88±3.75[b]	14.48±4.88[a]	53.90±2.75[b]	50.00	4.00

The values were expressed as mean ± SD (n=9). Values in the same row bearing the same superscript letters are not significantly different ($P<0.05$).

2 Mineral levels of water sources in Ishiagu and Ugwuaji communities measured in mg/l.

Parameters	Ishiagu stream	Ugwuaji stream	Ishiagu well	Ugwuaji well	FEPA (1991)	EPA (2009)
Cu	0.38±0.05[b]	0.17±0.02[a]	0.53±0.07[c]	0.37±0.01[b]	1.30	1.30
Mg	3.17±0.30[b]	0.73±0.14[a]	3.17±0.61[b]	6.65±0.48[c]	20.00	30.00
Ca	0.65±0.05[a]	0.99±0.07[b]	1.35±0.12[c]	0.87±0.14[b]	200.00	75.00
Fe	0.47±0.03[a]	0.33±0.06[a]	0.59±0.03[a]	1.27±0.15[b]	20.00	0.30
Mn	0.59±0.42[c]	0.02±0.04[b]	0.42±0.07[c]	0.00±0.00[a]	5.00	0.50
SO_4^{2-}	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	500.00	200.00
NO_3^-	339.67±38.81[b]	263.00±2.64[a]	336.33±35.88[b]	405.33±5.51[c]	20.00	10.00
Cl^-	130.00±10.24[c]	70.90±0.00[b]	94.47±17.04[b]	33.50±0.00[a]	600.00	250.00
P	21.00±6.24[b]	0.00±0.00[a]	17.00±1.82[b]	0.00±0.00[a]	5.00	0.10

The values were expressed as mean ± SD (n=9). Values in the same row bearing the same superscript letters are not significantly different ($P<0.05$).

Table 3. Heavy metal levels of water sources in Ishiagu and Ugwuaji communities measured in mg/l.

Parameters	Ishiagu stream	Ugwuaji stream	Ishiagu well	Ugwuaji well	FEPA (1991)	EPA (2009)
Zn	0.59±0.55[b]	0.25±0.12[a]	0.76±0.32[b]	0.55±0.03[b]	5.00	3.00
As	2.00±1.75[a]	4.57±0.16[b]	2.69±0.64[a]	2.98±0.03[a]	0.10	0.00
Cd	0.013±0.00[b]	0.010±0.01[b]	0.003±0.01[a]	0.010±0.00[b]	0.01	0.005
Hg	0.013±0.01[b]	0.001±0.00[a]	0.004±0.00[a]	0.010±0.01[b]	0.05	0.002
Pb	4.31±0.02[b]	6.13±0.40[c]	1.61±0.16[a]	4.47±0.15[b]	0.01	0.00

The values were expressed as mean ± SD (n=9). Values in the same row bearing the same superscript letters are not significantly different ($P<0.05$).