

Full Length Research Paper

Pollution profiles of non-metallic inorganic and organic pollutants of drinking and potable waters due to mining activities in Ishiagu (Ebonyi State) of Nigeria

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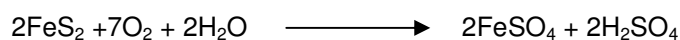
The pollution of drinking and potable water sources due to mining activities in Ishiagu District of Ebonyi State of Nigeria, by non-metallic inorganic and organic pollutants was investigated. Water samples were abstracted from the Ivo River (IR), Ishiagu Central School borehole (IB), Amaokwe General Hospital borehole (AB), Amaeke community well (AW₁) and Amata community well (AW₂). The Ivo River courses through the areas of metal deposits and intensive mining activities at Ishiagu. The parameters analysed for were pH, conductivity, colour, odour, total suspended solids (TSS), total dissolved solids (TDS), total alkalinity, total acidity, Cl⁻, SO₄²⁻, NO₃⁻, PO₄³⁻, biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The results showed that all the water sources had PO₄³⁻ concentrations exceeding WHO's tolerance limit, and the river water source was unwholesome for consumption due to high acidity; BOD and COD values for the well water sources do not support life and had high total solids (TS) and conductivity, while the borehole sources, though showing moderate to high conductivities and TS, seemed most suitable for consumption.

Key words: pollution, mining, Ishiagu, tolerance limits, NAFDAC.

INTRODUCTION

Ishiagu District in Ivo Local Government Area (LGA) of Ebonyi State is located in south-eastern Nigeria at latitudes 5° 43' - 5° 51' N and longitudes 7° 29' - 7° 35' E (Figure 1). It is richly endowed with mineral deposits, which are mainly heavy metal sulfide ores, chiefly galena (PbS), and are intensively and competitively exploited by several mining industries. Other metal ores include sphalerite (ZnS), chalcopyrite (CuFeS₂), siderite (FeCO₃), argentite (Ag₂S), limestone (CaCO₃) and cadmium sulphide (CdS). During our visits to Ishiagu *ab initio*, we observed that mining sites were at elevated land sites, which facilitate the run-off of dissolved metal species into

the Ivo River, and metal ores were dumped openly on the ground surface while manual dressing processes were employed. The river courses through the metal mining sites, and metal trails were scattered around after ore dressing and in abandoned mine pits. These mining activities and other geochemical processes often result in the generation of acid mine drainage (AMD), a phenomenon commonly associated with mining activities (Ogwuegbu and Ijioma, 2003). It is generated when pyrite (FeS₂) and other sulphide minerals in the aquifer at present and former mining sites are exposed to air and water in the presences of oxidizing bacteria, such as *Thiobacillus ferrooxidans*, and oxidised to produce metal ions, sulphate and acidity according to the following equations (Ogwuegbu and Muhanga, 2005).



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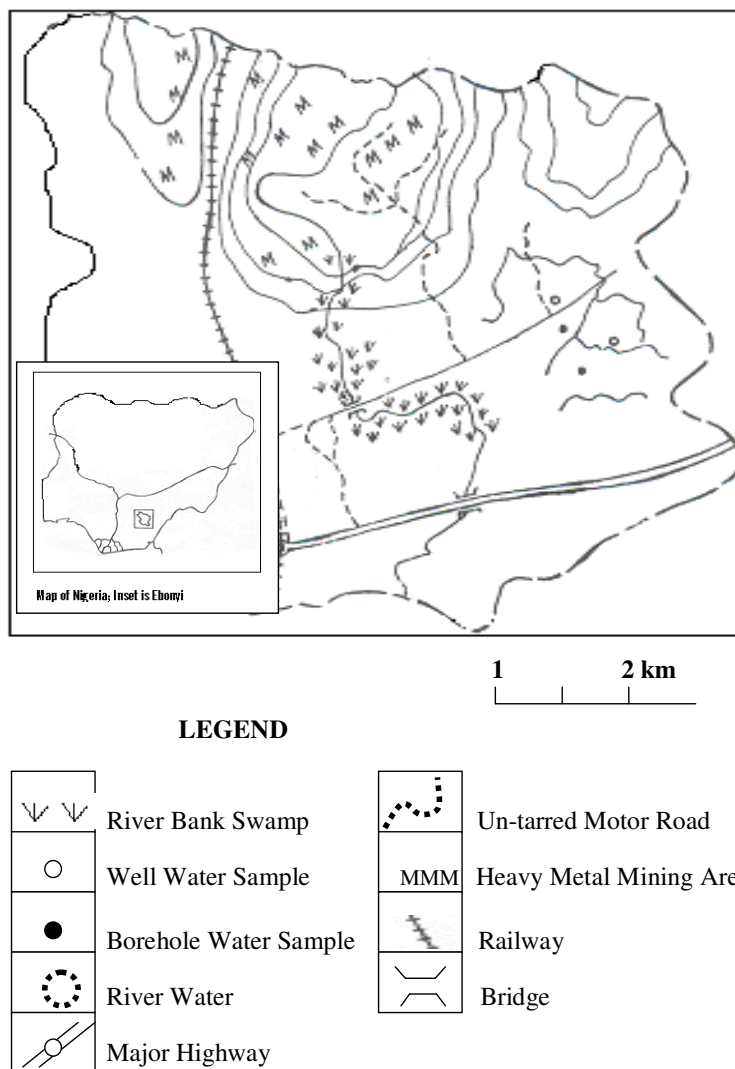
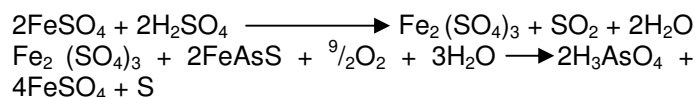


