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PHYSICO-CHEMICAL PROPERTIES OF SURFACE WATER QUALITY UNDER THE COAL MINING BELT OF KOGI STATE

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Abstract

This study investigated the impact of coal mining activities on water quality in the coal belt of Kogi East, Nigeria. Surface water samples were collected from Ika-Ogboyaga and Okaba mine sites and a control site in Ankpa town. In this study, 27 liters of water were collected in total; 9 liters each from Ika-Ogboyaga mine site, Okaba mine site and control site in Ankpa town, samples were taken in triplicate from upstream, midstream and downstream at each site, with each sample being 1 liter. Physical parameters, total dissolved solids (TDS), biological oxygen demand (BOD), chemical oxygen demand (COD), and heavy metals were analyzed. Physical parameters were measured in situ using a multi-parameter logging sensor The findings reveal that: Mean temperatures were 28.49±1.5°C, 27.94±1.17°C, and 28.45±1.5°C, exceeding the WHO standard (22°C) but within the FME standard (<40°C), pH values were 6.9±0.2, 6.8±0.2, and 6.74±0.15, conforming to WHO and FME standards, Electrical conductivity (EC) values were 562.39±4.5 µS/cm, 444.7±7.6 µS/cm, and 372.9±9.1 µS/cm, within WHO and FME standards, Total Dissolved Solids (TDS) in Ika (398.1±5.9 mg/l) exceeded WHO and FME limits, while Okaba (358.5±8.3 mg/l) and the control (298.8±2.9 mg/l) were within limits, Salinity, Total Hardness, BOD, COD and Nitrate values exceeded WHO and FME permissible limits in the mined sites. ANOVA results indicate significant differences in salinity, BOD and COD between mine and control sites (p < 0.05). This study underscores the need for stringent environmental regulations and remediation strategies to mitigate the adverse effects of coal mining on water quality in the region.

Key Words: *Coal, Mining, Water, Quality, Parameters*

Introduction

The mining sector worldwide is greatly important for income generation, employment, economic growth, development and competitive advantage (Jerome, 2003; Oelofse *et al.,* 2008). Mining, however, poses major threats and hazards that can jeopardize ecosystems of nations. Nigeria has been actively engaged in solid mineral exploitation for decades and is endowed with deposits of more than 34 solid minerals, including coal, tin, columbite, gold, lead, zinc, thorium, lignite, uranium and tantalum in more than 450 locations across the country (Mining Journal, 2006). Mining brought new potential hazards and risks to the environment (Lazareva and Pichler, 2007;

Othman and Al-Masri, 2007; Li, Zhang *et al*., 2014). In addition, mining waste land is an inevitable by-product which caused a great mass of soils being spoiled away (Liu *et al*., 2003; Li *et al*., 2014). On the contrary, coal is the most abundant fossil fuel on the earth (Rashid *et al*., 2014) that comprises about 75% of the total fuel resources (Elliott 1981; Rashid *et al*., 2014). Coal is necessary to meet the energy demand and are mined in different parts of the world where it is found. Although, coal mining activities has significant environmental, ecological and human health impacts. If not done properly, coal mining has potential to damage landscape, soils, surface water, groundwater, air during all phases of exploration (Martha, 2001).

Mining of solid minerals like coal has the potential of causing environmental degradation. Vegetation in form of natural forest and crop land are usually the first casualty in exploration and exploitation of coal. Open cast method of mining is in use in the coal mines in Ankpa and Omala LGA's of Kogi State. This strip-mining process involves removal of overburden that overlies the coal in order to expose it. The coal is scooped from the ground using very large cranes and trucks. It is an undeniable fact that coal mining and its uses have different effects on the ecosystem. Coal mining has effect on the surrounding landscape, water courses, flora and fauna, the air, groundwater as well as social effects on the local community (Thomas 2002).

It must be emphasized that the mining of the coal in the present study areas were never subjected to Environmental Impact Assessment, therefore, the study area lacks basal data on the ecological indices such as water quality.

The coal mining activities in the coal belt of Kogi East pose a significant environmental concern due to potential alterations in the physico-chemical properties of water sources, exacerbated by acid mine drainage. This study aims to investigate and quantify the impact of coal mining activities on parameters such as pH, turbidity, BOD and COD levels in water samples collected from mining-affected areas in the study area.

A number of studies have reported the high possibility of contamination by heavy metals and hazardous elements due to coal mining and exploitation in ecosystems within mine sites in Kogi State (Ameh *et al*., 2021) Assessed the Seasonal Variations of Toxic Metal Pollution in Soil and Sediment Around Okaba Coal Mine Area, Kogi, Nigeria, Oloche *et al*., 2019 Evaluated the Effect of Coal Mining on the Water Quality of Water Sources in Nigeria, (Ekwule *et al*., 2021) Assessed the Effect of Heavy Metal Concentration on the Soil of Odagbo Area, Kogi State Nigeria. However, none of the studies have examined the implications of coal mining on water qualiity in the Ika-ogboyaga mine sites in the study area and this constitute the gap of the study. Hence, the need for this study.

Study Area

Ankpa LGA lies between longitude 7°36'E to 7°39' E and latitude 07°23' N to 07°26' N (Figure 1). Ankpa has an area of 1,200km^2 and a population of 267,353 at the 2006 census (Ishaka, 2012). Ankpa falls within the Nigeria meteorological zone that is characterized by warm temperature days and moderately cool nights. Two distinct climatic divisions are demarcated as the dry and rainy seasons representing two broad periods of significant but contrasting variations of weather parameters. The area has warm Tropical Savanna Climate with clearly marked wet and dry seasons (Ali, 2010). Rainfall is well distributed and is of double maxima (Iloeje, 1972). The amount of rainfall ranges between 1,000mm to 1,750mm. Temperature is moderately high throughout the year, averaging 250C. The maximum temperature of the area lies between 29.70C – 35.60C while the minimum temperature ranges between 23.3°C and 25.2°C (Ali, 2010).

