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THE IMPACT OF COAL MINING ON WATER AROUND OKOBO AND ODAGBO AREA, ANKPA, NORTH-CENTRAL NIGERIA

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ABSTRACT

This research investigates the environmental impact of coal mining activities on water quality in the Okobo and Odagbo communities of Kogi State, Nigeria. The study highlights the significant coal reserves in the region and the economic importance of coal mining for energy production, compared with the detrimental effects on local water resources. Through systematic sampling and laboratory analysis, findings reveal that water from mining sites exhibits high turbidityrange of 13.79-67.44NTU, elevated levels of total dissolved solids (TDS) of 342mg/l - 1558mg/l, Electrical conductivity of the water 450-892 µS/cm and acidic pH of 2.78-4, compared to WHO standard of 5.0NTU, <300mg/l, <400µS/cm and 6.5-8.5 respectively indicating severe pollution. Heavy metal concentrations in the sample, particularly chromium (0.32mg/l), lead (0.152mg/l), manganese (0.433mg/l), and iron (7.848mg/l), exceed permissible limits set by Nigerian Industrial standards of <0.05mg/l, <0.01, <0.2mg/l and 0.3mg/l respectively, posing risks to human health and local ecosystems. This results underscore the urgent need for effective regulatory measures and sustainable mining practices to mitigate environmental degradation and protect the livelihoods of affected communities. The study advocates for comprehensive strategies involving stakeholders to implement pollution control and rehabilitate impacted areas for sustainable development in the coal mining sector.

Keywords: Coal, Pollution, Okobo, Odagbo, Heavy metals, North-central, Nigeria

INTRODUCTION

Coal mining has become a significant economic activity in various regions of Nigeria, particularly in the North-central part of the country, where it has become an important industry contributing to the region's economic development (Ogunro & Owolabi, 2022). The coal mining industry has played a crucial role in Nigeria's energy production landscape, primarily serving as a source of fuel for electric power generation, and has helped meet the growing energy demands of the Nigerian population (Nwatu & Ezenwa, 2020). However, this industry has also been associated with significant environmental consequences, particularly regarding the quality and quantity of water resources in the affected areas (Effiong, 2023). The Okobo and Odagbo communities in Ankpa, Kogi State, are among the areas heavily impacted by coal mining activities.

According to the Nigerian Bureau of Statistics, Okobo, Odagbo, as well as other villages and towns in Kogi State's Ankpa Local Government Area are fortunate to have well over 380 million tonnes of coal reserves. Millions of Nigerians who currently have poor or no access to power sources may simply rely on this enormous coal resource base to provide their electricity needs. However, these coal deposits have become a curse for the local inhabitants (Florence & Patrick, 2021). Increased coal mining activity spread throughout these areas after the Nigerian government gave the ETA Zuma Company and the Dangote Company PLC licences to mine coal in the areas. The ETA Zuma Group was permitted to mine 100 million tons of coal from, Okobo, and other villages in the Ankpa area, as well as permission to construct coal power plants in nearby Itobe, Kogi state, capable of generating 1,200 MW with Odagboand Okobo serving as coal feeders. The Dangote Cement Company PLC required coal to power their cement production plant.

The extraction and processing of coal can have detrimental impacts on the surrounding water bodies and ecosystems. The mining activities often involve the removal of large quantities of overburden and the exposure of coal seams, which can lead to the release of various pollutants, including heavy metals, acidic drainage, and sediments, into the local water sources (Zhang *et al*., 2022). These contaminants can severely degrade the water quality, rendering it unsuitable for domestic, agricultural, and industrial use. The high turbidity levels in the affected water bodies can also disrupt aquatic ecosystems by hindering photosynthesis and threatening the survival of aquatic life (Khalik *et al*., 2022).

The environmental consequences of coal mining in Nigeria are not limited to water pollution; they can also extend to land degradation, air pollution, and the displacement of local communities (Adigun & Kayode, 2019). The industry's impact on the natural resources and the well-being of the affected populations has become a significant concern for policymakers, environmental advocates, and the local communities themselves (Ukhurebor *et al*., 2021).

Figure 1: Open pit mining at Okobo

Figure 2: Drainage from the mine sites emptying waste water into the Okobo stream

The mining of coal at Okaba (Okobo and Odagbo) in the Ankpa local government area of Kogi State has had a profound and severe impact on the region. Over time, the quality of the water in the area has significantly deteriorated due to the detrimental impact of acid mine drainage (Adetunji *et al*., 2020). This polluted runoff from the coal mining activities is recognized as a major contributor to the widespread water contamination in the region. The elevated levels of acidity and heavy metals in the water sources have had a direct and concerning impact on the health and well-being of the local population and livestock that rely on these water sources for drinking and sustenance (Zhang *et al*., 2022). The pollution of these vital water resources threatens the livelihoods and long-term viability of the communities, who are forced to grapple with the severe environmental and public health consequences of the unregulated coal mining practices in the area (Adigun & Kayode, 2019). Addressing these challenges will require a comprehensive and coordinated approach involving stakeholders from government, industry, and civil society to develop and implement effective mitigation strategies and ensure the sustainable development of the coal mining sector in Nigeria (Isehunwa *et al*., 2006)

This research aims to evaluate the impact of coal mining activities on the water around Ankpa and its environs.

Location

Kogi State's eastern region is where Ankpa is situated. Ankpa is located on Ankpa sheet 269's northwest corner at a scale of 1:25,000. Within latitudes 07° 23' and 07° 54' N and longitudes 7° 20’ as well as 7° 49’ E, a 30-km^2 piece of land is covered by the research area. Farming and commerce are the main activities of the primarily Igala-speaking populace. The coal mining locations are situated in the Kogi State town of Okaba, in the Odagbo and Okobo sub-districts.

