Original Research Article

MINING ACTIVITIES: IMPACTS ON THE IKPESHI VILLAGE WATER QUALITY

ABSTRACT

Aims: To study the impact of mining activities on the water quality of Ikpeshi, Edo State, Nigeria.
Study design: The experimental design of this work involved the use of two different locations. The collection of water samples from three different sites, storage of samples, characterization of samples for specific contaminants, and interpretation of results.
Place and Duration of Study: The samples collection sited included a mine pit at the mining site, while a flowing stream and a borehole, both about 1 km from the mine in Ikpeshi, Edo State, Nigeria.
Methodology: 1500 mL each of water from three different sample space (mine pit, flowing stream, and borehole) were collected, stored in a refrigerator and then analyzed for their Physicochemical properties including the 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 results were then compared against World Health Organization (WHO) permitted standards for drinking water.
Results: The water samples analyzed 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. The concentration of chromium (Cr) in the mine pit water was 1.7 times higher than the WHO limit, that of cadmium (Cd) was 31 times more than the WHO permissible limit, while that of lead (Pb) was approximately 12.9 times the WHO cadmium limit. These values were significantly higher than the WHO limits (0.05, 0.003, and 0.01 mg/L in Cr, Cd, and Pb respectively). Borehole water (0.0, 0.0, and 0.005 mg/L for Cr, Cd, and Pb) and flowing streams (0.011, 0.002, and 0.007 mg/L for Cr, Cd, and Pb) respectively fell within these WHO limits. 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 while the WHO limits for these, which are 0.3 and 0.05 mg/L respectively.
Conclusion: These results showed therefore that water from the mine pits and flowing streams are unsafe for domestic consumption and would require a high levels of purification before release to the environment or water bodies because of their contaminant level was significantly higher than the permissible limit

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

1. INTRODUCTION

The environmental implications of mining activities in most developing nations are poorly documented; in the meantime, these operations use a number of primitive technology and management techniques which have inflicted enormous damage worldwide, particularly through land and water pollution. [1], [2], [39].

Mineral resource extraction has become critical across several developing economies and countries, notably Nigeria. Blessed with enormous mineral resources, and extracting these resources in Nigeria has made significant contributions to the country's income, as well as accompanying social and economic benefits.advantages. Nevertheless, because mining is the only realistic or functional technique to obtain mineral resources for industries, the environmental impact of mining has not been entirely positive. [3], [4].

Mining is one of the world's "worst contaminating" and "depleting" activities especially with respect to water supply. Nigeria was identified as among the most water-stressed countries in a 1999 report on the water crisis in African countries by the Economic Commission for Africa (ECA). [5], [6].

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng

The health of those living in mining towns in Nigeria is being impacted by the effects of mining corporations' activities on our water bodies, including dewatering, contamination of groundwater, the unregulated utilisation of water in mining activities, heavy metal pollution of streams, as well as other material leakages. [7]. The detrimental impacts of mining include depriving neighbourhoods of safe drinking water, which has an influence on human health of the neighboring residents because cyanide and heavy metal intake from rivers over an extended amount of time may cause serious health issues for those who reside in these communities. It also is acknowledged that having access to clean drinking water is a fundamental human right, and these mining activities which pollute these bodies of water violate the rights of both the mining towns and their the dependents to have access to clean water and a contaminant-free environment. [8], [9].

Sometimes, the costs to health associated with mining activities outweigh the advantages. Considering this, Awudi [10] has emphasised that amid these encouraging signs, the health issues are a result of the mining industry's involvement in all economic development. Despite the significant Foreign Direct Investment (FDI) that has been made in geosteering and mining progress over the past ten years, the industry is yet to get a significant impact on the economy of the nation as a whole. The sector's advantages in terms of increasing investment comes with tremendous environmental, health, and social costs to the population who have repeatedly voiced their opposition to the mining industry. These businesses have refused to concede that their operations are a significant contributor to social unrest and pollution.

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

Figure 1 depicts Ikpeshi, a community located along the Auchi-Ibillo expressway in the Akoko Edo Local Government Area of Edo State, South-South Nigeria..

Ikpeshi is home to several mining companies like Noble Marble Limited, Fakunle (Geo-works) limestone quarry, and Freedom 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. The two main seasons—the rainy and the dry—are significant in this study region. The dry season begins in November and can last until March, whereas the wet (rainy) season starts in March and should last until November with a little gap in August. About 1300 mm of rain precipitation occurs on average each year. From June till October, there seems to be a noticeable fluctuation in sunshine for about 3.3 hours, which is a result of declining sunlight hours due to rising cloudiness. The temperature ranges from 25^oC to 40^oC within this period. 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 (i.e. 500 mL from three different parts of each sample space). This was then transferred into sterilized sample bottles and placed in a cold box for onward transfer to the laboratory where they were stored in a refrigerator before analysis.