The dominant vegetation communities remain the tropical savanna woodland of secondary types and mixtures of scattered tropical trees and grassland formations. Vegetation distribution in this area follows a pattern that is similar to that of rainfall distribution, Ukwedeh (2003). The study area is known for its rich source of a variety of medicinal, cultural and edible wild plants, such as; *Abrus precatorius Linn*, *Allophyllus Africanus, Butyrospermum paradoxum* (Gaerrn, f.) *Hepper/ vitellaria paradoxum* (Gaertn,f), *Dennettia tripetala* and *Cola nitida* (Aniama *et al.,* 2016).

The prevalent land use and socioeconomic activity of the study area includes farming, mining, trading among others. Although, over time there has been a rapid change in the land-use/land cover characteristics in the study area due to development and change in land use from farmland to residential and commercial among others that are prevalent in the area and may be responsible for the considerable reduction in agrarian land use. In a study by Tokula and Ejaro, 2018, they discovered a considerable change in the land-use/land cover characteristics in Ankpa Town.

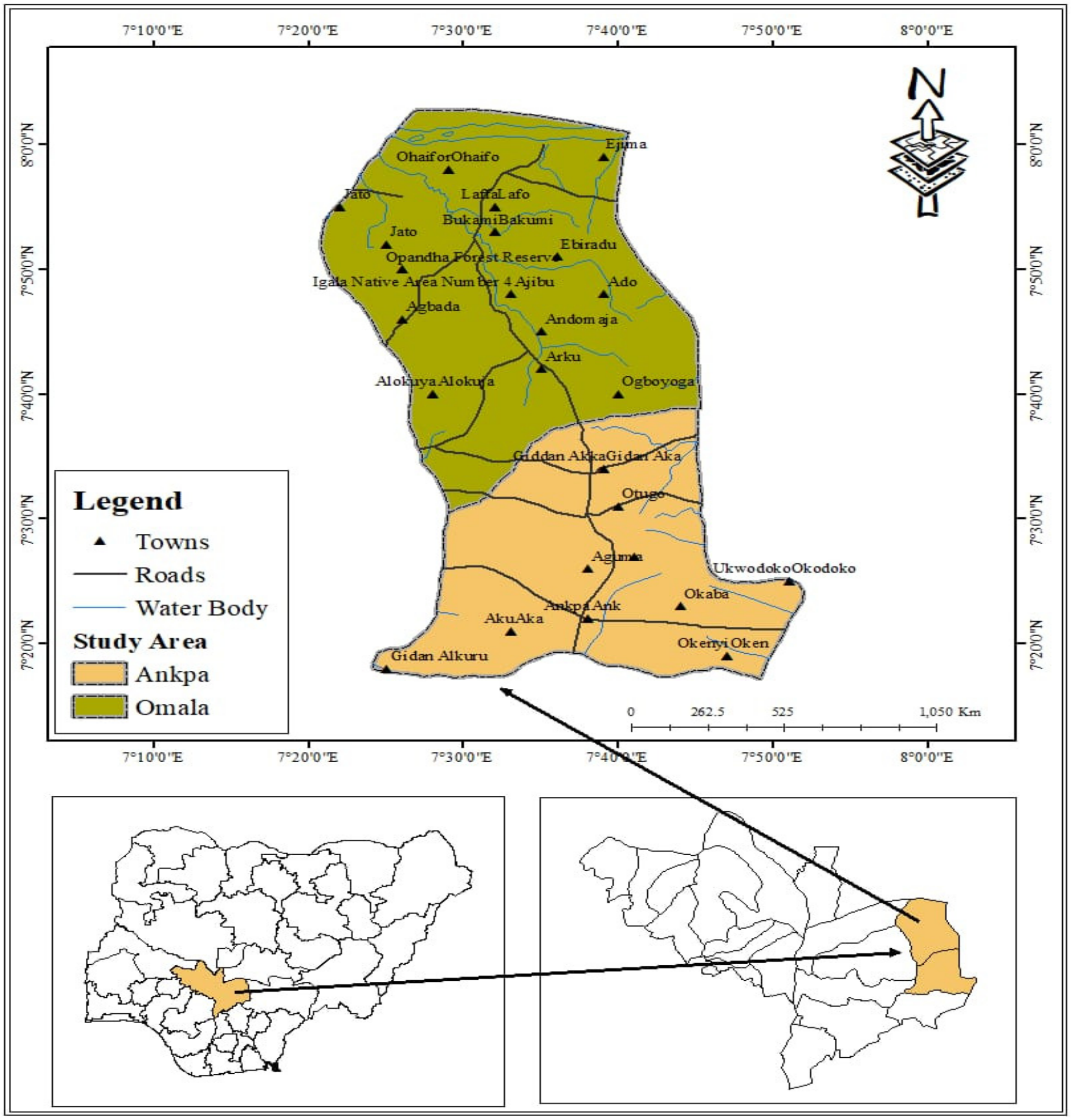

Fig. 1: Map of the Study area

Research Methods

Sampling Procedures

Surface water samples were collected from three sites: Ika-Ogboyaga mine site, Okaba mine site and control site in Ankpa town. At each site, samples were taken in triplicate from three different locations; upstream, midstream and downstream, each sample was collected in 1-liter volumes. For Ika-Ogboyaga mine site, a total of 9 liters of water was collected (3 liters from each location). The same procedure was followed for Okaba mine site and control site in Ankpa town, resulting in 9 liters of water collected from each site. In total, 27 liters of water were collected across all three sites. The samples were collected in nitric acid washed plastic bottles. The plastic bottles were also rinsed prior to being used to reduce contamination. After collection, drop of nitric acid not above (0.2%) was added as preservative. The samples were sealed, marked and labelled accordingly and preserved in plastic coolers containing ice block and transported to the laboratory for analysis.

Determination of the physical parameters of water

At each sampling station, pH, electrical conductivity, temperature, and dissolved oxygen were determined *in situ* using Multi-parameter loggin sensor-Green span CS304/CS4-1200.

Determination of total dissolved solids (TDS)

Samples' TDS were determined by gravimetric method (Adong, 2001). In this method, measured 100 ml filtrate poured in dried and pre-weighed porcelain container was evaporated to dryness in oven maintained at 105ºC for 1 hour 30 minutes for standardized dryness. Finally, the resultant residue was transferred to desiccator to cool to standard dryness to attain constant weight. The constant weight attained was calculated as the TDS.

