MINING ACTIVITIES: IMPACTS ON THE IKPESHI VILLAGE WATER QUALITY

ABSTRACT

The impact of mining activities on the water quality of Ikpeshi, Edo State, Nigeria was carried out on the three major sources of water. They included water from the mine pit, flowing stream, and borehole. Physicochemical characterization of the water samples was carried out and their results were compared with World Health Organization (WHO) permissible standards for drinking water. The water quality parameters included pH, electrical conductivity (EC), turbidity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved iron (Fe), manganese (Mn), chromium (Cr), cadmium (Cd), and lead (Pb). The result showed the concentration of dissolved Cr, Cd, and Pb in mine pit water to be 0.085, 0.093, and 0.09 mg/L respectively while those of the flowing streams were 0.011, 0.002, and 0.007 mg/L respectively. These values were significantly higher than the WHO limits of 0.05, 0.003, and 0.01 mg/L in Cr, Cd, and Pb respectively. Borehole water was however within the limits with values of 0.0, 0.0, and 0.005 mg/L for Cr, Cd, and Pb. Similarly, dissolved Fe and Mn were 0.95 and 0.167 mg/L respectively in mine pit water, 0.37 and 0.061 mg/L in flowing stream, and 0.24 and 0.018 mg/L in borehole water. The WHO limits for these are 0.3 and 0.05 mg/L respectively showing therefore that water from the mine pits and flowing streams are unsafe for domestic use because their contaminant level was significantly higher than the permissible limit.

Keywords: Water, physicochemical, standard, contaminant, quality, oxygen, WHO, borehole

1. INTRODUCTION

The environmental impacts of mining activities in most developing countries are not well documented; meanwhile, these operations feature several highly rudimentary technologies and management practices that have caused significant damage around the world, manifested primarily as water and land contamination [1], [2], [39].

The exploitation of mineral resources has assumed prime importance in several developing countries including Nigeria. Nigeria is endowed with abundant mineral resources which have contributed immensely to the national wealth with associated socio-economic benefits. Since the only practical or pragmatic way to extract minerals for industries is through mining, however, the impact of mining is not all favorable [3], [4].

Mining is an activity classified as most polluting as well as draining the dwindling water resources in the world. A study conducted by the Economic Commission for Africa (ECA) in 1999 on the water situation in African countries specifically cited Nigeria as being one of the most water-stressed countries [5], [6].

In Nigeria, the effects of the activities of mining companies on our water bodies through dewatering, groundwater pollution, the free use of water for mining operations, pollution of streams with heavy metals, and other waste spillages, are affecting the health status of the residents of mining communities [7]. The negative effects of mining are depriving mining communities of access to clean water and this has implications for the health status of the mining communities since the ingestion of cyanide and heavy metals in rivers for long period could lead to many serious health problems for the people living in mining communities. It is recognized that access to clean water is a human right and the pollution of rivers by mining operations constitutes a violation of the rights of the mining communities to clean water and an environment free of contamination [8], [9].

The health cost of mining operations sometimes outweighs the benefits gained. Given this, Awudi [10] has maintained that “despite these positive indicators, the role of the mining industry in any economic development is a suspect. Despite the huge Foreign Direct Investment (FDI) in mineral exploration and mine development during the last decade, the sector is yet to make any meaningful impact on the country's overall economy”. The gains from the sector in the form of increased investment are being achieved at great environmental, health, and social cost to the people, recording a series of public outcry against the mining companies who themselves are yet to explicitly concede that their investments are inherently a major pollutant and a source of social conflicts.

Therefore, this work looked at the impact of mining activities on the water quality of Ikpeshi in Edo State, Nigeria, and its health implications on human lives and domestic activities.

2. MATERIALS AND METHODS

2.1 Study area and sample stations

Ikpeshi is a village along the Auchi-Ibillo expressway in Akoko Edo Local Government Area in Edo State, South-South Nigeria as shown in Figure 1.