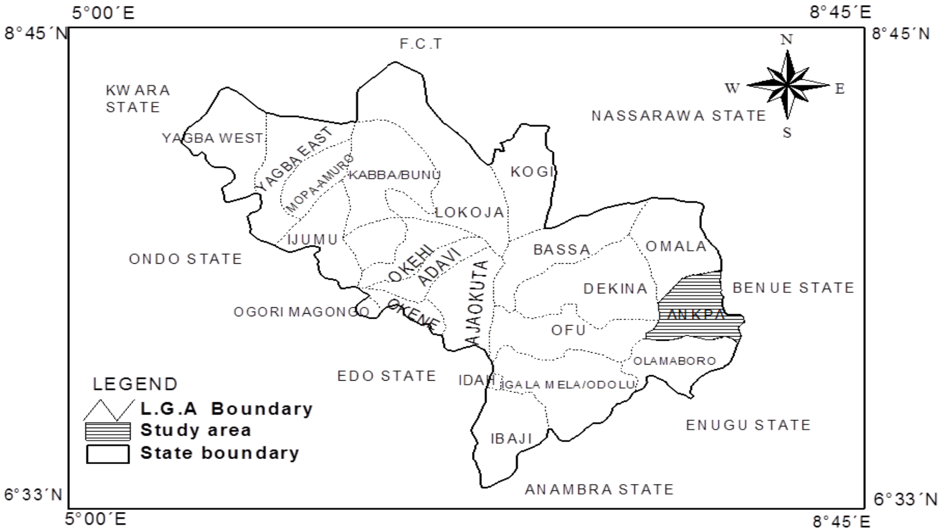

Figure 3: Administrative Map of Kogi State
Source: Kogi State Ministry of Information, 2005

The Geology of the Study Area

The Geology of the area shows that Ankpa falls within the Anambra basin whose genesis has been linked with the development of the Niger Delta Miogeosyncline and the opening of the Benue Trough (Fatoye *et al.*, 2024; Murat, 1972). Stratigraphically, Ankpa comprises of cyclic sedimentary sequence that started in the early Cretaceous time. Marine and fluviatile sediments comprising friable to poorly cemented sands, shales, clays and limestone were deposited, with occasional coal peat and thin discontinuous seams of lignite, Du Preez & Barber (1965). The sediments have been affected by the major Santonian folding and a minor Cenomanian folding and uplift, (Murat 1972). The study area is typical of Ajali Formation or the false bedded sandstone (Figure 4). The Ajali formation consists of thick friable poorly sorted sandstone, typically white in colour but sometimes iron-stained. Ajali sandstone is often overlain by a considerable thickness of red earthly sands, formed by the weathering and feruginisation of the Formation.

Physio-graphically, the Anambra basin can be sub-divided into three main sub-basins (Ladipo, 1986):

i. The shallow and smaller Ankpa sub-basin to the north, which is separated from
ii. The deeper and longer southern Onitsha submarine basement feature, the Nsukka high land and
iii. The south-western extension of the sub-basin constituting the third arm, the Benin flank.

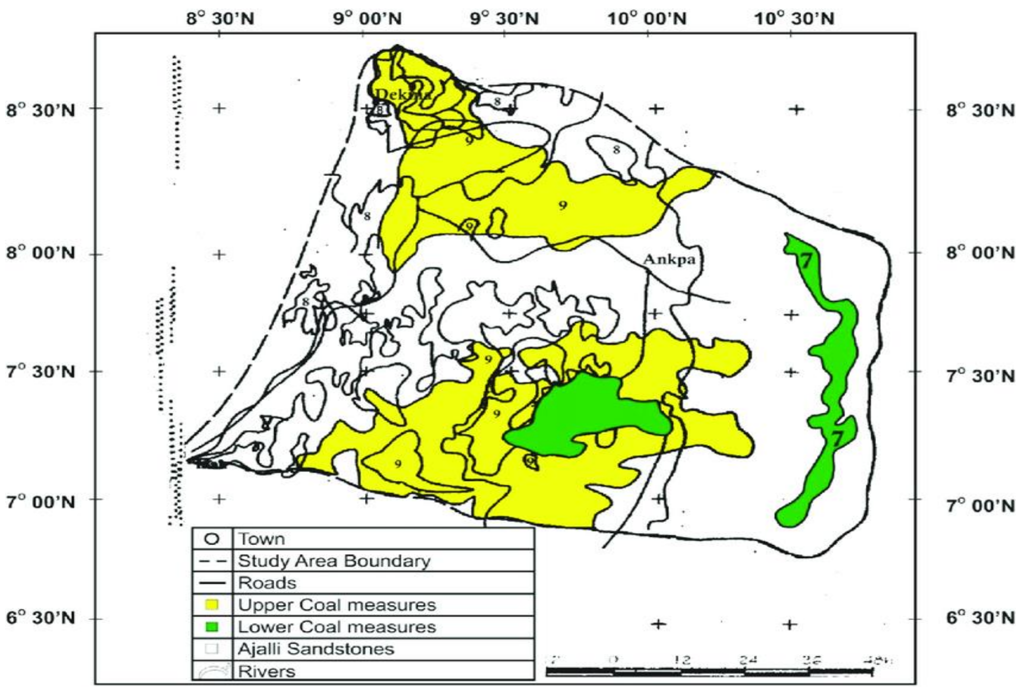

Figure 4: Geological Map of Ankpa Area

MATERIALS AND METHODS

maps and field equipment/ instruments were prepared. Some of the equipment used includes the Global Positioning System (GPS) for taking coordinates,and plastic bottles for storing water samples.

Water samples were collected at mining sites for analyses in the laboratory and labelled accordingly for easy identification. To obtain accurate results and representative data, collection of the water sample was pre-planned and done in a systematic manner rather than just randomly. Thus, prior consultation was carried out before carrying out any sampling to guarantee selecting specimens which would depict the scenario of the area and give a representative sample to carry out the tests for which answers are sought.

The samples were collected from two coal mines belonging to two different coal mining areas (Okobo and Odagbo). The samples were collected from different points around the study area around the mines. For each water sample, 1-litre bottles were used.

Laboratory Analyses

Flame atomic absorption spectrometry (FAAS)

Water samples collected from the field were neatly packaged and transported to National Research Institute for Chemical Technology, (NARICT), Zaria, Nigeria. The methods of analyses and the importance of such are discussed below.

A widely used analytical method for testing more than 60 elements, including sodium, potassium, calcium, magnesium, zinc, and iron, is flame atomic absorption spectrometry (FAAS). It is widely used in variety of industries because it is reliable and simple to use, all of which continue to take advantage of its special advantages.

Liquid samples are inhaled throughout the analysis and delivered into the flame through a spray chamber, which condenses the aspirated liquid into tiny droplets. The sample is dissolved, vaporised, and atomised when the flame is commonly produced using air/acetylene or nitrous oxide/acetylene gases. In order to enable measurement during atomization, hollow cathode lamps emit light that is unique to the element and directs it into the flame. The light path is always properly aligned for analysis thanks to high-performance optics and precision monochromator operation.