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng

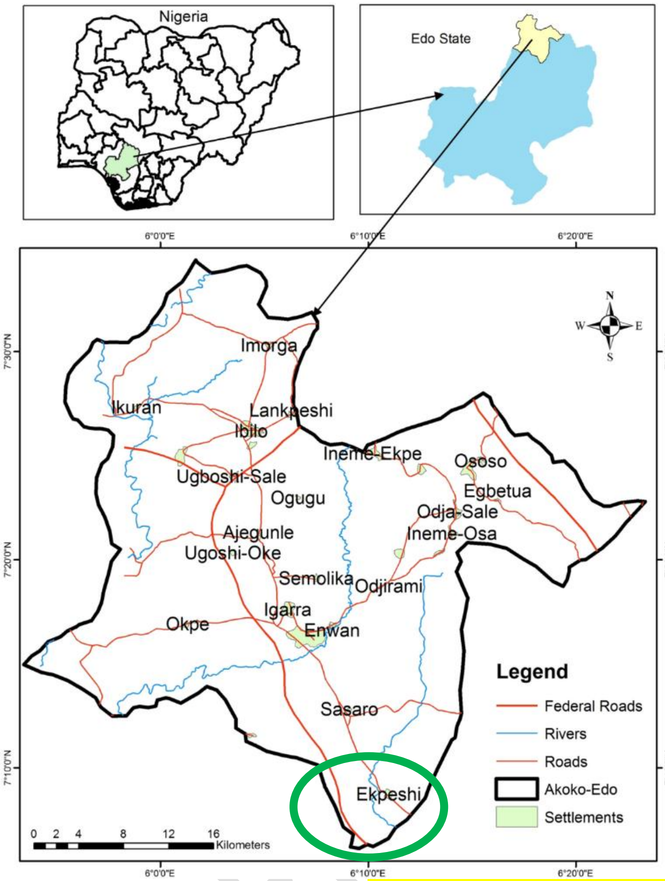

Figure 1: Map of Akoko Edo showing Ikpeshi [11] ** Ikpeshi is sometimes referred to as Ekpeshi*

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 Total Dissolved Solids and Electrical Conductivity

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 first rinsed and then immersed in the sample solution. The conductivity and TDS were thereafter read.

2.4 Turbidity

The turbidity of the samples was determined using a HACH turbidimeter [14]. Twenty-five (25) mL of each water sample was poured into a cuvette and read at zero with the spectrophotometer at 450 nm. Twenty-five (25) mLs of similar samples were also poured into another cuvette and read. Finally, the working standards were then read.

2.5 Dissolved oxygen

The amount of dissolved oxygen in the water samples was determined using modified Winkler's [15]. A 250 mL dissolved oxygen bottle was filled to the brim with the sample, taking care to minimize contact with air. One (1) mL of $MnSO_4$ solution and 1 mL of alkali-iodide-azide solution were added to the bottle, stopper put in place, shaken, and then left to settle. Two (2) mLs of concentrated H_2SO_4 was then added to dissolve the precipitate after it had settled. One hundred (100) mLs of water sample solution was

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng

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^oC. 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

Chemical oxygen demand (COD) levels in the water samples were measured using dichromate method [16]. Fifty (50) mLs of the sample was pipetted into a conical flask, 10 mL of 0.00833 M $K_2Cr_2O_7$ solution, 1 g of $HgSO_4$, and 80 mL of $Ag_2SO_4 .H_2SO_4$ solution with few beads were further 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 between the two titre values gave the titre of the sample.

2.8 Dissolved heavy metals

The concentration of dissolved iron, manganese, chromium, cadmium, and lead in the samples was measured using an atomic absorption spectrophotometer (AAS) solar unicam series with an air acetylene flame model. After the necessary bulb has been set in the instrument, a blank made of distilled water as well as the standard reference solution for each of the separate parameters used to calibrate the instrument were prepared. Until a satisfactory calibration was reached, the instrument was modified. The samples were run to find the concentration of the target metal in the sample once the necessary calibration was completed.

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 based on total solids dried at 103 -105 ^oC, sulfa ver 4, cadmium reduction, and Nessler methods, respectively [17]–[19].

3. RESULTS AND DISCUSSION

Figure 2 displays the average pH of the sample and the limit set by the World Health Organization (WHO) for drinking water. The average pH readings for the different samples were all well below WHO guideline pH level of 8.5; the borehole and flowing stream had pH values of 6.64 and 6.72, respectively, indicating that the water from these origins was mildly acidic. The mining pit sample, meanwhile, had a mean pH of 7.11. Acid mine drainage (AMD), which is a result of the extraction of sulphides containing rock from a pit or inside an underground mine, may be to blame for the mildly acid content of the flowing stream and borehole water samples. AMD occurs when large quantities of sulphide-containing rock react with water and oxygen to create sulphuric acid. Metals dissolve more readily in water and reduce pH the more acidic the solution is. However, considering that drinking water must have a pH between 6.5 and 8.5, the average values found in the water samples were good [20]–[25].