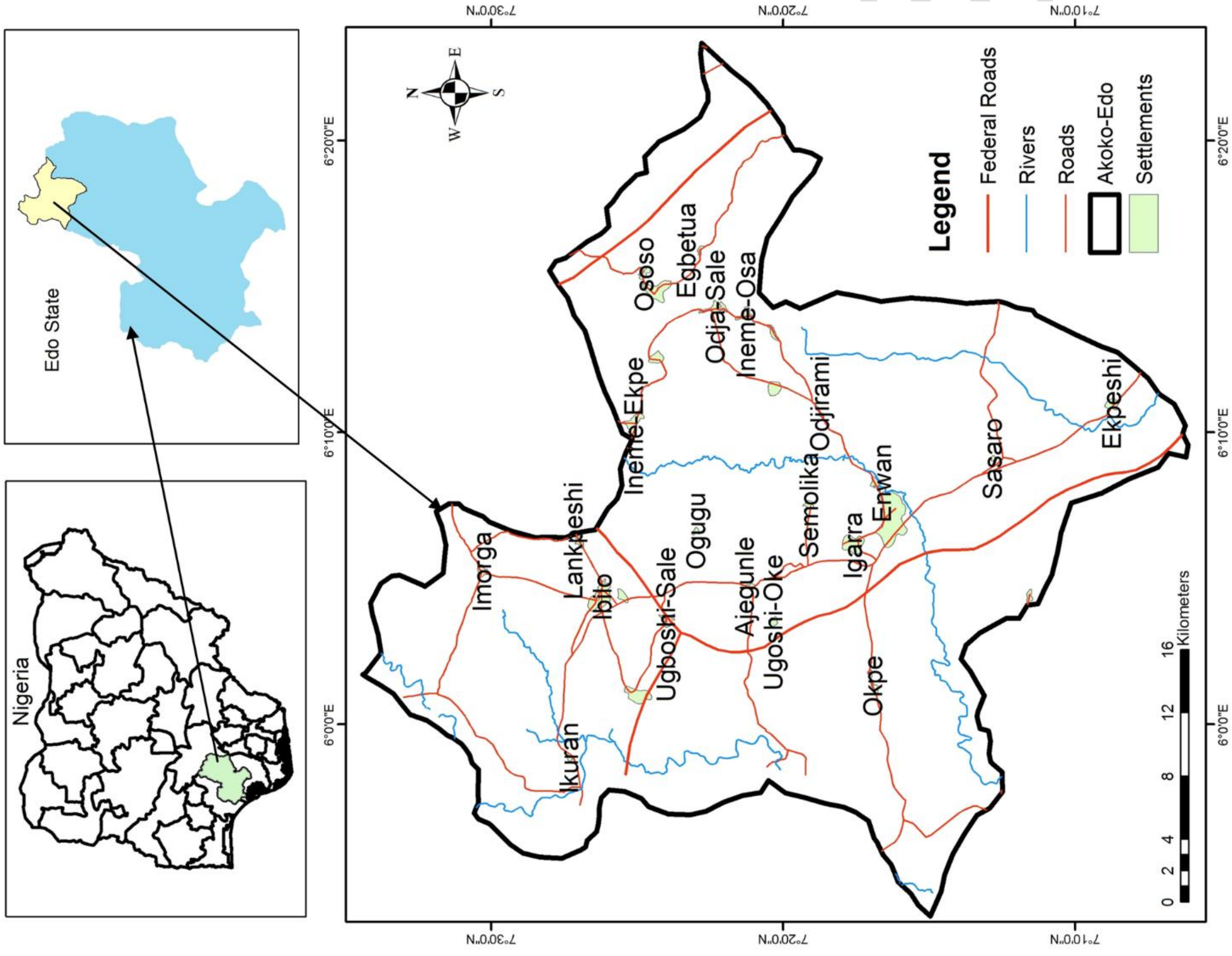

Figure 1: Map of Akoko Edo showing Ikpeshi [11]

Ikpeshi is home to several mining companies like Freedom Limestone quarry, Noble Marble Limited, and Fakunle (Geo-works) limestone quarry. Ikpeshi lies on latitudes 7^o 11' and 7^o 06' N and within the longitude 6^o 15', 6^o 08'E. Of importance in this study area are the two principal seasons, which are wet and dry. The wet (raining) season starts in March and lasts till November with a short break in August while the dry season starts in November and ends in March. The average annual rainfall is about 1300 mm. There is a marked variation in the sunshine hour of 3.3 hr while increasing cloud cover causes decreasing sunshine hours between June and October. The temperature ranges from 25^{o}C to 40^{o}C. Although limestone hardly supports thick vegetation, due to heavy rainfall, the surrounding area of the outcrop is covered by thick green grass shrubs [12].