Low level concentration of 0. 60, 0. 30, 0. 10, and then 9.00 ppm for Cr, Pb, As, Mn, Fe, and Cu were generated from the standard stock solutions of Cr, Pb, As, Mn, Fe and Cu solutions (1000 mg/L) and then used to produce the measurement point each of the metals. Using AAS - HP MY14470001, the collection of sample solution and the filtrate from the samples were analysed. The sample's heavy metal detection limit was estimated in parts per million (ppm). For such analysis of Cr, Pb, Fe, Mn, As and Cu, relevant cathode lamps containing chromium, iron, lead, manganese, arsenic and copper were utilised. For repeatability, absorbances were also measured in triplicate. All quality checks were closely followed, and only analytical-grade chemicals were utilised.

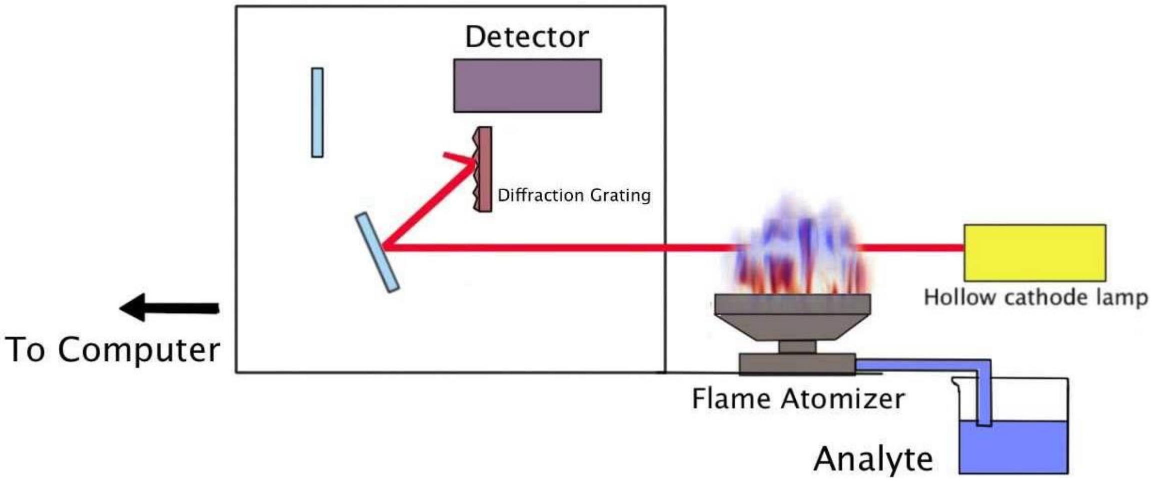

Figure 5: Flame Atomic Absorption Spectrometry

Testing the Electrical Conductivity of Water Sample

The conductance of each water sample was measured using the conductivity meter. Between samples, electrode(s) was washed with clear water and carefully wiped dry. Samples contain debris were allowed to settle. Readings were taken and recorded.

Turbidity

Depending on how much solid matter is present in a suspended condition, water becomes more or less turbid. It measures the water's ability to emit light, and the test is used to determine how well colloidal matter is removed from waste streams.

Total Dissolved Solids (TDS)

Numerous inorganics and some organic minerals or salts, including potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulphates, and others, can be dissolved by water. These minerals give the water an undesirable flavour and muted colour. This is a crucial variable while using water. Water with a high TDS rating is one that has a high mineral content. Total dissolved solids (TDS), also referred as parts per million (PPM), are quantified as a volume of water calculated with the unit milligrammes per litre (mg/L) (ppm).

pH of Water

The pH of the water samples was determined using a pH metre, which consists of a pH-sensitive electrode (often transparent glass) as well as a reference electrode. When assessing the acid-base balance of water, PH is a key factor. Additionally, it shows if the water is acidic or alkaline.

Chloride (Cl-)

Silver nitrate is used for titration in the Mohr Method; the normalcy is 0.0141. This is equivalent to 1 mg of chloride is present in 1 mL of solution, or 0.0141. The solution of silver

nitrate is standardized compared to a normal sodium chloride solution (NaCl). As part of the titration,
The precipitation of chloride ions.
Ag^{+}+Cl- <=> AgCl (Ksp=31010; Solubility Product Constant)
The endpoint is visualised with the addition of the indicator (potassium chromate), revealing the presence of surplus silver ions Solubility result of silver chromate in the presence of too much silver ions surpassed, a reddish-brown precipitate result. This stage is viewed as proof that all chloride exists. Only extra silver ions having reacted to chromate ions after all other ions have been consumed:
$2Ag^{+} + CrO_4^{2-}$<=> Ag_2CrO_4
Instruments: a pipette, a conical flask, a burette, and a measuring cylinder
Reagents: Standard silver nitrate for titration and potassium chromate indicator solution.

Sulphate
100 ml of the sample was transferred into 250 ml Flask. The mixture was placed on a magnetic stirrer and 5 mL of the conditioning reagent was added to mix. A teaspoon of crystals of barium chloride was added and timing was started right away. It was stirred for exactly one minute at a consistent speed.
After stirring, a portion of the mixture was placed into the photometer's absorption cell, and for four minutes, its turbidity was measured at 30-second intervals.
Typically, the turbidity reaches a peak within 2 minutes and then stabilises for the next three to ten minutes. So, the reading while the turbidity is at its highest within the first four minutes was taken.
Calculation:
SO_4 in mL=(mg of $BaSO_4$ x411.6)/(mLof Sample)

Hardness
The most common method to determine hardness is colorimetric titration using an EDTA solution. A titration entails gradually adding titrant solution and indicator solution to a sample water until the sample's colour changes. Using a burette as well as other liquid hardness test kit, the specimens were determined by titrating for total hardness.

RESULTS AND DISCUSSION
Presented below are laboratory analyses results for water samples analysed in the laboratory. Physicochemical analysis of water samples

Table 1: Results of physicochemical analyses of water

SN	SAMPLE	pH	EC(µS/cm)	TDS (mg/l)	HARD. (mg/l)	TURB. (NTU)	SO42- (mg/l)	Cl- (mg/l)
1	OKBW1	2.78	892	1522.1	632	34.1	48	67
2	OKBW2	4.38	687	800.23	483	54	66.4	179.94
3	OKBW3	2.93	750	1200.12	602	23.6	12.12	167.95
4	OKBW4	3.34	810	1023.06	481	19.23	34.76	339.89
5	OKBW5	4.70	611	989.67	367	29.04	43.9	58.23
6	OKBW6	3.03	900	1067.54	513	46.16	62.01	267.01
7	OKBW7	4.0	598	485.87	508	32.09	28.53	135.21
8	OKBW8	3.73	836	976	522	67.44	26.79	72.69
9	OKBW9	6.43	475	342.5	354	18.1	0.04	142
10	OKBW10	4.0	450	482.9	200	13.79	14.5	83.61
11	ODGW1	3.51	734	1558.11	531	47.8	32.11	54.78
12	ODGW2	4.21	697	927.54	367	32.41	10.94	68.32
13	ODGW3	3.99	768	879.4	293	51.2	78.21	32.56
14	ODGW4	4.12	657	671.98	347	26.7	39.61	78.32
15	ODGW5	3.82	903	1478	516	44	53.72	38.62
16	ODGW6	3.89	514	893.33	287	38.47	119	68.22
17	ODGW7	4.11	859	1082.44	429	29.51	134.11	342
18	ODGW8	4.32	785	1240.59	532	32.04	86.04	43.58
19	ANKW1	6.79	170.2	117.98	79	8.88	0.4	12
20	ANKW2	7.2	195.3	209.67	119	7.10	0	25.5