The average 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. The possibility that more particulates may well have been injected and dissolved into such water sources following regular mining operations may be the cause of the mine pit and borehole sample's higher results.

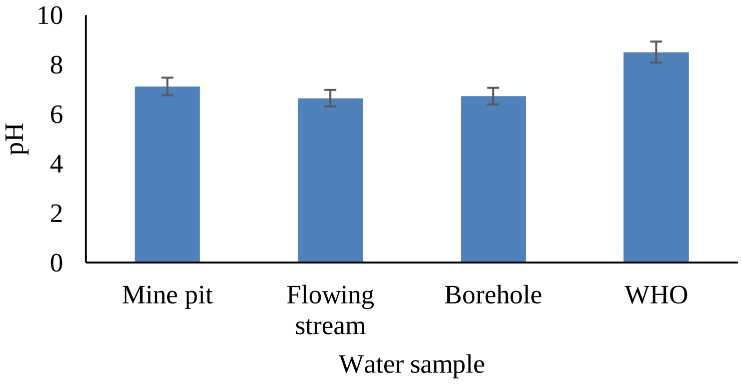

Figure 2: pH of water samples

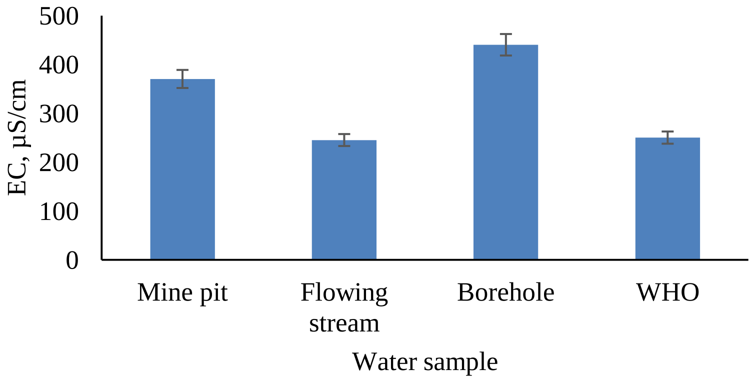

Figure 3: Electrical conductivity of water sample

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. Nevertheless, the borehole sample did not contain any turbidity. The large quantity and type of suspended organic and inorganic elements in the water may have contributed to the excessive turbidity [26], [27].

Dissolved oxygen in the water samples and the maximum WHO limit in drinking water are presented in Figure 5. For the three samples, the measured dissolved oxygen levels exceeded the WHO-set limit of 5 mg/L. 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.

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng

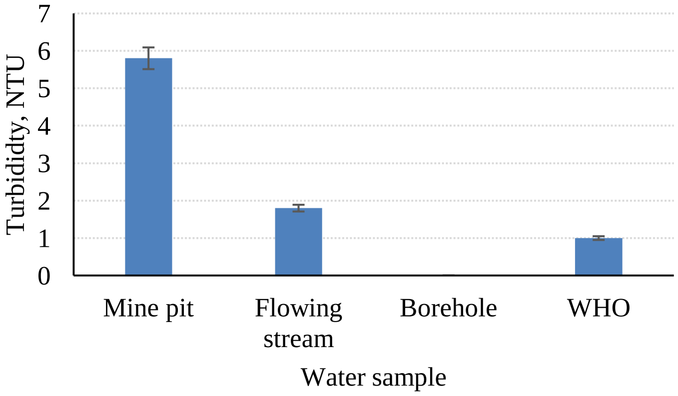

Figure 4: Turbidity of water samples

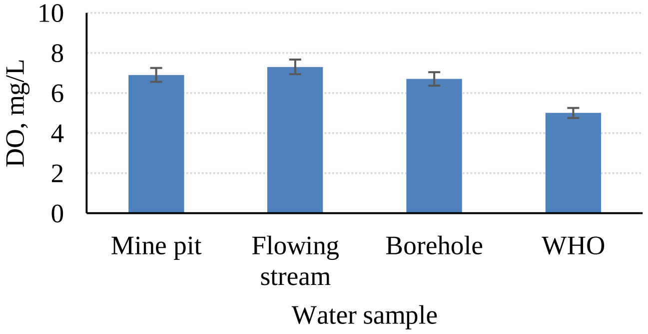

Figure 5: Dissolved oxygen in the water samples

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.