Figure 1. Map of Ishiagu district in Ivo Local Government Area; inset is map of Nigeria.



AMD results in the acidification of mine wastes, presence of high sulphate, low total suspended solids (TSS), but high total dissolved solids (TDS); and is also associated with the releasing of trace amounts of heavy metals contained in pyrites (Ogwuegbu and Ijioma, 2003). Acidic waters resulting from AMD facilitate high dissolution of metals from their ores and mine wastes to pollute water sources at adverse concentrations. However, near neutral pH values (pH 6-7) have been established for some metals, such as Zn, Cd, and As (INECAR, 2000; Lenntech, 2004). Other factors such as downstream distances from the mining sites, colloid loads, pH perturbations, and dilution also ultimately control the quality of water sources.

Our interest in conducting this research emanated from the results of our previous work on heavy metal pollution in Ishiagu. Preliminary studies and informal investigations indicated the existence of notable cases of health problems amongst the natives, viz; imbecility, dullness and confusion in children, mainly below the age of 14 years, some sudden cases of fully blown madness in adults and other prevailing health dysfunctions. These have been shown to be caused by the consumption of unwholesome and polluted waters. Heavy metal pollution of surface and underground water sources at Ishiagu has been investigated and is presently being considered for publication elsewhere. No report however has been made for other non-metallic inorganic and organic pollutants. Pb toxicity causes damage to the brain, the central nervous system (CNS) and the peripheral nervous system (PNS) (Fabuss and Fabuss, 1974; Fosmire, 1990; McCluggage, 1991; INECAR, 2000; Ferner, 2001; Nolan, 2003; Udedi, 2003;

Young, 2005), and Pb mining as galena results in the generation of AMD, which adversely pollutes surface and underground water sources.

The objective of this investigation was to experimentally analyze the water sources from the mining communities of Ishiagu in Ebonyi State of Nigeria to assess their consumability with respect to their pollution profiles of non-metallic and inorganic pollutants. It was also intended to relate the levels of pollution of these water sources to sustainability of life and the medically diagnosable ailments that are found in Ishiagu. References were made to internationally accepted standards for the analyzed parameters. The parameters included the pH, colour, odour, conductivity, total alkalinity, total acidity, TDS, TSS, BOD, COD, chloride (Cl⁻) sulphate (SO₄²⁻), phosphate (PO₄³⁻) and nitrate (NO₃⁻).

EXPERIMENTALS

Reagents and equipments

All the reagents used were of analytical grades, and were used as supplied without any purification. Double-distilled water was used for all dilution purposes. The following equipments were used: HANNA EC 215 conductivity meter, LABTECH pH meter; oven (Gallenkamp, size one, model OV 165); uv spectrophotometer (Pharmacia LKB – Ultrospec III model), and Jenway 6035 model turbidimeter.

Sampling and procedure

Representative samples of water were collected from domestic wells and boreholes, from which the natives abstract drinking and potable water, during the rainy season, when high profile dissolution of the solid ore minerals were expected. The samples were collected and labelled for easy identification. Five representative samples were collected from each source, from which the average of the results of each set of analyses was computed. The analytical samples were collected and preserved in clean sterilized polythene bottles at room temperature. The water analyses were done according to standard methods (Fabuss and Fabuss, 1974; American Public Health Association (APHA) and American Waterworks Association (AWWA), 1975; Vogel, 1989; Greenberg et al., 1992; Nwokedi et al., 1992; USEPA, 1994; Udedi, 2003; Kanu et al., 2006).