Heavy metal analysis of water samples
Table 2: Results of heavy metals tested in the laboratory on the water samples is presented below

SN	SAMPLE	Cr^{6+}	Pb^{2+}	As	Mn^{2+}	Fe^{2+}	Cu^{2+}
1	OKBW1	0.29	0.13	0	0.4	15	0.88
2	OKBW2	0.12	0.17	0.02	0.7	7.55	0.69
3	OKBW3	0.01	0.14	0.01	0.32	13.02	0.41
4	OKBW4	1.21	0.27	0.03	0.43	9.134	1.02
5	OKBW5	0.08	0.08	0.01	0.61	6.49	0.91
6	OKBW6	0.1	0.02	0	0.04	10.77	0.07
7	OKBW7	1.21	0.3	0	0.09	5.98	0.09
8	OKBW8	0.08	0.04	0.01	0.19	6.8	0.4
9	OKBW9	0.01	0.01	0	0.01	3.97	0
10	OKBW10	0	0	0	0	2.67	0.01
11	ODGW1	0.47	0.35	0.02	0.2	9.59	0.02
12	ODGW2	0.33	0.18	0	0.02	9.04	0
13	ODGW3	0.63	0.22	0.01	1.94	14.09	1.73

14	ODGW4	0.34	0.26	0.01	2.36	16.25	1.83
15	ODGW5	0.02	0.03	0.01	0.07	2.99	0.1
16	ODGW6	1.14	0.18	0.03	0.29	8.61	0.86
17	ODGW7	0.88	0.38	0.02	0.1	4.53	0.05
18	ODGW8	0.48	0.26	0.06	0.9	9.33	0.65
19	ANKW1	0	0.01	0	0	0.12	0
20	ANKW2	0	0.01	0	0	1.03	0
	MEAN	0.37	0.152	0.012	0.4335	7.8482	0.486

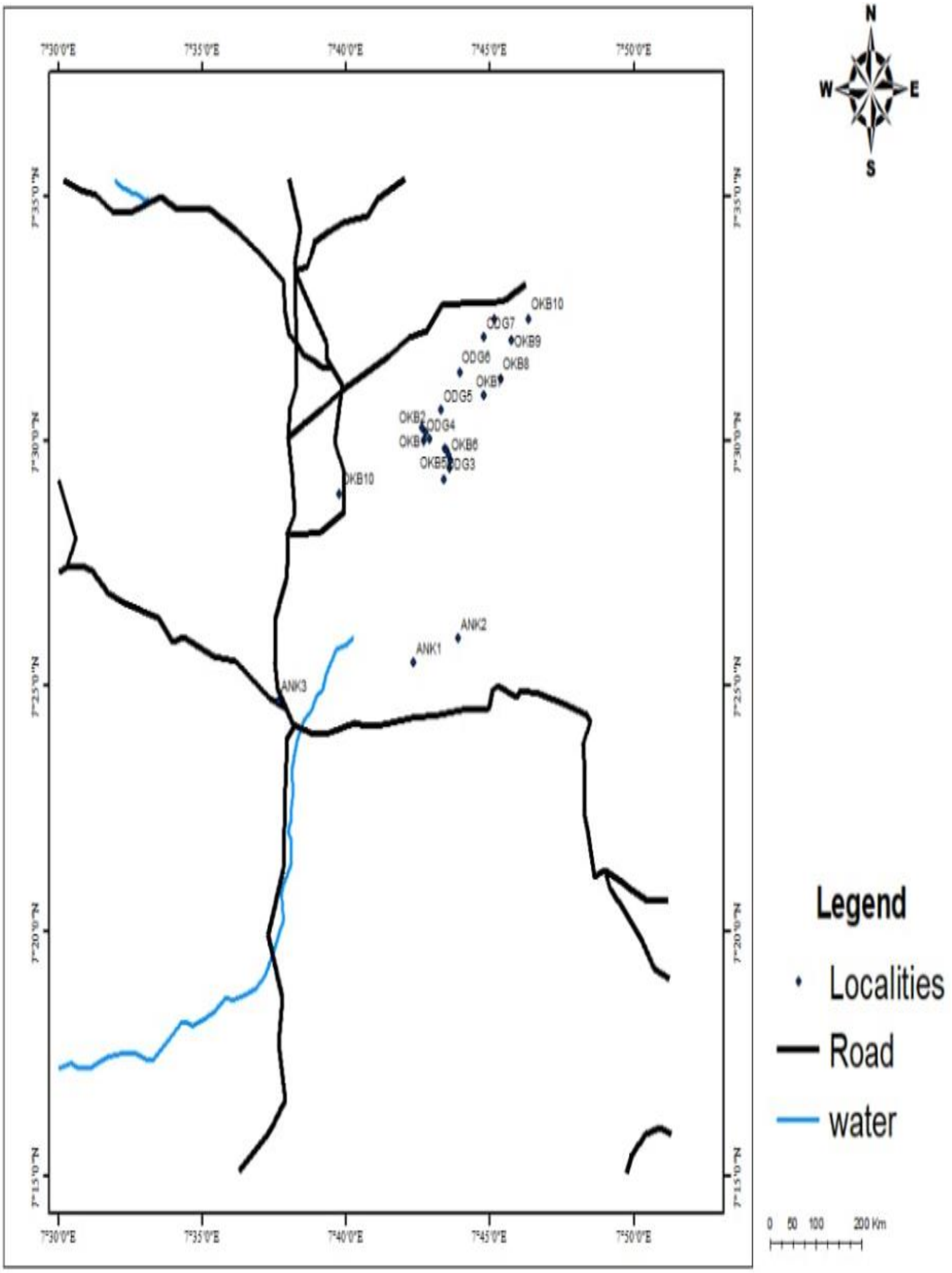

Figure 6: Map of the study area showing mining and sample collection sites

Discussion

Physicochemical parameters

i. *Turbidity*: Depending on how much solid matter is present in a suspended condition, water becomes more or less turbid. It measures the water's ability to emit light, and the test is used to determine how well colloidal matter is removed from waste streams. In comparison to the WHO-recommended limit of 5.00 NTU, the turbidity values at Okobo and Odagbo mining areas ranges from 13.79 to 67.44 while Ankpa town where mining activities is not taking place have turbidity value ranging from 2.5 to 3.2 (Table 1). These results shows that water bodies around the coal mining areas are highly turbid while the results from Ankpa town falls within the WHO recommended limit for turbidity. This is a pointer to the effect coal mining in the study area.