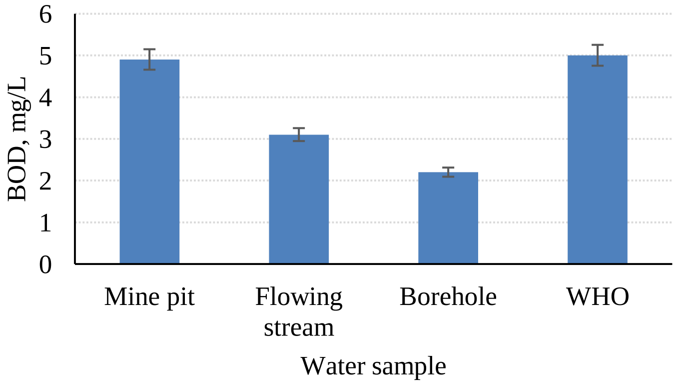

Figure 6: BOD of water sample

The BOD of the samples was lower than the WHO maximum of 5 mg/L. The borehole sample, however, 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].

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng

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 numbers offered information on the concentration of reduced inorganic metal and helped compare biological to chemical oxidation when choosing a treatment method and its effectiveness.

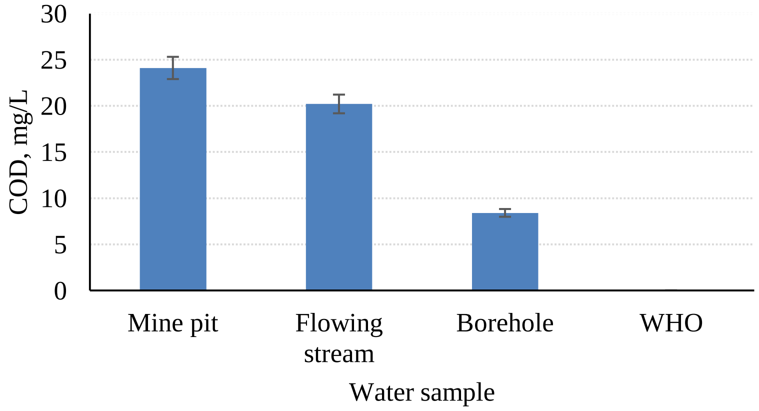

Figure 7: COD of water sample

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

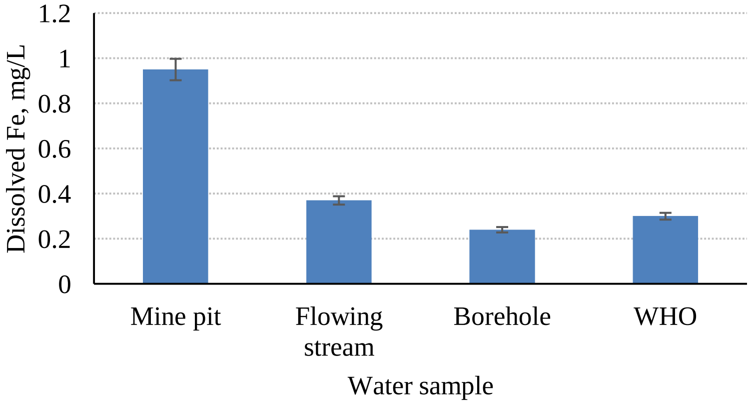

Figure 8: Dissolved Fe in the water samples

When the concentration of Iron in the samples collected was compared to the WHO permissible guideline values, it became clear that the borehole had lower mean values of dissolved iron than the WHO standard while the mine pit and flowing stream samples had mean values that were above the recommended value of 0.3 mg/L. The high levels may be linked to the rock's high concentrations of iron and other hazardous compounds like manganese, which may have happened as a result of the rock weathering system's. Alternative sources of these iron can include infrequent mining waste dumps and acid-mine drainage, which could raise levels of iron in surface water. [35]. Iron storage disease i.e. when the liver develops cirrhosis, can be brought on by prolonged exposure to elevated concentrations of iron in potable water. It imparts a harsh flavour to water and therefore can discolour clothing and ceramics [6], [32]–[34].

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng

The value of dissolved manganese in the water sample and the maximum limit of WHO in drinking water are presented in Figure 9. When the manganese content in the samples was also compared to the WHO acceptable limits, it was discovered that the mine pit and flowing stream samples had mean values of dissolved manganese which were greater than the maximum value of 0.05 mg/L, whereas the borehole sample had values that were lower than the WHO benchmark. These high levels of manganese can interfere with the neurological system and haemoglobin renewal [2].

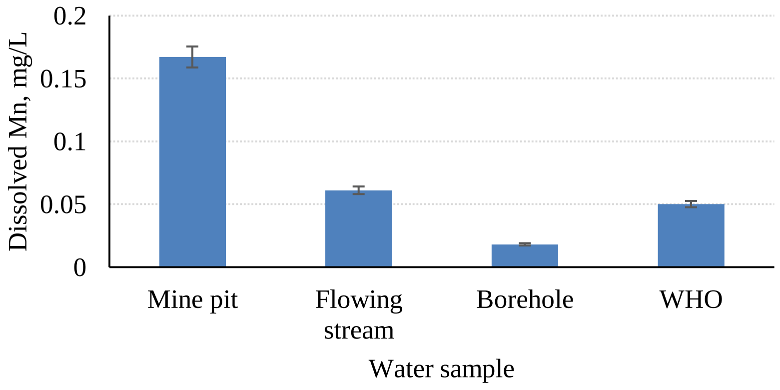

Figure 9: Dissolved Mn in the water samples

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.