The physical appearances of the water samples were noted, colour and odour were determined by the procedures reported by Fabuss and Fabuss (1974). Colour was determined by matching the samples against white background, and then making a visual observation; odour was determined by organoleptic method of smelling using a panel of five observers. The conductivity was determined by direct reading from the conductivity meter; the meter was first standardized using 0.01 M and 0.0005 M KCl. The pH values were determined with a LABTECH pH meter, which was first standardized using acetate buffer at pH 4.0 and phosphate buffer at pH 9.2. The turbidity was determined using a Jenway 6035 model turbidimeter, which was first standardized using filtered de-ionized water as blank. The alkalinity was determined by titration with 0.02 M HCl, using phenolphthalein and methyl orange indicators to the two colour changes at pH 8.3 and pH 4.5 respectively. Acidity and chloride contents were determined by titration; sulphate, phosphate, and nitrate contents were determined spectrophotometrically (Fabuss and Fabuss, 1974). Sulphate was precipitated from the

samples as BaSO₄ by adding 5 ml of a conditioning reagent (glycerol, 50 ml; NaCl, 75 g in distilled water, 300 ml), and then BaCl₂; phosphate was determined by the molybdate blue method, and the transmittance was measured at 465 nm; nitrate was determined by the phenoldisulphonic acid method and the absorbance was measured at 550 nm using the uv spectrophotometer. Total solids (TS) were determined by drying a known volume of sample at 105°C for 1 h, then cooled and weighed; suspended solids were measured by filtering a known volume of sample through a filter paper, while dissolved solids were obtained by difference from TS and suspended solids (Nwokedi et al., 1992). The BOD was determined by a polarographic method using a DO meter, while the COD was obtained by dichromate method.

RESULTS AND DISCUSSIONS

The results of the various analyses are summarized in Tables 1 and 2. All the water sources met the criteria of colour and odour as outlined by the World Health Organization (WHO) and the Nigeria's Agency for Food and Drugs Administration and Control (NAFDAC), except the river water source, which was slightly cloudy. During the rainy season, flowing waters exhibit turbulence, resulting in the unsettling of suspended particulate matters (SPM). The pH of all water samples at 28°C fell within the recommended limits of WHO (7.0 - 8.5) and NAFDAC (6.5 - 8.5), having no notable trend in variation amongst the samples; the river water samples had the lowest pH of 6.85, which was attributable to the leaching of metal values from the dumps, where they are piled in heaps for manual dressing, and the generated AMD, which is washed into the stream. Waters from the sources investigated were characterized by high specific conductance, TS, COD and BOD.

All well and borehole water sources showed very high electrical conductivity which is a measure of total concentrations of anionic solutes and minerals in the samples (Fabuss and Fabuss, 1974). The AW₂ samples had the highest electrical conductivity and quantity of dissolved metals while IR had the least values of both parameters. The values of non-metallic/ionic solutes were also generally high for AW₂ relative to the other samples.

With the exception of IR and AB, the other water sources had their alkalinities exceeding recommended value of 100 mg l⁻¹. This is due to dissolved CaCO₃ (as limestone) and Ca(HCO₃)₂. The geographical deposits of limestone at Nkalagu, Enugu State spread in traces to Ishiagu (Iloje et al., 2001). From geographical information, total alkalinity is mainly due to CaCO₃. Surface streams are reported to be normally slightly alkaline (Fabuss et al., 1974), and this is reflected in the lowest alkalinity value of the river samples (IR). Conversely, IR had the highest acidity value. These results are comparable with the reported pH values in Table 2. Since high acidity usually results from contamination with mineral acids from AMD (Garbarino et al., 1995; Peplow, 1999; Ogwuegbu and Ijioma, 2003), the result is an indication of AMD from the mining sites into the Ivo River. Phosphate concentrations in all the sources exceeded WHO tole-

Table 1. Physical parameters of water samples.

| Sample | PHYSICAL PARAMETERS | | | |
|-----------------|---------------------|-----------------|-------|------------|
| | General Appearance | Colour | Odour | pH at 28°C |
| IR | Slightly turbid | Slightly cloudy | NO | 6.85 |
| IB* | Clear | Colourless | NO | 7.24 |
| AB* | Clear | Colourless | NO | 7.50 |
| AW ₁ | Clear | Colourless | NO | 7.18 |
| AW ₂ | Clear | Colourless | NO | 7.48 |

NO: Not Objectionable; *Boreholes were deep boreholes (180 – 200 m deep at Ishiagu).
 IR = Ivo River; IB = Ishiagu Central School borehole; AB = Amaokwe General Hospital borehole;
 AW₁ = Amaeke autonomous community well; AW₂ = Amata autonomous community well.