ii. *Total dissolved solids (TDS):* Numerous inorganics and some organic minerals or salts, including potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulphates, and others, can be dissolved by water. These minerals give water an undesirable flavour and muted colour. This is a crucial variable while using water. Water with a high TDS rating is one that has a high mineral content. According to the WHO recommended standard for TDS level for drinking purposes as shown in Table 3 below, results from the Laboratory analysis of the water samples (Table 1) shows that Ankpa town with TDS values ranging from 117.98mg/l to 209.67mg/l falls within the excellent water rating while Okobo and Odagbo with TDS values ranging from 342mg/l to 1558mg/l falls within good to unacceptable range. This is a clear indication that mining activities is impacting on the water in the host communities.

Table 3: WHO recommended TDS range for drinking water

Level of TDS (milligrams per litre	Rating
Less than 300	Excellent
300 – 600	Good
600 – 900	Faith
900 – 1,200	Poor
Above 1,200	Unacceptable

iii. *Electrical conductivity (EC):* Pure water acts more as an insulator than a conductor of electrical current. The conductivity of water's electricity is improved by an increase in ions. The electrical conductivity of a liquid is typically a function of the dissolved solids content. A solution's ability to transport current through its ionic mechanism is really measured by electrical conductivity (EC). WHO guidelines state that the EC value should not be higher than 400 S/cm. The results of the current experiment showed that the EC value ranged from 170.2 to 195.3 S/cm in Ankpa town while EC value for Okobo and Odagbo ranged from 450 to 892 S/cm. These findings show unequivocally that water in the research area is significantly ionised compared to water in Ankpa where mining activities is not taking place and has a low degree of ionic concentration activity because of small soluble solids.

iv. *pH of water*: When assessing the acid-base balance of water, PH is a key factor. Additionally, it shows if the water is acidic or alkaline. The maximum pH allowed range, according to WHO, is between 6.5 and 8.5. The current investigation's ranges fell between 6.79 and 7.2 in Ankpa town which is within WHO criteria while pH values for Okobo and Odagbo ranges from 2.78 to 4.0 showing that the water is acidic. The total finding suggests that the water source at Okobo and Odagbo is not acceptable. The amount of dissolved carbon dioxide (CO_2), which produces carbonic acid in water, essentially determines the pH of a solution.

v. *Chloride (Cl):* Chloride is mostly created when hydrochloric acid salts, such as table salt (NaCl) and NaCO2, dissolve and are then added to other substances including sea water, sewage, and industrial waste. Chloride concentrations in surface water bodies are frequently lower than those in subsurface water. It is crucial for the human body's metabolism function as well as other critical physiological processes. High chloride concentrations injure growing plants as well as metallic structures and pipes. The content of chloride should not be more than 250 mg/l, as per WHO guidelines. The chloride level in Ankpa town is between the range of 12 to 25mg/l, while the value at Okobo and Odagbo Communities ranges from 265 to 372mg/l. (Table 1)

vi. Sulphate: Nearly all bodies of water contain large amounts of sulphate, which is mostly produced when sulfuric acid salts dissolve. Sulphate concentrations may be high due to mine drainage, pyrite oxidation, and other factors(Sahoo, 2010). Natural water contains between a few and several hundred mg/liter of sulphate, although there have been no significant adverse effects on human health noted. The greatest recommended level of sulphate in drinking water has been determined by the WHO to be 250 mg/l. The mean value of SO4 in the study area ranges from 0.4 to 134mg/l (Table 1) around the study area and Ankpa town. The findings show that the sulphate concentration in Odagbo, Okobo and Ankpa was below the upper limit and may not be detrimental to humans.

v. *Hardness*: Calcium carbonate concentrations in water range from 60 mg/l to 180 mg/l, with 60 mg/l to 120 mg/l being moderately hard, 120 mg/l to 180 mg/l being hard, and more than 180 mg/l being much harder. Results from analysed water samples obtained from coal mining sites at Okobo and Odagbo ranges from 200mg/l to 632mg/l which falls between hard and very hard range while results from Ankpa town ranges from 79 to 119 which falls within the WHO value for hardness in water.

Heavy Metals

i. Chromium Cr^{6+} Pollution in Water

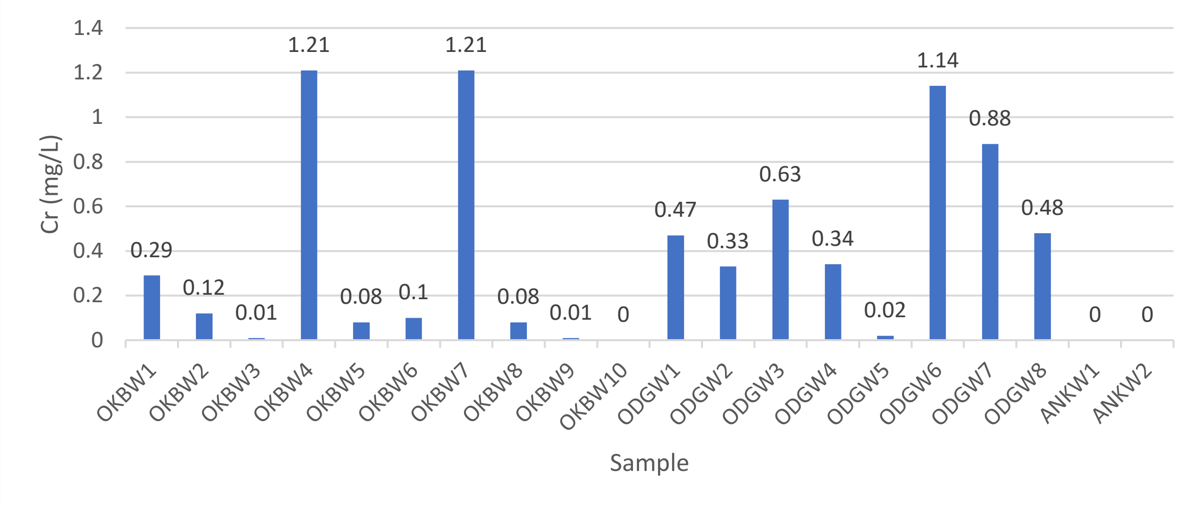

Figure 7: Chromium concentration in collected surface water samples

Chromium is typically a key trace element required for the growth of both plants and animals. Except when it is in its hexavalent state, it is essentially non-toxic. Chromium (Cr^{6+}) in drinking water is permitted up to 0.05 mg/L (Nigerian Industrial Standards (NIS), 2007). The considerable presence of chromium in the examined samples further indicates the potential existence of a coal deposit in a clay environment (Finkelman, 1993).