Determination of BOD

Biological oxygen demand was determined by using BOD OxiTop meter as described by Yuan *et al*. (2001). A 100 ml volume of test sample was put into dark BOD bottles with magnetic stirrer. Two pellets of sodium hydroxide were placed in the bottles and tightly corked. They were then put into BOD meter and incubated at 20°C for 5 days. After which the BOD5 results were obtained directly from the meter reading.

Data Analysis

Data obtained from the water quality test was analyzed using descriptive and inferential statistical tools. Descriptive tools included averages, tables and charts for easy understanding of the pattern and variability in the physico-chemical characteristics of the water. One-way analysis of variance (ANOVA) was used to compare the means of various parameters to determine their differences. Significant level was obtained as $P < 0.05$. ANOVA model can be specified as follows:

$$\text{TSS} = \Sigma_i \Sigma_j \left(X_{ij} - X_{++}\right)^2$$

$$\text{BSS} = \sum_j n_j \left(X_{+j} - X_{++}\right)^2$$

$$\text{WSS} = \Sigma_j \Sigma_j \left(X_{ij} - X_{Xj}\right)^2 = \sum_j \left(n_j - 1\right) s_j^2$$

Interpretation of the results was done using pollution factor indices and comparisons made with World Health Organization WHO (2011).

Results and Discussion

Physico-chemical Characteristics of Water Samples in the study area.

Temperature of sampled water

Temperature is an important parameter regulating water chemistry. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. Below is the result of temperature for the sampled water (Figure 2).

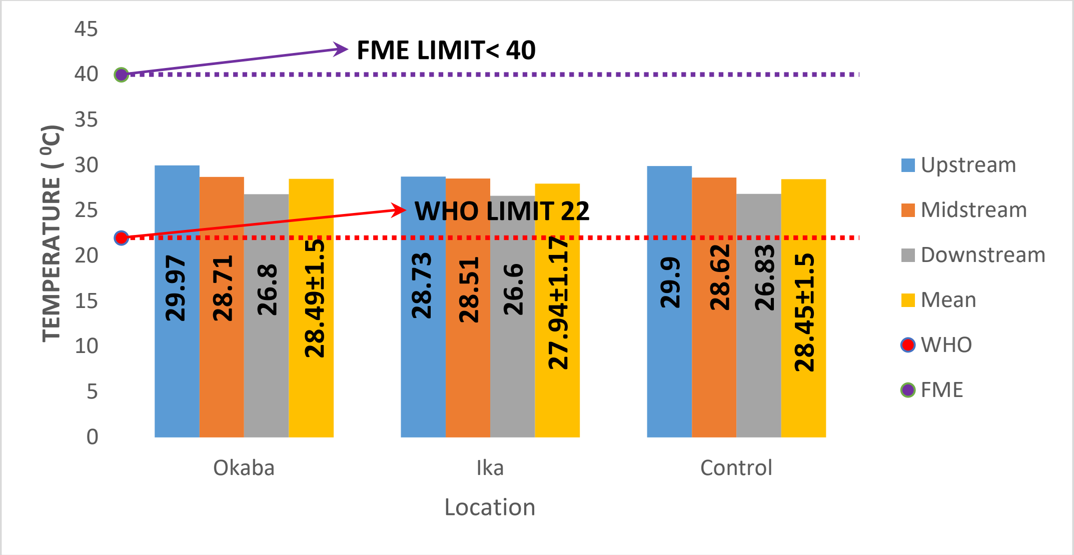

Fig. 2: Temperature of the Sampled Water

Figure 2 shows that the mean temperature recorded in upstream, midstream and downstream samples of water from Okaba, Ika and the control site include; 28.49±1.5 °C, 27.94±1.17 °C and 28.45±1.5 °C respectively. The temperature of the water samples falls short of the WHO standard (22°C) but commensurate to the FME standard (<40°C).

Temperature is a measure of the average energy (kinetic) of water molecules. It is measured on a linear scale of degrees Celsius or degrees Fahrenheit. Temperature is a basic water quality variable. It determines the suitability of water for various forms of aquatic life. Depending on the geographic location the mean annual temperature varies in the range of 10 to 21°C with an average of 16°C. Temperature affects a number of water quality parameters such as dissolved oxygen which is a chemical characteristic. Oxygen solubility is less in warm water than cold water. Temperature also affects the aquatic life, for example, trout and salmon require cool temperature for survival and reproduction whereas bass and sunfish do better at warmer temperatures. Temperature in water bodies generally follows mean daily air temperature. It influences: amount of oxygen that can be dissolved in water, rate of photosynthesis by algae and other aquatic plants, metabolic rates of organisms, sensitivity of organisms to toxic wastes, parasites and diseases, and timing of reproduction, migration, and aestivation of aquatic organisms.

The implication of this result is that the solubility of oxygen will decrease due to high temperature (Wetzel, 2001). The maximum solubility of oxygen in water at 1 atmospheric pressure (standard air pressure at sea level) ranges from about 15 mg/L at 0°C to 8 mg/L at 30°C —that is, ice-cold water can hold twice as much dissolved oxygen than warm water (Wetzel, 2001).

pH of the Sampled Water

Measurement of pH relates to the acidity or alkalinity of the water. A sample is considered acidic if the pH is below 7.0. Meanwhile, it is alkaline if the pH is higher than 7.0. However, there exist permissible limit for pH concentration in water. The pH concentration in the sample water are presented in Figure 3.