Table 2. Results for chemical and non-metallic parameters.

| Parameter | Sample | | | | | Tolerance Limits (USEPA, 1993; NAFDAC, 2000) | |
|--|-------------|-------------|-------------|-----------------|-----------------|--|------------------|
| | IR | IB | AB | AW ₁ | AW ₂ | WHO | NAFDAC |
| pH at 28°C | 6.85 | 7.24 | 7.50 | 7.18 | 7.48 | 7.00-8.50 | 6.50-8.50 |
| Conductivity at 28°C ($\mu\text{S cm}^{-1}$) | 44.6 | 504 | 251 | 476 | 519 | -- | -- |
| Total suspended solids (TSS) (mg l^{-1}) | 13.10 | 11.82 | 12.00 | 18.20 | 17.80 | * | * |
| Total Dissolved solids (TDS) (mg l^{-1}) | 18.08 | 272.32 | 97.98 | 299.46 | 293.94 | * | * |
| Total Solids (TS) (mg l^{-1}) | 31.18 | 284.14 | 109.98 | 317.66 | 311.74 | 500.00 | 100.00 |
| Total Alkalinity (mg l^{-1}) | 21.90 | 149.70 | 78.10 | 176.40 | 277.80 | 100.00 | 100.00 |
| Total Acidity (mg l^{-1}) | 35.00 | 0.00 | 20.00 | 0.00 | 0.00 | -- | -- |
| Chloride, Cl^{-} (mg l^{-1}) | 5.96 | 45.16 | 11.36 | 65.75 | 25.75 | 200.00 | 75.00 |
| Sulphate, SO_4^{2-} (mg l^{-1}) | 21.58 | 31.94 | 7.27 | 31.87 | 21.58 | 200.00 | 200.00 |
| Phosphate, PO_4^{3-} (mg l^{-1}) | 14.20 | 35.85 | 24.73 | 23.88 | 29.29 | 10.00 | -- |
| Nitrate, NO_3^{-} (mg l^{-1}) | 2.10 | 2.80 | 0.24 | 2.80 | 2.20 | 50.00 | 45.00 |
| BOD (mg l^{-1}) | 3.00 | 2.80 | 2.80 | 3.20 | 3.20 | 3.00 | 3.00 |
| COD (mg l^{-1}) | 293.96 | 274.36 | 274.36 | 313.56 | 313.56 | 294.00 | 294.00 |

$\mu\text{S cm}^{-1}$ = microsiemens per centimeter; mg l^{-1} = milligrams per litre; *both TDS and TSS are cumulatively evaluated as total solids (TS); -- no guideline given.

rance limits; total solids (TS) for all water sources, except IR, were moderately high. IR had the lowest value of TS, which could be attributed to either the high self-purification capacity of the flowing river, or sink capacity for the pollutants, or both (Kraemer et al., 2001). TS values for the borehole water sources were lower than those from the wells. This is related to the greater depths of the boreholes, which result in greater physical purities of their waters. The recorded low TSS and high TDS was the consequence of AMD.

The BOD and COD results of the river and borehole water sources met the required standards; those of the well samples exceeded the tolerance limits. The presence of nitrates which indicates the activities of nitrifying and denitrifying bacteria in water affects the BOD because organic nitrogen serves as food for those organisms. Also, BOD indicates the presence of biochemically decomposable organic matter in water for

biodegradation activities. However, COD test is used to provide a rapid measure of organic pollutant concentration by oxidation with a strong chemical oxidant. COD is always expected to be higher than BOD, otherwise, there is no correlation between the two (Nwokedi et al., 1992). The reported higher COD values agree with the cited literature. Going by international standards, BOD and COD values of the river and borehole waters support life, whereas those of the well waters do not support life. The results of the study conform to literature reports on water pollution at immediate and surrounding areas of mining sites (Garbarino et al., 1995; Peplow, 1999; INECAR, 2000). Notably, the values obtained were affected by rainy season dilution effect due to the rise in the water table. Values are expected to increase (or triple) when the water level falls to about one third during the dry season (investigations for the dry season are underway).

Conclusion

From the results of our investigations, the river water source is acidic and unwholesome for consumption; the BOD, COD and total alkalinity results show that the well water sources are unwholesome for consumption, because the reported values do not support life. The TS values of the underground sources were moderately high, exceeding NAFDAC, but falling within WHO limits, and our prerogative is our national standard. From the parameters analysed, the borehole sources appear most suitable for consumption. However, an overall conclusion on the consumability of waters from the borehole sources can only be more clearly drawn by considering their pollution profiles of heavy (biotoxic) metals being mined in Ishiagu.

Recommendations

Since pollution of surface and underground water sources is prevalent at mining areas, the government should as a matter of duty ensure the provision of wholesome water to the people of Ishiagu LGA in Ebonyi state by enforcing the treatment of the water sources before consumption for health safety. Also, for environmental safety pollution surveillance is recommended. Ensuring the health safety of the people of Ishiagu cannot be over emphasized.

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