According to the examined samples, the content of chromium in the water samples ranges from 0.02 to 1.21 mg/L (Table 2 and Figure 7). The fact that no chromium was detected in the control water samples (ANKW1&2) may be related to the distance between the sampling location and the mining sites.

ii. Lead (Pb^{2+}) Pollution in Water

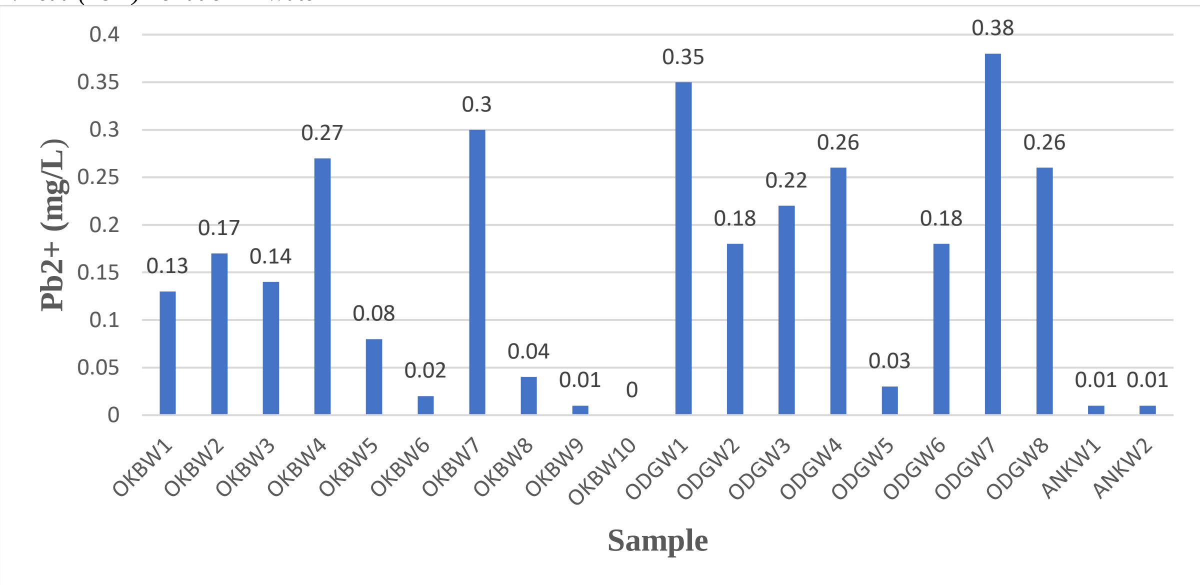

Figure 8: Lead concentration in collected surface water samples

Galena, which is mostly lead (II) sulphide (PbS), is a trace element of lead that can be found in coal (Swaine, 1983). Weathering and mining have an impact on how it decomposes into water bodies, which causes pollution (Keim & Markl, 2015).

Lead in drinking water concentrations above 0.01 mg/L is dangerous to human health (WHO, 2012). However, legal lead consumption limits for aquatic and other terrestrial animals differ in diverse amounts (Environmental Protection Agency (EPA), 2013; Nigerian Industrial Standards (NIS), 2007). The average lead concentration in the water samples analysed was 0.152 mg/L, exceeding the legal limit of 0.01 mg/L (see Table 2 and Figure 8), indicating that drinking this water could result in lead poisoning-related health problems such dullness and kidney impairment. This supports a previous study that demonstrates the lead concentration in the coal deposits in Okobo and Odagbo which is also detrimental to both plants and animals (Okorie *et al*, 2014). However, neither the control sample of ANKW1&2 nor some sites contained any residues of lead.