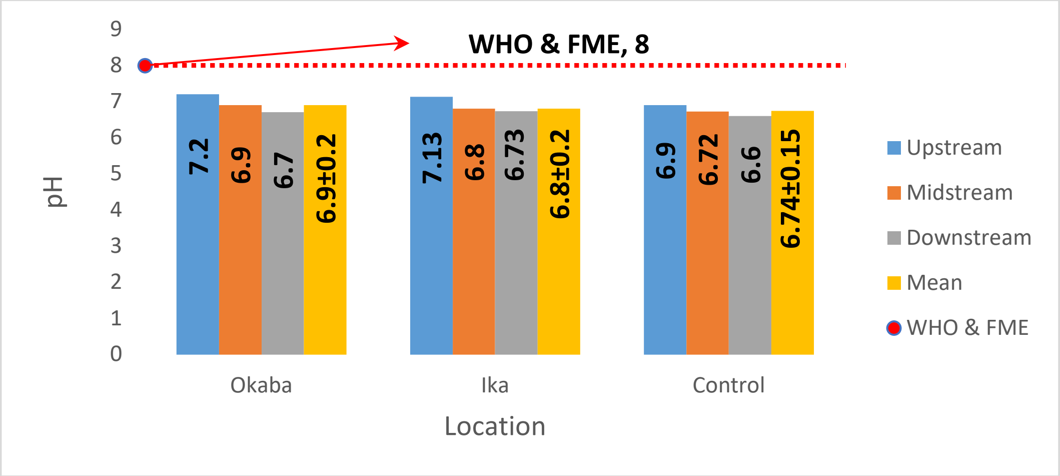

Fig. 3: pH of the sampled water

Figure 3 shows that the mean pH values recorded in upstream, midstream and downstream samples of water from Okaba, Ika and the control site include 6.9±0.2, 6.8±0.2 and 6.74±0.15 respectively. The results indicate that the sampled water deviate slightly from neutral towards being alkaline. However, the pH values of all the samples falls within the standard limit for pH range set by FME and WHO.

The range of natural pH in fresh waters extends from around 4.5, for acid, peaty upland waters, to over 10.0 in waters where there is intense photosynthetic activity by algae. However, the most frequently encountered range is 6.5-8.0. The range of pH apt for fisheries is considered to be 5.0-9.0, though 6.5-8.5 is preferable. At the extreme ends of the pH scale, (2 or 13) physical damage to gills, exoskeleton and fins occurs. Changes in pH may alter the concentrations of other substances in water to a more toxic form. Ammonia toxicity, chlorine disinfection efficiency, and metal solubility are all subjective to changes in pH value.

This result is consistent with the findings obtained by Ahaneku and Adeoye (2014). pH is classified as one of the most important water quality parameters. Leach metals such as Iron, Manganese, Copper, Lead, and Zinc characterize water with acidic pH levels. High level of these metals in drinking water places adults at risk of health problems such as cancer, stroke, kidney disease, memory problems, stomach cramps, vomiting, diarrhea, and high blood pressure (U.S. EPA, 2007).

Electrical Conductivity of the Sampled Water

Electrical conductivity is the ability of any medium; water in this case, to carry an electric current. The electric conductivity of the sampled is illustrated in Figure 4.

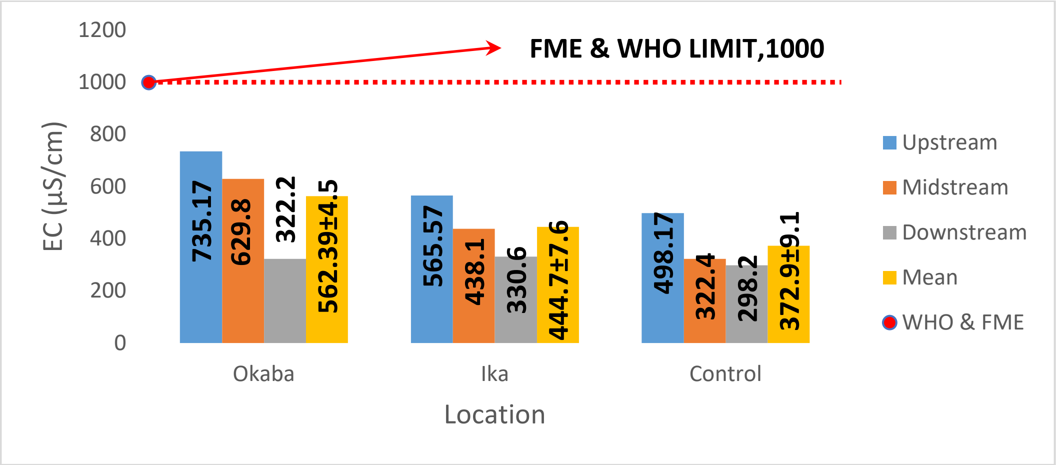

Fig. 4: Electrical conductivity of sampled water

Also, figure 4 shows that the mean Electrical conductivity values recorded in upstream, midstream and downstream samples of water from Okaba, Ika and the control site include; 562.39±4.5 µS/cm, 444.7±7.6 µS/cm and 372.9±9.1 µS/cm respectively. Water samples obtained from the coal sites revealed higher values as compared with water samples from the control site. The EC of the sampled water fall short of the standard of FME and WHO (400µs/cm).

The conductivity of water is an expression of its ability to conduct an electric current as a result of breakdown of dissolved solids into positively and negatively charged ions. The major positively charged ions are sodium (Na^+), calcium (Ca^{+2}), potassium (K^+) and magnesium (Mg^{+2}). The major negatively charged ions in water include chloride (Cl^-), sulfate (SO_4^{-2}), carbonate (CO_3^{-2}), and bicarbonate (HCO_3^-). Nitrates (NO_3^{-2}) and phosphates (PO_4^{-3}) are minor contributors to conductivity, although they are very important biologically. Conductivity in itself is a property of little interest, but it is an invaluable indicator of the range of hardness, alkalinity and the dissolved solids content of the water. Conductivity will vary with water source: ground water, water drained from agricultural fields, municipal wastewater, rainfall. Therefore, conductivity can indicate groundwater seepage or a sewage leak.

Water with high conductivity leads to corrosion of metal surface of equipment such as boiler (Meride and Ayenew, 2016).

Total Dissolved Solid (TDS) of the Sampled Water

Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions. The total solids content of water is defined as the residue remaining after evaporation of the water and drying the residue to a constant weight at 103°C to 105°C. Figure 5 present the result of TDS concentration recorded from the water samples.