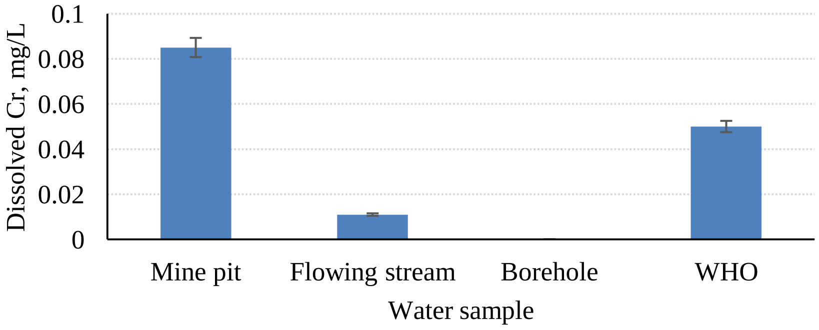

Figure 10: Dissolved Cr in the water samples

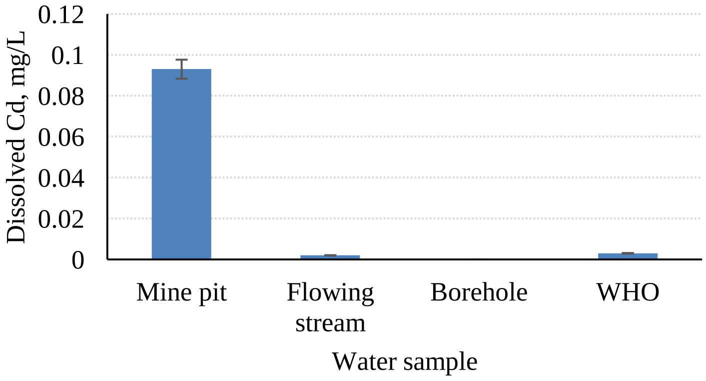

Figure 11: Dissolved Cd in the water samples

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng

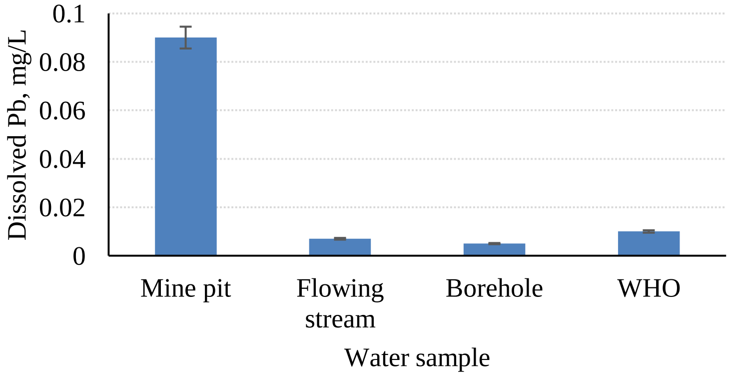

Figure 12: Dissolved Cd in the water samples

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. Such high amounts could be ascribed to panner excavation, which culminate in metal leaching and deposited downstream as water runs 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.