iii. Arsenic

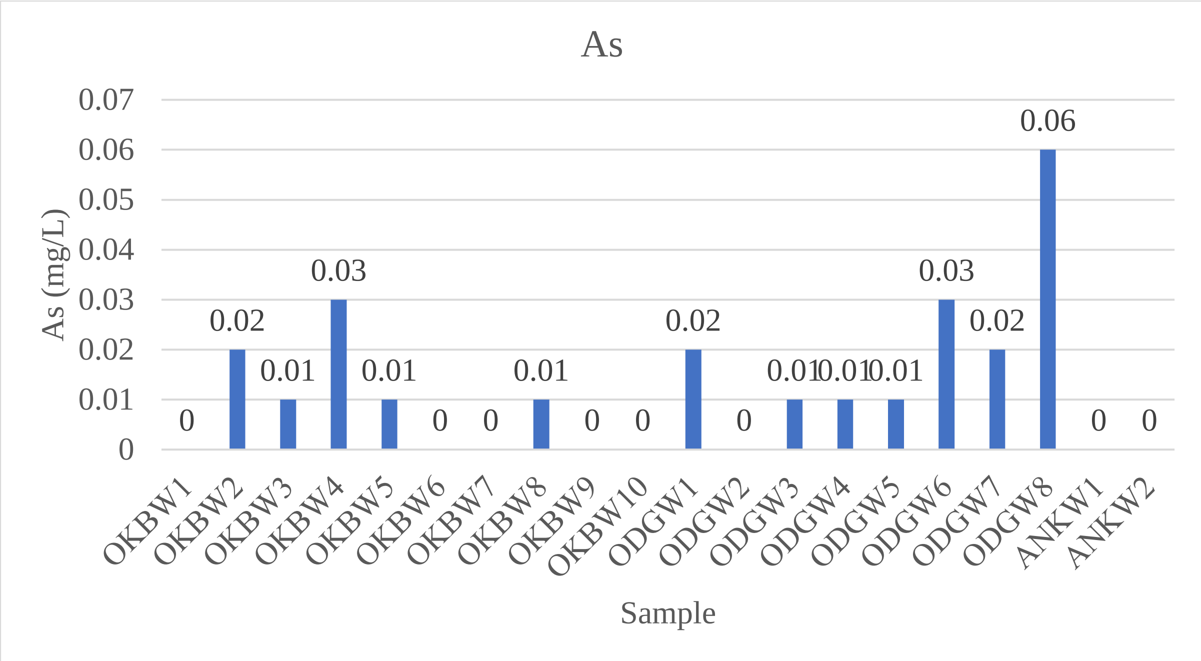

Figure 9: Arsenic concentration in collected surface water samples

People who live close to an emission source should be especially concerned about arsenic-containing particulate matter (PM) emissions. According to Martin (2014), group 1 carcinogens arsenic and inorganic arsenic compounds are linked to malignancies of the lung, bladder, kidney, skin, liver, and prostate. It should be noted that inhalation is only considered a minor exposure mechanism for inorganic arsenic compounds in the general population, and that ingestion is thought to be the main exposure pathway (Martin, 2014). However, there is a higher risk of extra exposure for people who live close to an arsenic emission source because they may breathe in particles that are polluted with arsenic (Carrizales, 2006).

The study's findings demonstrate that arsenic has no adverse effects on the water body. The analysed sample's content ranges between 0 to 0.06 mg/l, which is close within the 0.05 mg/L WHO acceptable limit.

iv. Manganese (Mn^{2+}) Pollution in Water

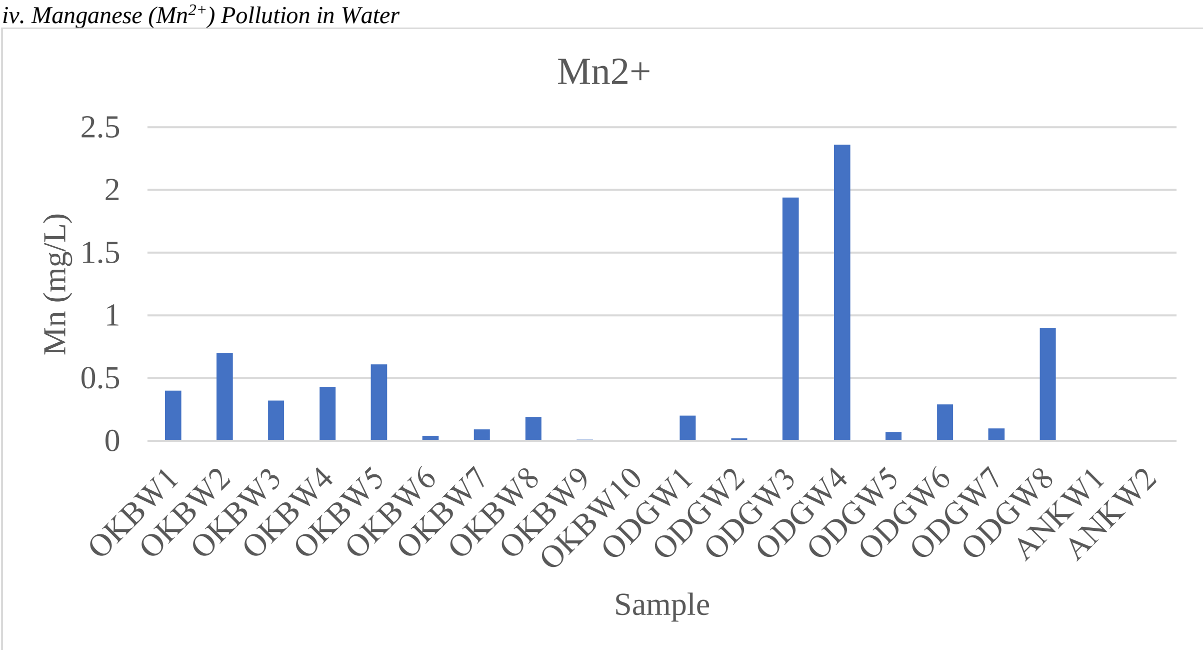

Figure 10: Manganese concentration in collected surface water samples

Manganese is a trace mineral that the body contains in very small amounts. The liver, kidneys, pancreas, and bones are where it is most commonly found. Manganese aids in the formation of bones, connective tissue, blood clotting components, and sex hormones in the body. Additionally, it contributes to the metabolism of fats and carbohydrates, calcium levels, and blood sugar control. Additionally,

manganese is required for healthy nerve and brain function (Kazi, 2008)
However, aberrant manganese levels in the brain, particularly in the basal ganglia, have been linked to neurological conditions including Parkinson's disease. Neurodevelopment may be impacted by high or low levels of manganese exposure throughout early life. High manganese levels are also linked to subpar cognitive function in school-aged children. Menezes-Filho (2014).
The World Health Organization (WHO), 2012 and the Nigerian Industrial Standards (NIS), 2007 both claim that neurological diseases are associated with manganese concentration in drinking water that are more than 0.2 mg/L. The average manganese concentration in the water samples from the coal mines in Okobo and Odagbo is 0.4335mg/L. This is above the allowable limit for drinking (Table 2). In the past, it has been discovered that Okobo and Odagbo coal contain manganese (Adedosu *et al*., 2007). However, there were no evidence of manganese in the water samples from OKBW10 and the two control samples (ANKW1&2), suggesting that water taken from a position far from coal mining sites—about 3 km away—may be free of chemical substances that could leak into water bodies from the coal deposit.
Although manganese has been detected in numerous coal samples from throughout the world, studies of the mineral abundance of manganese in coal are relatively difficult because it is primarily found in clay (Swaine, 1983). The quantities of manganese found in test samples, however, could be explained by signs of potential clay in the deposit.