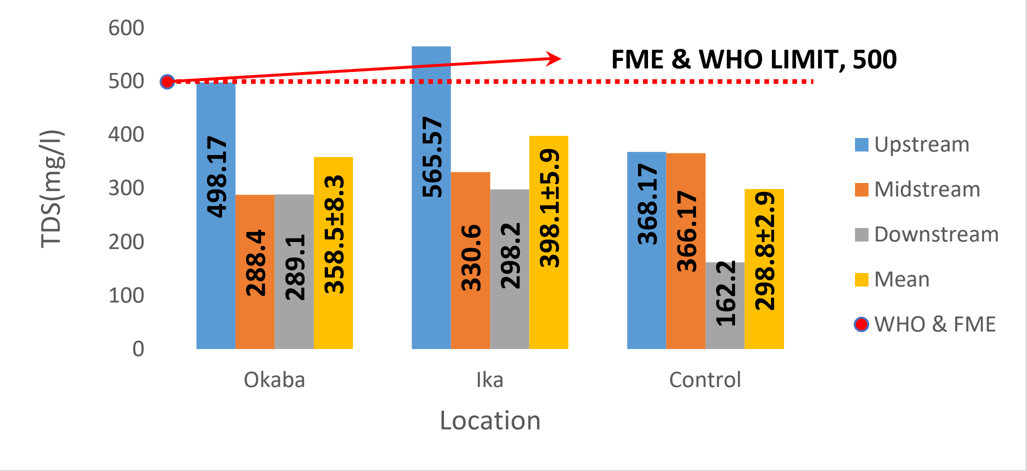

Fig. 1: TDS concentration of the sampled water

In the same vein, figure 5 reveals that the mean TDS values recorded in upstream, midstream and downstream samples of water from Okaba, Ika and the control site include; 358.5±8.3 mg/l, 398.1±5.9 mg/l and 298.8±2.9 mg/l respectively. The figure further shows that values recorded in Ika mine site was above the permissible limits of the WHO and FME. While the values observed in Okaba mine site and the control were within the limit of the WHO and FME. Studies have shown that the presence of dissolved solids in water may affect its taste (Islam, 2017; Abaje *et al*., 2009). The palatability of drinking water has been rated in relation to its TDS level as follows: excellent, less than 300mg/L; good, between 300 and 600mg/L; fair, between 600 and 900 mg/L; poor, between 900 and 1200mg/L; and unacceptable, greater than 1200mg/L (Islam, 2017). Based on this rating, water from the study area is safe for domestic use.

Salinity of the Sampled Water

Salinity is a measure of the amount of salts in the water. Because dissolved ions increase salinity as well as conductivity, the two measures are related. The salts in sea water are primarily sodium chloride (NaCl). However, other saline waters owe their high salinity to a combination of dissolved ions including sodium, chloride, carbonate and sulfate. Result of the salinity of the sampled water is presented in Figure 6.

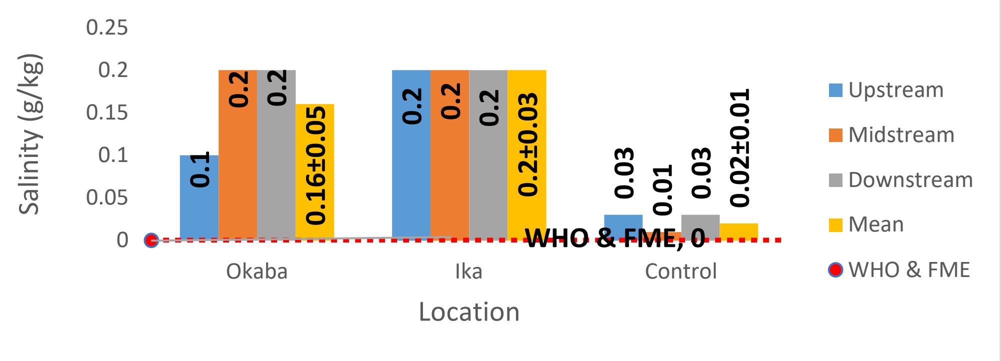

Fig. 6: Salinity of the sampled water

Figure 6 shows that the mean Salinity values recorded in upstream, midstream and downstream samples of water from Okaba, Ika and the control site include 0.16±0.05 g/kg, 0.2±0.03 g/kg and 0.02±0.01 g/kg respectively. The salinity of the sampled water is far above the FME and WHO standard (0g/kg). This implies that water from the study area is invariably poor for domestic use, and its adoption for irrigation will pose a great threat to plant by increasing the salt content of the soil – particularly at the downstream areas, which records high amount of salinity. Consequently, the intrusion of salinity into the river poses a significant risk to people's access to potable water (Abedin *et al*., 2013).

Total Hardness of the Sampled Water

Hardness is a natural characteristic of water which can enhance its palatability and consumer acceptability for drinking purposes. Result of the total hardness of the sampled water is presented in Figure 7.