For accuracy, 1500 mL each of water from the mine pit (sample A), flowing stream (sample B), and borehole (sample C) was collected at Ikpeshi, Edo State into sterilized sample bottles and placed in a cold box for onward transfer to the laboratory. At the laboratory, the samples were stored in a refrigerator before analysis.

2.2 pH

The samples were analyzed for pH using a pH meter (model HI 9813–5, Hanna Instruments Inc., USA). For each water sample, the already calibrated pH meter was immersed in it for about 5 min to enable stable readings before recording.

2.3 Electrical conductivity and total dissolved solids

The electrical conductivity (EC) and total dissolved solids (TDS) were determined using conductivity/TDS/DO meter model 4520 [13]. The meter was switched on and allowed to stabilize for 10 min. The meter was calibrated by immersing the probes in KCl solution. The probe was rinsed and immersed in the sample solution. The conductivity and TDS were then read.

2.4 Turbidity

The turbidity of the samples was determined using a HACH turbidimeter [14]. 25 mL of water samples were poured into a cuvette and read at zero in the spectrophotometer at 450 nm. 25 mL of similar samples were poured into another cuvette and read. Finally, the working standards were also read.

2.5 Dissolved oxygen

The amount of dissolved oxygen in the water samples was determined using modified Winkler's [15]. 250 mL dissolved oxygen bottle was filled to the brim with the sample, taking care to minimize contact with air. 1 mL of $MnSO_4$ solution and 1 mL of alkali-iodide-azide solution were added to the bottom of the bottle, stopper well, shook, and left to settle. 2 mL of concentrated H_2SO_4 was added to dissolve the precipitate after it had settled. 100 mL of water sample solution was measured out and 2 drops of the starch indicator was added to it. The dark blue sample solution was then titrated to colorless with 0.0125 M thiosulphate.

2.6 Biological oxygen demand

The amount of biological oxygen demand (BOD) in the water samples was determined using modified Winkler's [15]. The dissolved oxygen (DO) in the sample was first determined as DO_1. The sample was also aerated thoroughly and seeded with a little diluted domestic wastewater (1-2 mL per litre). A screw-topped incubation bottle was filled to the brim with the remainder of the diluted water and was sealed and incubated in the dark for 5 days at 20^{o}C. Dissolved oxygen (DO_2) determination was carried out on a suitable portion for the incubated sample by allowing for dilution of the sample.

$$BOD = DO_1 - DO_2 \qquad (1)$$

2.7 Chemical oxygen demand

The amount of chemical oxygen demand (COD) in the water samples was determined using [16], dichromate method. 50 mL of the sample was pipetted into a conical flask, 10 mL of 0.00833 M $K_2Cr_2O_7$ solution and 1 g of $HgSO_4$, and 80 mL of $Ag_2SO_4 .H_2SO_4$ solution with few beads were added to the pipetted sample. A reflux greaseless condenser was fit into the conical flask, heated gently to boiling for exactly 10 min, left to cool and the condenser rinsed with 50 mL of water, while the flask was cooled under running tap water. Two drops of ferroin indicator were added to the solution and titrated with 0.025 M $Fe(NH_4)(SO_4).6H_2O$ until the colour changed from blue-green to red-brown. Blank determination was also done on 50 mL of water. The difference in value between the two titres gave the titre of the sample.

2.8 Dissolved heavy metals

Atomic absorption spectrophotometer (AAS) solar unicam series with air acetylene flame model was used in determining the dissolved iron, manganese, chromium, cadmium, and lead concentration in the samples. Blank prepared from distilled water as well as the standard reference solution for the individual parameters were used to calibrate the instrument after the required lamp has been fixed in the instrument. The instrument was adjusted until acceptable calibration was achieved. Once the required calibration was achieved, the samples were run to determine the metal concentration of interest in the sample.

2.9 Total suspended solids, sulphate, nitrate, and ammonia nitrogen

Total suspended solids (TSS), sulphate (SO_4), nitrate (NO_3), and ammonia nitrogen (NH_4N) were determined by total solids dried at 103 – 105 ^oC, sulfa ver 4, cadmium reduction, and Nessler methods, respectively [17]–[19].