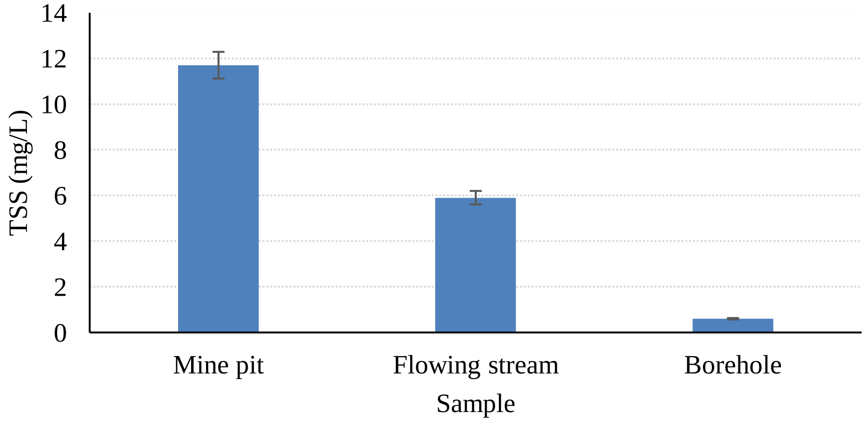

Figure 13: TSS in the water samples

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng

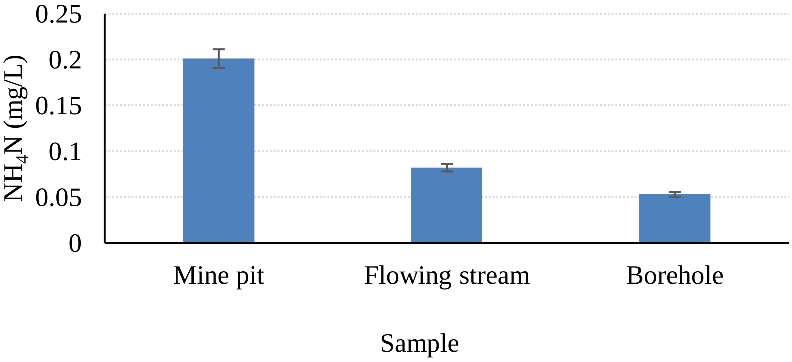

Figure 14: NH_4N in the water samples

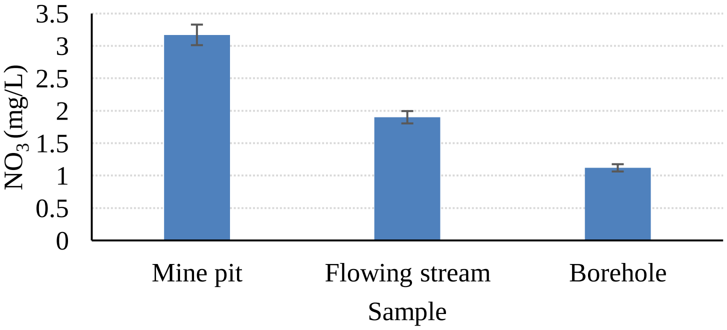

Figure 15: NO_3 in the water samples

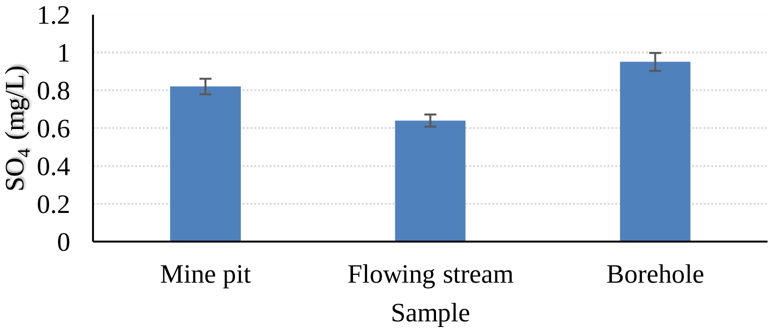

Figure 16: SO_4 in the water samples

All the minimum values were recorded in borehole samples except for SO_4 which was recorded in the flowing stream sample from Figure 16 above. 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.

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng

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 pollutants in water samples are related to mining activities, which increase the susceptibility to weathering, erosion, and heavy metal leaching as water washes over the rock surfaces, resulting in the production of concentrated sulfuric acid and ferric hydroxide as shown by the samples' mild acidic values. iven the greater level of turbidity, electrical conductivity, iron, dissolved oxygen, manganese, cadmium, chromium, and lead which surpassed the WHO maximum contamination threshold, mining activities in Ikpeshi have had an impact on the water quality of the mine pit and flowing stream. It is important that residents of the study region have access to drinkable water, and that these water sources must be well purified before being discharge into the environment or aquatic bodies.

5. REFERENCES

[1] Azcue, J. M. (Ed.)., (2012). Environmental impacts of mining activities: emphasis on mitigation and remedial measures. Springer Science & Business Media.

[2] C. N. Emeribe, A. W. Butu, K. S. Adebowale, and E. T. Ogbomida, ‘Analysis of Selected Heavy Metals in Surface Water and Sediments from Unreclaimed Mining Ponds Used for Irrigation Farming in Jos South, Nigeria’, *GJSTD*, vol. 8, no. 1, pp. 61–80, May 2022, doi: 10.47881/280.967x.

[3] Ajakaiye, D. E., (1985). Environmental problems associated with mineral exploitation in Nigeria. Paper presented at the 21st annual conference of the Nigeria Mining and Geosciences Society held at Jos. 140-148.

[4] M. O. Eyankware and O. C. Akakuru, ‘Appraisal of groundwater to risk contamination near an abandoned limestone quarry pit in Nkalagu, Nigeria, using enrichment factor and statistical approaches’, *Int J Energ Water Res*, Mar. 2022, doi: 10.1007/s42108-022-00186-0.

[5] A. A. Adeyemi and Z. O. Ojekunle, ‘Concentrations and health risk assessment of industrial heavy metals pollution in groundwater in Ogun state, Nigeria’, *Scientific African*, vol. 11, p. e00666, Mar. 2021, doi: 10.1016/j.sciaf.2020.e00666.