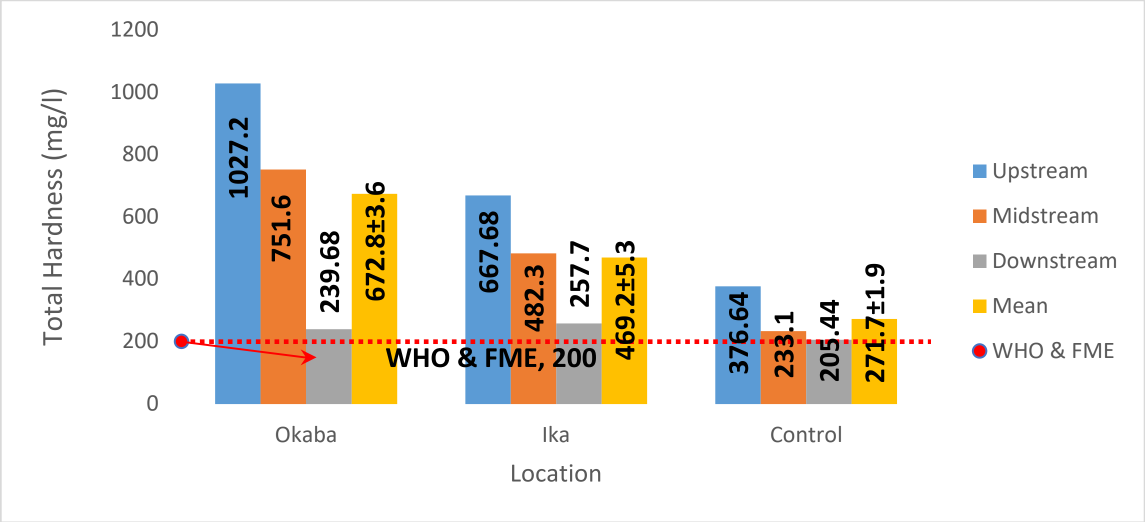

Fig. 7: Total hardness of the sampled water

Figure 7 shows that the mean Total hardness recorded in upstream, midstream and downstream samples of water from Okaba, Ika and the control site include 672.8±3.6 mg/l, 469.2±5.3 mg/l and 271.7±1.9 mg/l respectively. Higher values were recorded in the mined sites as compared with the control site. The values recorded were also above the permissible limits of the WHO and FME standard. The hardness of water is due to the presence of calcium and magnesium minerals that are naturally present in the water. The common signs of a hard water supply are poor lathering of soaps and scum. The hardness is made up of two parts: temporary (carbonate) and permanent (non-carbonate) hardness. The temporary hardness of water can easily be removed by boiling the water. Since the rivers in the mined sites receives effluent/or runoff directly, the increase in hardness could be a resultant effect caused by the presence of multivalent ions from natural minerals which are known to dissolve in water (Eze and Chigbu, 2015). Hard water has no known adverse health effect; however, it may limit the ability of water to precipitate soap (Galan *et al*., 2002).

Sulphate Content of the Sampled Water

Result of the sulphate content in the sampled water is presented in figure 8.

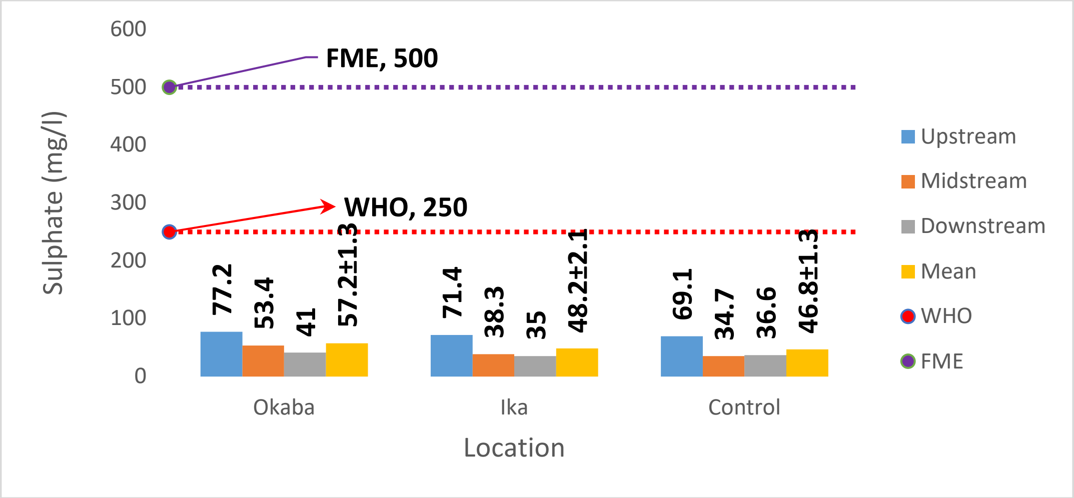

Fig. 8: Sulphate content of the sampled water

Figure 8 shows that the mean Sulphate values recorded in upstream, midstream and downstream samples of water from Okaba, Ika and the control site include 57.2±1.3 mg/l, 48.2±2.1 mg/l and 46.8±1.3 mg/l respectively. The result depicts that sulphate minerals fell below the WHO (150mg/l) and FME standard (500mg/l). The considerable increase in the sulphate content of the samples from the mined sites as compared to the control site is probably due to runoff received from the mine pit. A similar observation was made by Wu *et al*. (2008).

BOD Content of the Sampled Water

Biological oxygen demand is the amount of dissolved oxygen required by aerobic biological organisms to degrade the organic material present in a water body at certain temperature over a specific time period. Result of the concentration of BOD in the sampled water is presented in figure 9.

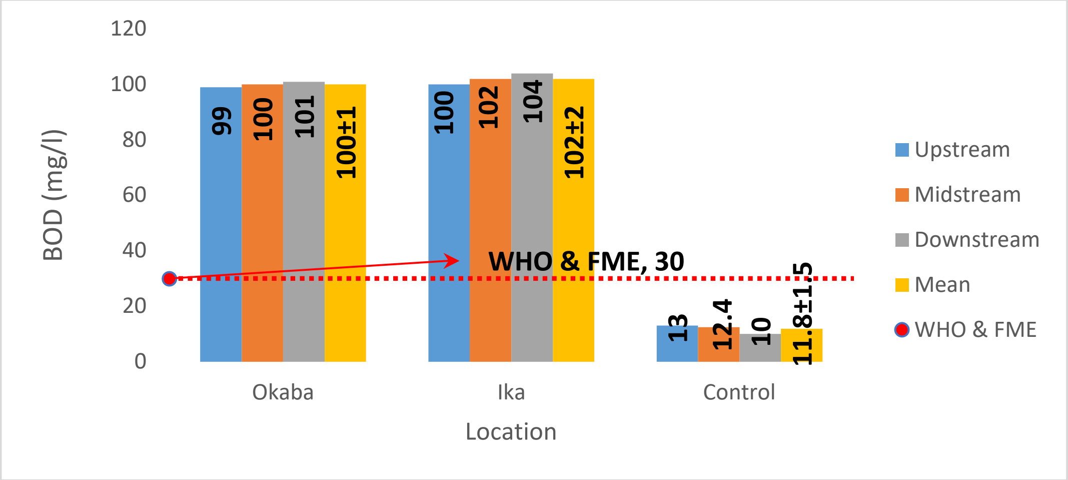

Fig. 9: BOD content of the sampled water

Figure 9 shows that the mean BOD values recorded in upstream, midstream and downstream samples of water from Okaba, Ika and the control site include 100±1 mg/l, 102±2 mg/l and 11.8±1.5 mg/l respectively. The figure further shows that higher values of BOD was recorded in the Okaba and Ika mine sites when compared to the control sites, this may be due to nutrient runoff from mining activities which can lead to eutrophication and cause algal blooms. When algae die, they decompose and increase the organic load in the water, raising the BOD. Also, the figure shows that values recoded in the mine sites were far above the permissible limits of the WHO and FME (30 mg/l). According to Al-Badaii *et al*. (2013), high value of BOD shows decline in DO and a significant threat to aquatic life. (Al-Badaii *et al*., 2013).