3. RESULTS AND DISCUSSION

The mean values of the pH of the sample and those of the World Health Organization (WHO) limit for drinking water are presented in Figure 2. The mean values of the pH recorded for the various samples were below the WHO standard pH value of 8.5. 6.64 and 6.72 were recorded for the flowing stream and borehole, respectively, which meant that the water from these sources is slightly acidic. However, the mine pit water sample exhibited a mean pH value of 7.11. The slightly acidic nature of the flowing stream and borehole water samples may be attributed to the initial stages of acid mine drainage (AMD) which occurs when large quantities of rock containing sulphide minerals are excavated from an open pit or opened up in an underground mine reacts with water and oxygen to create sulphuric acid. The stronger the acid solution, the more the metals become soluble in the water and thus lower the pH. Nevertheless, the mean values obtained in the water samples were good since the pH range of 6.5–8.5 is the standard for drinking water [20]–[25].

The mean values of the electrical conductivity for the three samples and the maximum limit of WHO in drinking water are presented in Figure 3. The mean EC values recorded for the three samples showed the values of the mine pit and borehole samples to be higher than the WHO standard and the flowing stream sample lower than the WHO standard of 250 µS/cm. These higher values of the mine pit and borehole sample may be attributed to the fact that a lot of particles may have been introduced into these sources of water and dissolved into solution as a result of frequent mining activities

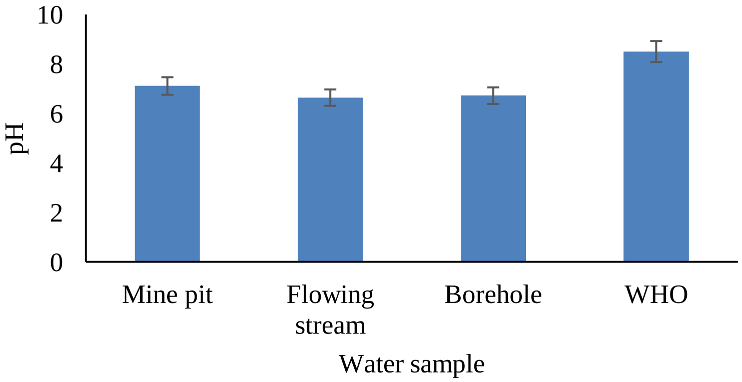

Figure 2: pH of water samples

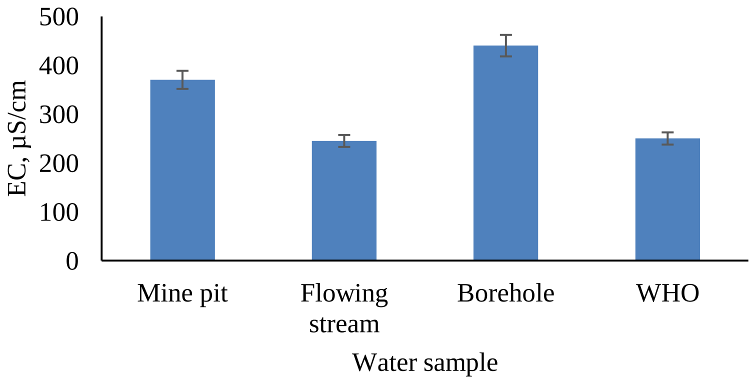

Figure 3: Electrical conductivity of water sample

The mean turbidity values of the samples and the maximum limit of WHO in drinking water are presented in Figure 4. The values for mine pit and flowing stream water were higher than the WHO standard value of 1 NTU for drinking water. However, turbidity was not detected in the borehole sample. The high turbidity may have been influenced by the high amount and nature of suspended organic and inorganic materials in the water [26], [27].

Dissolved oxygen in the water samples and the maximum WHO limit in drinking water are presented in Figure 5. The dissolved oxygen values recorded were higher than the WHO set limit of 5 mg/L for the three samples. This may be attributed to the movement of air through unsaturated materials above the water table [6],[28],[29]. This high level of DO is required for the survival of aquatic life.

