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Determination of Physicochemical Parameters of Water and Soil Samples around Owukpa Coal Mine, Benue State Nigeria

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ABSTRACT

This research assessed the physicochemical parameters of water and soil samples in the vicinity of Owukpa Coal Mine, Benue State Nigeria. Surface water samples were obtained from the two (2) main sources of water for the people of Eyari and Anchimodo in Owukpa as well as control samples from River Okpokwu. Six Soil samples were obtained from six different locations around the mining site and Two (2) control samples were collected 7 km away from the mining site. Results indicated that the water bodies are acidic as the pH values 6.20, 4.70 and 4.65 for Anchimodo, Eyari and control samples respectively fell below the recommended limit of 8.00 by W.H.O. Other physicochemical parameters measured in the water samples were generally far less than the concentrations set by W.H.O. The concentration of the soil physicochemical parameters generally fell below the recommended values by W.H.O. However, the values of magnesium (83.0 and 195 mg/kg for soil and control soil samples respectively) were much more than the concentration (50.0 mg/kg) given by WHO. The high level of acidity observed in the water sample is a source of concern; Government and policy makers should take some proper steps by ensuring that mining policy is up to date and applied accordingly in the mining site.

Keywords: Coal mine, Owukpa, Physicochemical parameters, Soil, Water

INTRODUCTION

Coal mining is the act, process, or industry of extracting coal from the earth (Collins Dictionary, 2020). The mining sector worldwide is greatly important for income generation, employment, economic growth, development and competitive advantage (Sikakwe *et al.*, 2015). The coal industries also bring numerous jobs, increase in some household incomes, and raises revenue for the government which is significant for regional development (Li, 2016). Mining, however, poses major threats and hazards that can degrade the natural environment. Mining operations alter a site's soil and water quality thereby disrupting the ecological balance, natural landscapes, agricultural lands, plantations and vegetation as well as the economic food and tree crops (Buba *et* al., 2017). Mining also affects fresh water through heavy use of water in processing ore, and through water pollution from discharged mine effluent and seepage from tailing and waste rock impoundments (Ola *et al.*, 2019). Soil degradation resulting from generated mine wastes during exploitation activities results in low pH, solubility of heavy metals, depleted organic matter, nutrients, reduced biological activities, poor physical structure, texture, drainage and porosity (Oladipo *et al.*, 2013). The change in the soil structures and soil chemistry as a result of mining activities in turn pollutes the surrounding water.

The quantity and the quality of water are equally important. Water is always referred to as a universal solvent because it can dissolve many types of substances, but humans require water that contains fewer impurities. The major categories of impurities in water are micro-organism, pyrogens, dissolved inorganic salts, dissolved organic compounds, suspended particles and dissolved gasses. Generally, the quality of drinking water is determined based on the appearance, taste, color and odor of the water (Ola *et al.*, 2019). Better quality of water is described by its physical, chemical and biological characteristics. Thus, estimation of quality of water is extremely important for proper assessment of the associated hazards.

The aim of this study was to determine physicochemical parameters such as temperature, colour, turbidity, pH, conductivity, total dissolved solid, total suspended solids, calcium, magnesium, chloride, sulphate, fluoride, alkalinity, nitrate and, phosphate in water samples and also determine physicochemical parameters such as pH, moisture content, electrical conductivity, bulk density, nitrogen, Phosphorus, cation exchange capacity calcium, and essential elements such as magnesium, sodium, potassium in soil samples from Owukpa Coal Mine. Assessment of water quality and soil is extremely important for proper the wellbeing of the end users. Therefore this study would ascertain the level of contamination or otherwise of the environmental samples.

MATERIALS AND METHODS

Materials

Instrumental analysis was carried out by the uses of UV spectrophotometer (SM, 7504: Uniscope), Atomic Absorption Spectrophotometer. pH meter (pH 10A; Ecosense) thermometer, turbidity meter (20008: Micro-TPI) TDS/COND meter (850039: Sper Scientific), Analytical weighing balance (DT 300A: EEC); Ion Selective Electrode (Orion Model 25100).

Study Area

The study area is located within latitudes 6° 30' and 7° 26'N and longitudes 7° 10' and 7° 30'E. Owukpa is a district situated in Ogbadibo Local Government Area, Benue State Nigeria. It shares boundary with Obollo Eke in Udenu Local Government Area, Enugu State while Orokam borders Owukpa in the West and covers an area of about 1286 km^2. The study area has a tropical sub-humid climate, with two distinct seasons, namely wet and dry season. The wet season lasts for seven months, starting from April to October. The annual rainfall total ranges from (1,200 to 1500) mm. Temperatures are generally very high during the day, particularly in March and April. The region records average maximum and minimum daily temperatures of 35 °C and 21 °C in summer and 37 °C and 16 °C in winter, respectively. The meta-sediments are dominantly sand stone, but also contain shale, siltstone, limestone and quartzite. The residents of the study area depend solely on water from the nearby rivers, streams and well for domestic uses such as drinking, bathing, washing etc. and for irrigation purpose in the dry season and rain water in the rainy season.