[6] P. N. Obasi, M. O. Eyankware, and B. E. B. Akudinobi, ‘Characterization and evaluation of the effects of mine discharges on surface water resources for irrigation: a case study of the Enyigba Mining District, Southeast Nigeria’, *Appl Water Sci*, vol. 11, no. 7, p. 112, Jun. 2021, doi: 10.1007/s13201-021-01400-w.

[7] M. T. Enyigwe, O. S. Onwuka, and J. C. Egbueri, ‘Geochemical distribution, statistical and health risk assessment of toxic elements in groundwater from a typical mining district in Nigeria’, *Environmental Forensics*, vol. 0, no. 0, pp. 1–13, Apr. 2021, doi: 10.1080/15275922.2021.1907822.

[8] M. Shams *et al.*, ‘Heavy metals exposure, carcinogenic and non-carcinogenic human health risks assessment of groundwater around mines in Joghatai, Iran’, *International Journal of Environmental Analytical Chemistry*, vol. 102, no. 8, pp. 1884–1899, Jun. 2022, doi: 10.1080/03067319.2020.1743835.

[9] U. C. Ugochukwu, N. Chukwuone, C. Jidere, B. Ezeudu, C. Ikpo, and J. Ozor, ‘Heavy Metal Contamination of Soil, Sediment and Water Due to Galena Mining in Ebonyi State Nigeria: Economic Costs of Pollution Based on Exposure Health Risks’. Rochester, NY, Apr. 25, 2022. doi: 10.2139/ssrn.4092478.

[10] Awudi, B. K., (2002). The role of foreign direct investment (FDI) in the mining sector of Ghana and the environment. Paper presented at the Conference on Foreign Direct Investment and the Environment, Paris, France.

[11] O. E. Aluko and O. Igwe, ‘Automated Geological lineaments mapping for groundwater exploration in the basement complex terrain of Akoko-Edo area, Edo-State Nigeria using remote sensing

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng

techniques', *Model. Earth Syst. Environ.*, vol. 4, no. 4, pp. 1527–1536, Dec. 2018, doi: 10.1007/s40808-018-0511-4.

[12] M. A. Saliu and Komolafe, 'Investigating the Effect of Dolomite Exploitation on Groundwater Condition of Ikpeshi, Akoko Edo, Edo State, Nigeria - PDF Free Download'. https://docplayer.net/143590333-Investigating-the-effect-of-dolomite-exploitation-on-groundwater-condition-of-ikpeshi-akoko-edo-edo-state-nigeria.html (accessed Jun. 18, 2022).

[13] 'Standard Test Methods for Electrical Conductivity and Resistivity of Water'. https://www.astm.org/d1125-14.html (accessed Jun. 18, 2022).

[14] ASTM (1979). Annual Book of America Society for Testing and Materials Standards, 1289, Philadelphia, ASTM Tech. Publ. 630pp.

[15] APHA (1995) Standard Methods for the Examination of Water and Wastewater. 19th Edition, American Public Health Association Inc., New York.

[16] 'Standard Test Methods for Chemical Oxygen Demand (Dichromate Oxygen Demand) of Water'. https://www.astm.org/d1252-06r20.html (accessed Jun. 18, 2022).

[17] APHA, Standard method for the examination of wastewater, America Public Health Association, Washington, DC, USA, 20th edition, 2003.

[18] HACH DR/4000 1997-2003, "Spectropho Tometer Procedures Manual. © HachCompany, USA,"

[19] M. O. Eyankware, O. C. Akakuru, and E. O. Eyankware, 'Interpretation of hydrochemical data using various geochemical models: a case study of Enyigba mining district of Abakaliki, Ebonyi State, SE Nigeria', Sustain. Water Resour. Manag., vol. 8, no. 1, p. 33, Jan. 2022, doi: 10.1007/s40899-022-00613-4.

[20] Alabaster, J. S. and Lloyd, R., (1980). Water Quality Criteria for Fresh Water Fish. London-Boston, Butterworth, pp. 297.

[21] Abulude, F. O. and Lawal, L., (2002). Analysis of selected nutrients of wine obtained from felled palm tree. Journal of Science and International Research, 45, 386-397.

[22] P. N. Obasi, M. O. Eyankware, and B. E. B. Akudinobi, 'Characterization and evaluation of the effects of mine discharges on surface water resources for irrigation: a case study of the Enyigba Mining District, Southeast Nigeria', *Appl Water Sci*, vol. 11, no. 7, p. 112, Jun. 2021, doi: 10.1007/s13201-021-01400-w.

[23] D. D. Gbedzi *et al.*, 'Impact of mining on land use land cover change and water quality in the Asutifi North District of Ghana, West Africa', *Environmental Challenges*, vol. 6, p. 100441, Jan. 2022, doi: 10.1016/j.envc.2022.100441.

[24] J. C. Onwuka, E. E. Jasper, and D. A. Egyegbola, 'Radiological Health Risk Evaluation of Domestic Sources of Water in Selected Lead Mining Communities of Nasarawa State, North Central, Nigeria', *Journal of Chemical Society of Nigeria*, vol. 47, no. 2, Art. no. 2, May 2022, doi:10.46602/jcsn.v47i2.700.