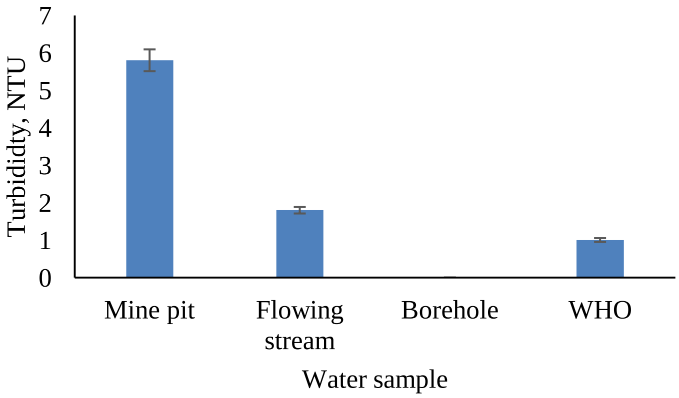

Figure 4: Turbidity of water samples

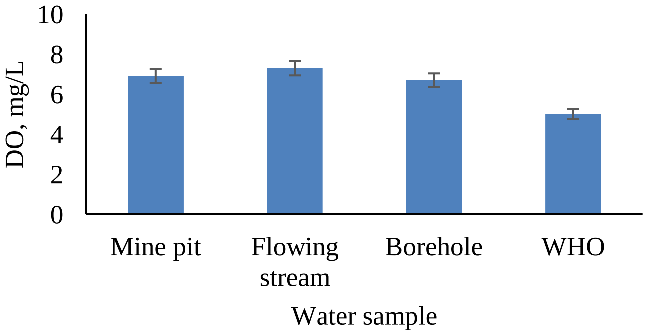

Figure 5: Dissolved oxygen in the water samples

The mean value of the biological oxygen demand of the water samples and the maximum WHO limit for drinking water are presented in Figure 6.

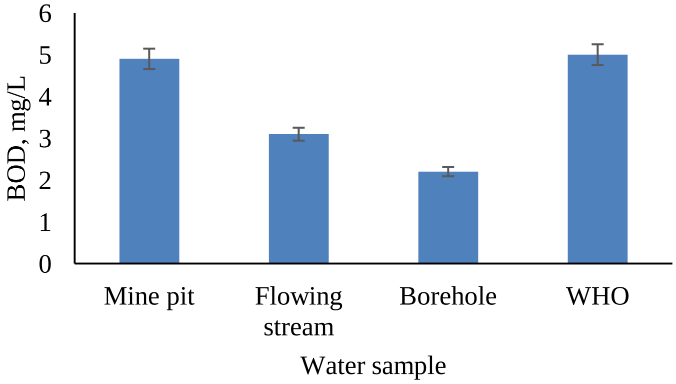

Figure 6: BOD of water sample

The BOD of the samples was lower than the WHO set limit of 5 mg/L. However, the borehole sample had a BOD of 2.2 mg/l which showed that the water was very clean. The mine pit and flowing stream had BOD within the range of 3-5 mg/l, showing moderately clean water. These lower values of BOD are due to a lack of microbial activities which are related to the dumpsite [27],[30].

The mean values of the chemical oxygen demand of the samples and WHO standard in drinking water are presented in Figure 7. The COD of the samples varied with the mine pit sample having the highest COD value of 24.1 mg/L, followed by the flowing stream sample with COD of 20.2 mg/L and the borehole sample with COD of 8.4 mg/L. Water with high COD indicates inadequate oxygen availability in the water samples [31]. These values assisted in comparing biological to chemical oxidation in the selection of treatment process and performances, as well as provided insight into the concentration of reduced inorganic metal.

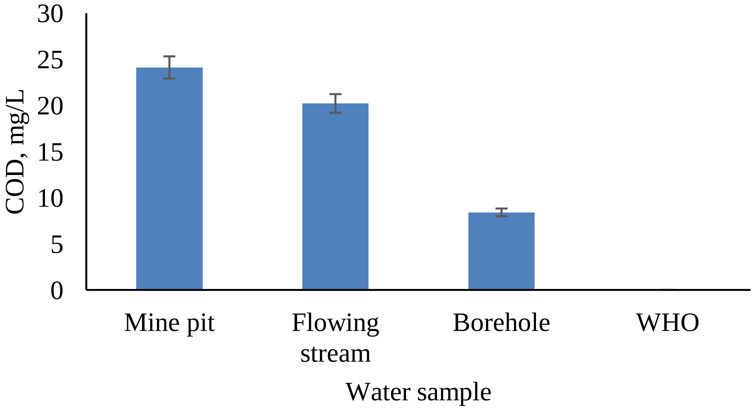

Figure 7: COD of water sample

The mean values of dissolved iron in the three samples and the maximum limit of WHO in drinking water are presented in Figure 8.