v. Iron (Fe^{2+}) Pollution in Water

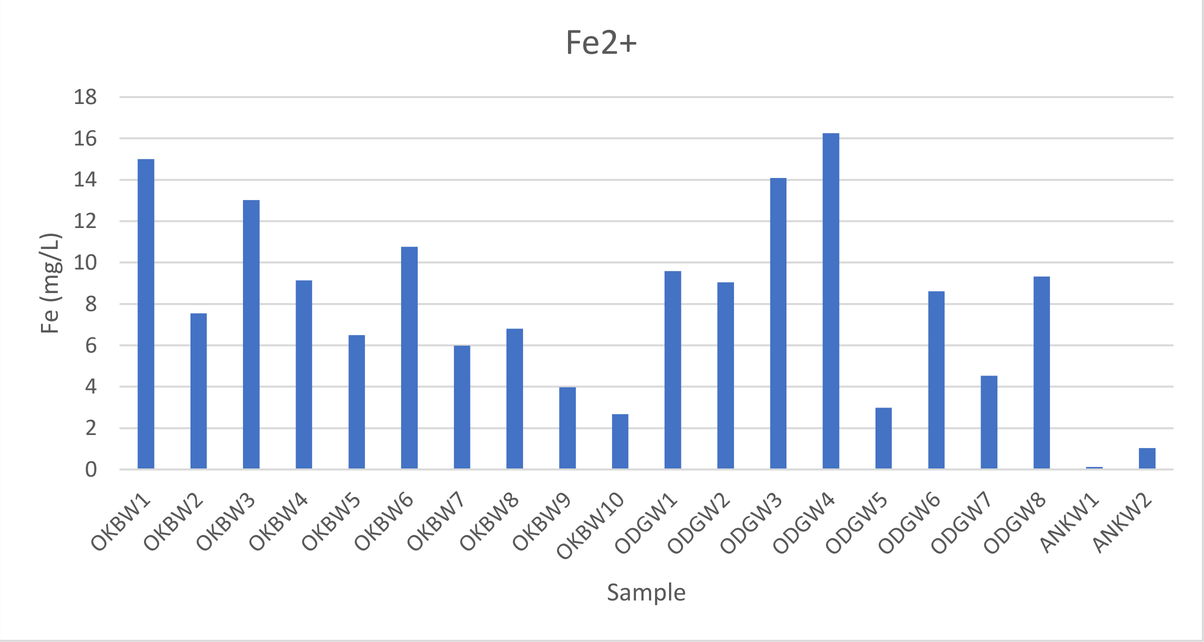

Figure 11: Iron concentration in collected surface water samples

Iron (II) is more soluble than iron (III), it can be released into solution when an electron lands on an iron atom at a mineral surface, which has a significant impact on the chemistry and mineralogy of soils and surface waters.
When it comes to the mobility of toxins in the environment, iron reduction is very crucial. The alteration may also have an impact on the spread of some contaminants because many of them, most especially uranium, bind to iron. While iron with bigger particles can be employed to trap contaminants in filter systems, a soluble iron form will aid in spreading the contamination.
According to international standards, the maximum amount of iron in drinking water is 0.3 mg/L (Dietrich, 2015; Nigerian Industrial Standards (NIS), 2007; WHO, 2003).The range of iron concentration in the surface water under examination is 0.03-16.25 mg/L, with a mean value of 7.8482 mg/L, indicating that the research area's surface water has a high iron content (Table 2). The fact that ODGW4 has the greatest iron concentration—16.25 mg/L—could be related to its close proximity to the mining site. When taken, drinking water with a high percentage of iron can cause major health issues like cancer and liver difficulties (World Health Organization (WHO), 2003). Iron concentrations in the control samples are below the global permissible range (0.12 and 0.03).

vi. Copper (Cu^{2+}) Pollution in Water

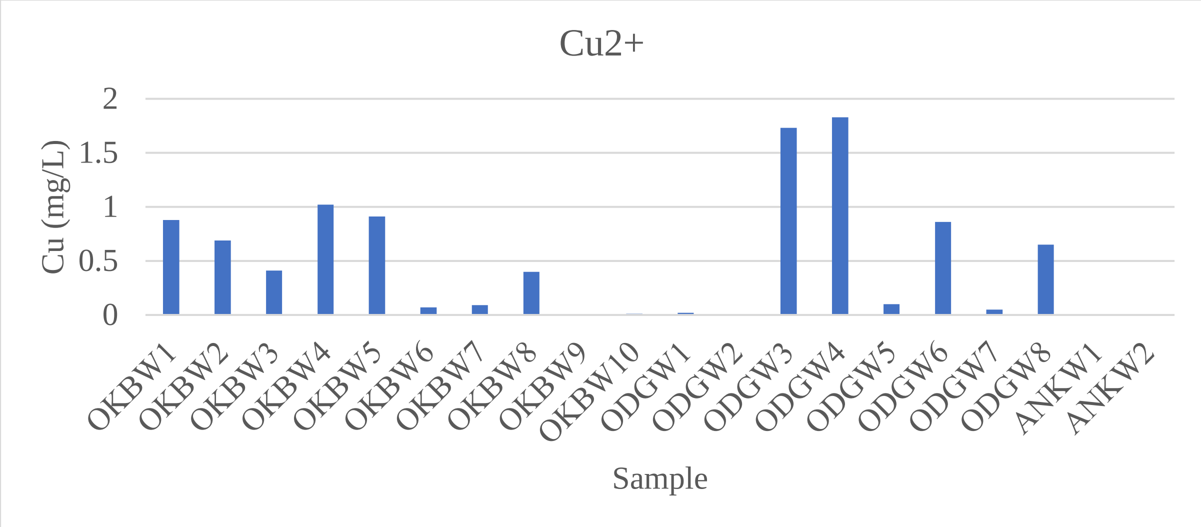

Figure 12: Copper concentration in collected surface water samples

Copper concentrations in water samples from OKBW5 and ODGW3&4 are beyond the upper limit permitted for drinking water (Nigerian Industrial Standards (NIS), 2007) (Table 2). The concentration of copper in additional surface water samples taken from the stream in the mining regions and the control water samples (ANKW 1&2) is below the permitted limits for human consumption (WHO, 2012).
Chalcopyrite ($CuFeS_2$) is often the copper mineral that is most likely to be present in coal. In addition to numerous other coal deposits around the world, chalcopyrite has been detected in coal from the UK (Leicestershire) and Belgium (Swaine, 1983). The water body in the two communities of Okobo and Odagbo is not negatively polluted by copper, according to the average concentration of copper in test samples of 0.486 mg/L. (Adigun & Kayode, 2019; Ameh & Ojonimi, 2021)

CONCLUSION

The sole streams around Okobo and Odagbo, which served as their primary water source, have been contaminated by mining. The stream's turbidity prevents photosynthesis from taking place, which inevitably results in the demise of the local plant and animal life. High concentrations of heavy metals, particularly iron (Fe), have been found in the available water supply in the research region. These concentrations are currently dangerous for human consumption and may increase over time. Health, economic, and social wellness, as well as life quality, all depend on access to clean water.
Carefully isolating the water runoff from mine workings can reduce water pollution. Technology should be utilised to purify the waste water, and the surplus dust can be reduced by sprinkling treated water—which can be used in coal-fired power plants—onto the roads. The government should make sure that the corporations involved implement land reclamation policies, and enforcement should be made sure when these companies don't.

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