[25] 'The Effects of Mining Activities on the Soil Quality of Ikwo, Ebonyi State Nigeria', vol. 7, no. 12, p. 13, 2021.

[26] D. D. Gbedzi *et al.*, 'Impact of mining on land use land cover change and water quality in the Asutifi North District of Ghana, West Africa', *Environmental Challenges*, vol. 6, p. 100441, Jan. 2022, doi: 10.1016/j.envc.2022.100441.

[27] N. Golla, M. Koduru, and Prof. D. P. R. Borelli, 'Mushrooms (Agaricus bisporus) mediated biosynthesis of sliver nanoparticles, characterization and their antimicrobial activity', *International Journal of Nano Dimension*, vol. 2, pp. 29–36, Jan. 2011.

[28] Cunningham, W. P., and Saig, B. W., (1995). Environmental Science: A Global Concern. 3rd Edition, WNC Brown publisher.

[29] A. E. Ukpe, C. Ihejirika, and S. M. O. Akhionbare, 'The Effects of Mining Activities on the Soil Quality of Ikwo, Ebonyi State Nigeria', vol. 7, no. 12, p. 13, 2021.

[30] J. C. Egbueri, M. T. Enyigwe, and D. A. Ayejoto, 'Modeling the impact of potentially harmful elements on the groundwater quality of a mining area (Nigeria) by integrating NSFWQI, HERisk code, and HCs', *Environ Monit Assess*, vol. 194, no. 3, p. 150, Feb. 2022, doi: 10.1007/s10661-022-09789-w.

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng

[31] M. T. Enyigwe, O. S. Onwuka, and J. C. Egbueri, ‘Geochemical distribution, statistical and health risk assessment of toxic elements in groundwater from a typical mining district in Nigeria’, *Environmental Forensics*, vol. 0, no. 0, pp. 1–13, Apr. 2021, doi: 10.1080/15275922.2021.1907822.

[32] M. Shams *et al.*, ‘Heavy metals exposure, carcinogenic and non-carcinogenic human health risks assessment of groundwater around mines in Joghatai, Iran’, *International Journal of Environmental Analytical Chemistry*, vol. 102, no. 8, pp. 1884–1899, Jun. 2022, doi: 10.1080/03067319.2020.1743835.

[33] U. C. Ugochukwu, N. Chukwuone, C. Jidere, B. Ezeudu, C. Ikpo, and J. Ozor, ‘Heavy Metal Contamination of Soil, Sediment and Water Due to Galena Mining in Ebonyi State Nigeria: Economic Costs of Pollution Based on Exposure Health Risks’. Rochester, NY, Apr. 25, 2022. doi: 10.2139/ssrn.4092478.

[34] AGC, (2001). Ashanti Goldfields Company: Environmental Impact Statement for the Sansu Project. Ashanti Goldfield Company (AGC) limited, Obuasi, Ghana

[35] M. Shams et al., ‘Heavy metals exposure, carcinogenic and non-carcinogenic human health risks assessment of groundwater around mines in Joghatai, Iran’, International Journal of Environmental Analytical Chemistry, vol. 102, no. 8, pp. 1884–1899, Jun. 2022, doi: 10.1080/03067319.2020.1743835.

[36] J. C. Onwuka, E. E. Jasper, and D. A. Egyegbola, ‘Radiological Health Risk Evaluation of Domestic Sources of Water in Selected Lead Mining Communities of Nasarawa State, North Central, Nigeria’, Journal of Chemical Society of Nigeria, vol. 47, no. 2, Art. no. 2, May 2022, doi:10.46602/jcsn.v47i2.700.

[37] Al-Badaii, F., Shuhaimi-Othman, M. and Gasim, M. B., (2013). Water quality assessment of the Semenyih River, Selangor, Malaysia. Journal of chemistry, 2013.

[38] C. N. Emeribe, A. W. Butu, K. S. Adebowale, and E. T. Ogbomida, ‘Analysis of Selected Heavy Metals in Surface Water and Sediments from Unreclaimed Mining Ponds Used for Irrigation Farming in Jos South, Nigeria’, *GJSTD*, vol. 8, no. 1, pp. 61–80, May 2022, doi: 10.47881/280.967x.

[39] WHO, (1993). Recommendation on water quality: Guidelines from drinking water quality Volume 1, Geneva

[40] WHO, (1997). Guideline for drinking water quality.2nd edition Vol. 2.Health criteria and other supporting information WHO, Geneva.

[41] WHO, (2004). Guideline for drinking water quality (Addendum). Geneva. Available www.who.int/water_sanitationhealth/publications/facts2004/en/index.htm/ accessed on 31/08/2021.

*+234(0)8035604778;
Email address: otoikhian.kevin@edouniversity.edu.ng