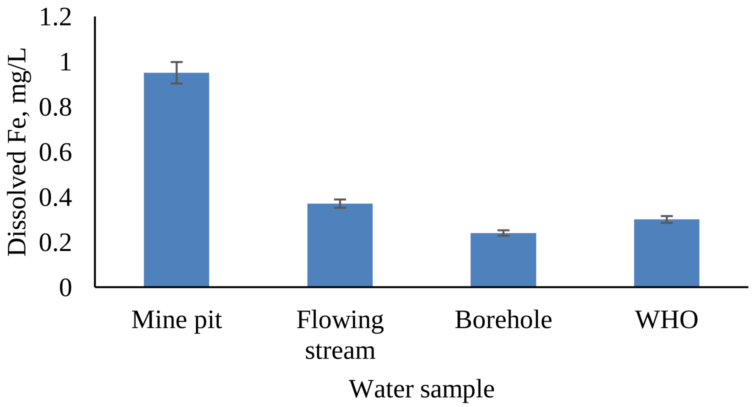

Figure 8: Dissolved Fe in the water samples

A comparison of iron concentration in water samples from the study area with the WHO permissible guideline values revealed that mine pit and flowing stream samples recorded mean values of dissolved iron that were above the recommended value of 0.3 mg/L, while that of the borehole was lower than WHO standard. The high values may be attributed to high amounts of iron and other toxic chemicals such as manganese in the rock system that may have resulted from the weathering of the rock system. Other sources of iron may include the occasional discharge of mining waste and acid mine drainage which may increase iron levels in the surface water [35]. Exposure to high levels of iron in drinking water can result in iron storage disease where the liver becomes cirrhotic. It gives a stringent taste to water and can cause staining laundry and porcelain [6], [32]–[34].

The value of dissolved manganese in the water sample and the maximum limit of WHO in drinking water are presented in Figure 9. A comparison of manganese concentration in water samples from the study area with the WHO permissible guideline values revealed that mine pit and flowing stream samples recorded mean values of dissolved manganese which were above the recommended value of 0.05 mg/L, while that of the borehole was lower than WHO standard. These elevated manganese levels can disrupt the nervous system and the regeneration of haemoglobin [2].

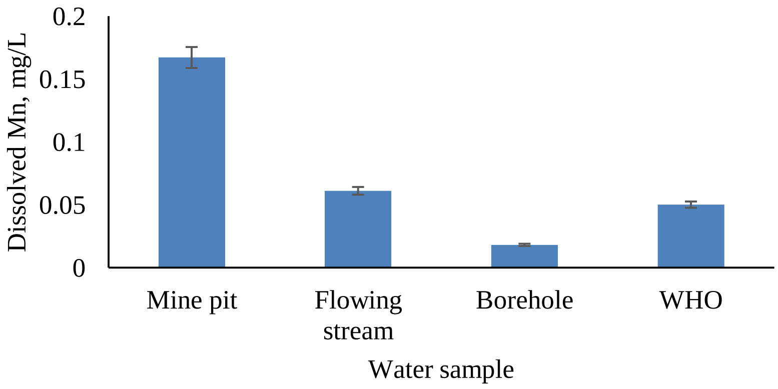

Figure 9: Dissolved Mn in the water samples

The mean value of dissolved chromium, cadmium, and lead in the water samples and the maximum limit of WHO in drinking water are presented in Figures 10, 11, and 12.