COD Content of the Sampled Water

Chemical Oxygen Demand (COD) determines the quantity of oxygen required to oxidize the organic matter present in water body under specific conditions of oxidizing agent, temperature and time. COD is an important water quality parameter as it provides an index to assess the effect discharged wastewater will have on the receiving environment. Result of the concentration of COD in the sampled water is presented in figure 10.

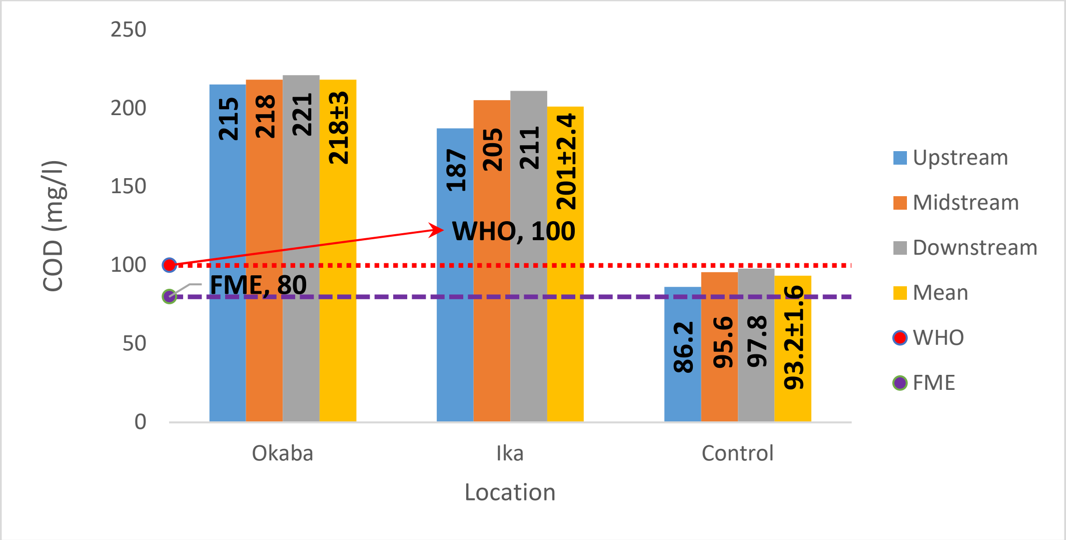

Fig. 10: COD content of the sampled water

Figure 10 shows that the mean COD values recorded in upstream, midstream and downstream samples of water from Okaba, Ika and the control site include 218±3 mg/l, 201±2.4 mg/l and 93.2±1.6 mg/l respectively. The figure further shows that higher values of COD was recorded in the Okaba and Ika mine sites when compared to the control sites. Coal mining activities can introduce a significant amount of organic pollutants into water bodies, this can include plant material, soil organic matter and by-products from the mining process, this may have accounted for the high value of COD recorded in the mine sites. The COD concentration in all the water samples fall above the FME and WHO standard (80 mg/l and 100 mg/l). According to Eisakhani and Malakahmad (2009) a wide usage of chemical and organic fertilizer and discharge of sewage affect COD level.

Nitrate Content of the Sampled Water

Nitrates are found in several different forms such as ammonia (NH_3), nitrates (NO_3), and nitrites (NO_2). The concentration of nitrate element in the sampled water is presented in Figure 11.