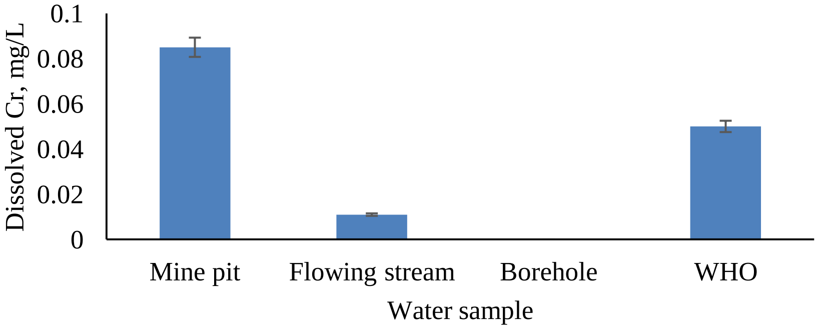

Figure 10: Dissolved Cr in the water samples

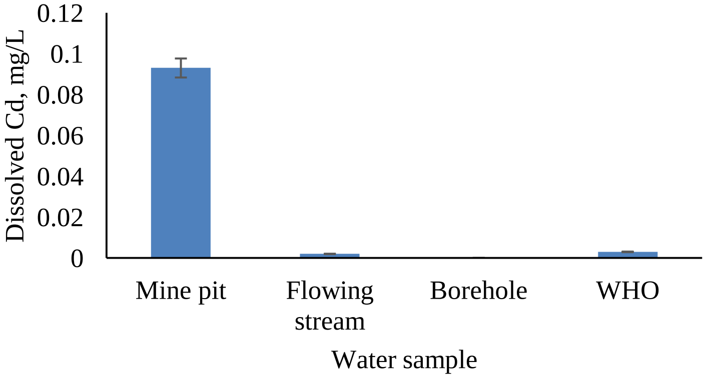

Figure 11: Dissolved Cd in the water samples

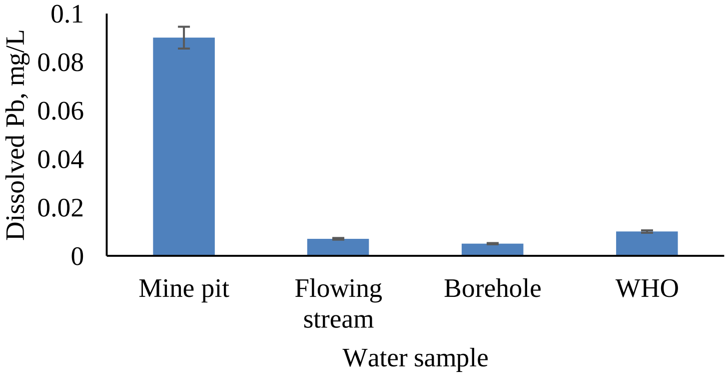

Figure 12: Dissolved Cd in the water samples

The mean values of dissolved chromium, cadmium, and lead (0.05 mg/L, 0.003 mg/L, and 0.01 mg/L, respectively) recorded for the three samples showed that only the mine pit sample had higher values than the WHO standard. Meanwhile, samples from the flowing stream and borehole were lower than the WHO standard. These higher values may be attributed to excavations made by panners as these result in the metal being leached out and carried downstream as water washes over the rock surface [6], [36], [37]. Common symptoms that may result from these higher values are lead poisoning that results in abdominal pains, constipation, fatigue, depressed appetite, and decreased endurance. Long-term exposure may lead to nerve and kidney damage and anemia. Cadmium poisoning is associated with kidney disease and hypertension, and possible mutations.

The mean values of TSS, SO_4, NO_3, and NH_4N for the water samples are presented in Figures 13, 14, 15, and 16. The TSS values varied from 0.6 to 11.7 mg/L, SO_4 values varied from 0.64 to 0.95 mg/L, NO_3 values varied from 1.12 to 3.17 mg/L and NH_4N values varied from 0.053 to 0.201 mg/L. The maximum TSS, NO_3, and NH_4N values were recorded in mine pit samples and while the maximum SO_4 value was recorded in the borehole sample.

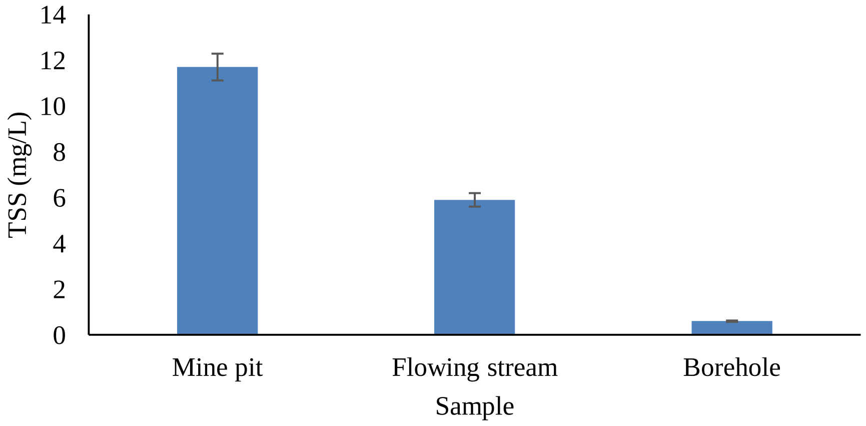

Figure 13: TSS in the water samples

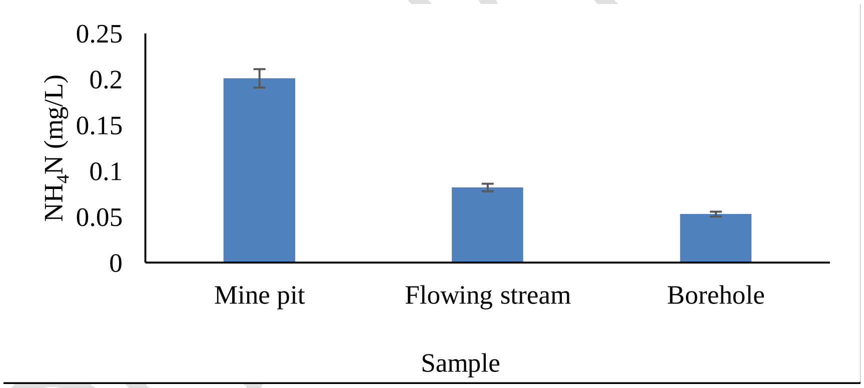

Figure 14: NH_4N in the water samples

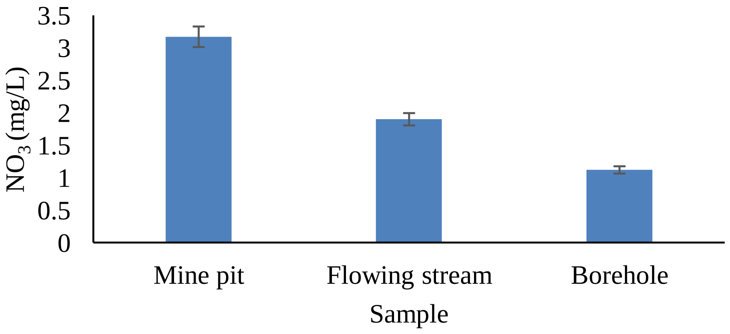

Figure 15: NO_3 in the water samples

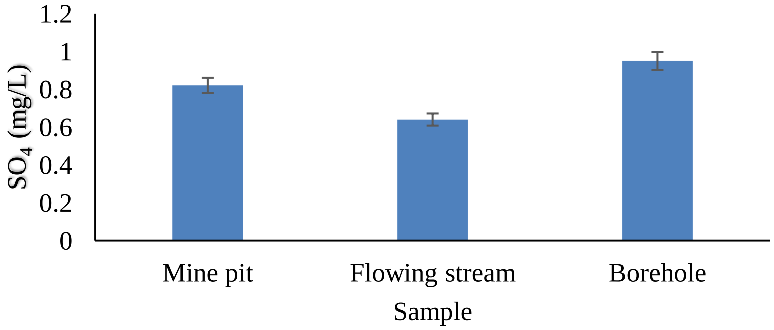

Figure 16: SO_4 in the water samples

Meanwhile, their minimum values were recorded in borehole samples except for SO_4. Generally, these values are within the acceptable limits as reported by WHO in 1993 [39], 1997 [40], and 2004 [41]. However, water bodies which are high in nitrates, sulfates, and ammonia nitrogen are potentially harmful to human and animal life and could reach high levels leading to the death of aquatic animals [3]. These contaminants are either naturally occurring due to rock weathering, volcanoes human activities like mining, waste discharge, and fossil combustion process [19],[38]. Therefore, using water from the mine pit may not be worrying in this regard, but would be more advisable to utilize water from the borehole.

4. CONCLUSIONS

The results of the research showed that the mine pit water and flowing stream water are polluted. The physicochemical characterization of the mine pit water revealed that the mean value of electrical conductivity, turbidity, chemical oxygen demand, dissolved oxygen, iron, manganese, chromium, cadmium, and lead all exceeded the WHO permissible levels for drinking water. Similarly, the concentration of dissolved iron, manganese, chemical oxygen demand, and dissolved oxygen in the flowing stream water was higher than that of the WHO limit. This raises serious concerns about the quality of water being used from these sources. These contaminations in water samples are associated with mining activities which result in increased susceptibility to erosion, weathering, and leaching of heavy metals as water washes over the rock surfaces, resulting in the formation of sulphuric acid and ferrous hydroxide as reflected in the slight acidic values of the samples. Mining activities in Ikpeshi have impacted the water quality of the mine pit and flowing stream considering the higher level of electrical conductivity, turbidity, dissolved oxygen, iron, manganese, chromium, cadmium, and lead which exceeded the WHO maximum contaminant level. It is pertinent for residents in the study area to be provided with potable water.

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