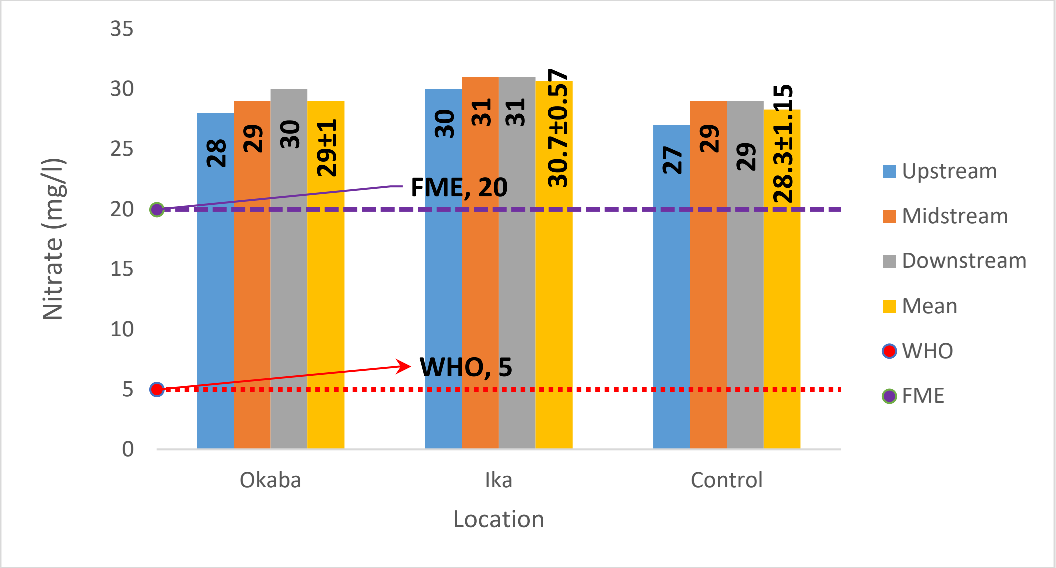

Fig. 11: Nitrate content of the sampled water

Figure 11 shows that the mean Nitrate values recorded in upstream, midstream and downstream samples of water from Okaba, Ika and the control site include; 29±1 mg/l, 30.7±0.57 mg/l and 28.3±1.15 mg/l respectively. The figure also reveals that samples from the mine sites recorded higher amount of nitrate as compared with the control site. This can be attributed to drainage water from mine workings which can carry nitrates if there are natural deposits of nitrate minerals of if the water has come into contact with nitrogen compounds used in the mining process. Also, leaching from waste rock piles and tailings can contain residual nitrates from blasting agents and other mining processes, this could also account for the high values of nitrates recorded. In the same vein, high values observed in the control sites might be attributed to fertilizer use as this has also been reported to bring about elevated nitrate levels in water. The nitrate concentration in surface water is normally low but can reach high levels due to contamination from agricultural runoff, human or animal wastes (CCME, 2009). As shown in Figure 11, the concentration of nitrate element fell above the standard of WHO (5mg/l) and FME (20mg/l) respectively.

Table 1: ANOVA of Spatial Variation in the Physico-chemical characteristics of sampled water

TDS						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14986.66	2	7493.331	0.450361	0.65731	5.14325285
Within Groups	99831	6	16638.5			
Total	114817.7	8				
EC						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	54895.25	2	27447.62	1.146972	0.378591	5.14325285
Within Groups	143583.1	6	23930.52			
Total	198478.3	8				
pH						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.061067	2	0.030533	0.695168	0.535132	5.14325285
Within Groups	0.263533	6	0.043922			
Total	0.3246	8				
Total Hardness						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	241340.4	2	120670.2	1.721431	0.256533	5.14325285
Within Groups	420592.6	6	70098.77			
Total	661933.1	8				
Salinity						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.052867	2	0.026433	22.875	0.001559	5.14325285
Within Groups	0.006933	6	0.001156			
Total	0.0598	8				
Sulphate						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	190.6156	2	95.30778	0.255848	0.782297	5.14325285

Within Groups	2235.107	6	372.5178			
Total	2425.722	8				
BOD						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15919.28	2	7959.64	3175.388	8.41E-10	5.14325285
Within Groups	15.04	6	2.506667			
Total	15934.32	8				
COD						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	27484.88	2	13742.44	203.1303	3.08E-06	5.14325285
Within Groups	405.92	6	67.65333			
Total	27890.8	8				
Nitrate						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.666667	2	4.333333	4.875	0.055286	5.14325285
Within Groups	5.333333	6	0.888889			
Total	14	8				

Spatial Variation of Sampled Parameters

Table 1 shows that for the following parameters; Total Dissolved Solid (F-value=0.450361; F-crit=5.14325285; P-value=0.65731), EC (F-value=1.146972; F-crit=5.14325285; P-value=0.378591), pH (F-value=0.695168; F-crit=5.14325285; P-value=0.535132), Total Hardness (F-value=1.721431; F-crit=5.14325285; P-value=0.256533), Sulphate (F-value=0.255848; F-crit=5.14325285; P-value=0.782297), and Nitrate (F-value=4.875; F-crit=5.14325285; P-value=0.055286) the F-values are much lower than the critical F-value, indicating that the variance between the groups is not significantly larger than the variance within the groups. This suggests that there is no significant difference in TDS, EC, pH, Total hardness, Sulphate and Nitrate concentrations between the mine sites and the control site. Also, the P-values are much higher than the typical significance level of 0.05. this indicates that the observed difference in the concentrations of the parameters are likely due to random chance and are not statistically significant.

Similarly, the table shows that the following parameters; Salinity (F-value=22.875; F-crit=5.14325285; P-value=0.001559), BOD (F-value=3175.388; F-crit=5.14325285; P-value=8.41E-10) and COD (F-value=203.1303; F-crit=5.14325285; P-value=3.08E-06), the F-values are much higher than the critical F-values, indicating that the variance between the groups is much larger than the variance within the groups. This suggests a significant difference in the concentrations of Salinity, BOD and COD between the mine sites and the control site. Also, the P-values are much smaller than the typical significance level of 0.05. this indicates that the observed differences in the concentrations of the parameters are statistically significant and not due to random chance.

Conclusion

The findings of this study reveal that coal mining activities in the Ika-Ogboyaga and Okaba mine sites significantly impact water quality in the coal belt of Kogi East, Nigeria. The water samples from these sites exhibited elevated levels of Salinity, TDS, BOD, COD and nitrates which surpass the permissible limits set by WHO and FME. These deviations indicate potential health hazards and environmental degradation. ANOVA results revealed significant differences in salinity, BOD and COD levels between the mine sites and the control, underscoring the substantial environmental impact of coal mining activities. Therefore, it is imperative to implement effective monitoring, regulation, and remediation measures to protect water quality and public health in the region.

Recommendations

1. ***Regular Monitoring:*** Establish a continuous water quality monitoring program to assess the impact of coal mining activities and ensure compliance with environmental standards.
2. ***Pollution Control Measures:*** Implement stringent pollution control measures at the mining sites to reduce the discharge of contaminants into water bodies. This includes the treatment of acid mine drainage and proper waste management practices.

3. ***Remediation Strategies:*** Develop and implement remediation strategies for contaminated water bodies, such as phytoremediation and constructed wetlands, to restore water quality.
4. ***Public Awareness:*** Conduct awareness campaigns to educate local communities about the risks associated with contaminated water and promote the use of safe water sources.
5. ***Policy Enforcement:*** Strengthen the enforcement of existing environmental regulations and policies related to mining activities. Introduce stricter penalties for non-compliance to deter irresponsible practices.
6. ***Research and Development:*** Encourage further research on innovative and sustainable methods for managing and mitigating the environmental impacts of coal mining.
7. ***Alternative Water Sources:*** Explore and develop alternative water sources for affected communities to ensure access to safe and potable water.
8. ***Community Engagement:*** Involve local communities in decision-making processes related to mining activities and water resource management to ensure their needs and concerns are addressed.

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