Figure 1: The mining site and sampling points

Water sample collection

Six water samples were collected from the sites where the residents of the study area get their drinking water. The samples were obtained from the following site during the field survey for physicochemical analysis; Eyari, Anchimodo and two control samples were collected from River Okpokwu. Clean PVC plastic bottles properly labeled with the identification of the sampling site were used in collecting the water samples. This is to avoid adsorption of metal from the samples to the wall of glass containers or interference of metals from metallic containers.

Soil sample collection and treartment

Six Soil samples were collected from six different locations around the mining site at a depth (25 cm). Two control samples were collected 7 km away from the mining site. A total of eight soil samples were collected. Polyethylene bags were used for the collection of the soil samples from various sample locations. Samples were kept in airtight polythene bags and labeled accordingly. Samples were air dried for 3 days. The air dried samples were crushed and sieved using mesh size of < 2 mm and stored for digestion. The samples were coded as shown in the Table 1.

Digestion of Water Samples

The digestion of the water sample was carried out by the method described by Eneji *et al.* (2017) without modification. A 200 mL of water sample was measured and 5.0 mL of concentrated HNO_3 (73 % w/w) was added, shaken and heated to about 110 °C in a conical flask until the water reduced to 10.0 mL. Another 5.00 mL of Conc. HNO_3 was added and further concentrated to solubilise particulate matter content until it became clear. The sample was allowed to cool; thereafter, a little quantity of distilled water was added and filtered through a filter paper. The filtrate was made up to mark in a 100 mL volumetric flask then transferred to plastic sample bottle and covered

Digestion of Soil Samples

The digestion of the soil sample was carried out by the process described by Adedosu and Adewuyi (2013). Exactly 1.00 g of dried and sieved soil samples was weighed into a 25.0 mL conical flask. 12.0 mL of freshly prepared aqua – reqia (3 mL HNO_3 + 9 mL HCl) was added. The flask was covered with a filter paper to enable the digestion to take place under constant volume. The content was heated for 1 hour on the medium heat of a hot plate. The mixture was allowed to cool and then filtered through a filter paper into a 50.0 mL standard volumetric flask. The filtrate was diluted to 50 mL with distilled water and then transferred to plastic sample bottle and covered.

Table 1: Sample type, Location, Description and Code

S/No	Sample type	Samplelocation	Sample Description	Sample code
1	Surface Water	Eyari	Eyari Upper Stream	EUS
2	Surface Water	Eyari	Eyari Mid Stream	EMS
3	Surface Water	Eyari	Eyari Lower Stream	ELS
4	Surface Water	Anchimodo	Anchimodo Upper Stream	AUS
5	Surface Water	Achimodo	Anchimodo Mid Stream	AMS
6	Surface Water	Anchimodo	Anchimodo Lower Stream	ALS
7	Control sample	Okpokwu	Okpokwu North	OCS_1
8	Control Sample	Okpokwu	Okpokwu South	OCS_2
9	Soil Sample	Mining Site 1	Soil Sample 1	SAS_1
10	Soil Sample	Mining Site 2	Soil Sample 2	SAS_2
11	Soil Sample	Mining Site 3	Soil Sample 3	SAS_3
12	Soil Sample	Mining Site 4	Soil Sample 4	SAS_4
13	Soil Sample	Mining Site 5	Soil Sample 5	SAS_5
14	Soil Sample	Mining Site 6	Soil Sample 6	SAS_6
15	Control Sample	7 km Away	Soil control Sample 1	SCS_1
16	Control Sample	7 km Away	Soil control Sample 2	SCS_2

Analytical Procedures for Water Analysis

pH: The pH of the water samples was determined after the pH meter used in this study was calibrated with buffer solutions of pH 4 and 7 respectively. The electrode was then rinsed and dried before taking measurement. The pH of the water samples was measured by inserting the electrode directly into a 10 mL solution which was agitated with a stirrer and allowed to stand for 2 minutes, after which the pH was recorded.

Temperature: The temperature of the water sample was determined using Mercury-in-glass Thermometer (thermometric Method).

Total Dissolved Solids: Total dissolved solid in the water samples were measured using electrometric method (APHA 2004). The equipment was calibrated with 1413.00 µS/cm 0.0100 M KCl solution and the TDS electrode of the meter was rinsed thoroughly with distilled water. Exactly 100 mL of the sample was poured into a beaker and the electrode was dipped into the sample. The equipment was selected to read TDS and the OK button was pressed. The reading was taken after it became stabilized.

Electrical Conductivity: Electrical conductivity of the water samples were measured using electrometric method (APHA 2004). The equipment was calibrated with 1413.00 µS/cm 0.0100 M KCl solution and the EC electrode of the meter was rinsed thoroughly with distilled water. Exactly 100 mL of the sample was poured into a beaker and the electrode was dipped into the sample. The equipment was selected to read EC and the OK button was pressed. The reading was taken after it became stabilized.

Turbidity: The turbidity of the water sample was determined using electrometric method. The power sources was switched on and the instrument allowed to warm-up for 30 minutes, 0 NTU polymer standard was Inserted into the chamber and covered and the range switch was set to 20.0 NTU. The zero control potentiometer was used to set the meter to read 0.00 NTU. Exactly 10.0 NTU standard solution was also inserted into the chamber and covered, the Set range was switched to “20.0”. The reading of the meter was taken and it read 10.00. The standard solution was replaced with the sample and the meter was adjusted to the range of “20.0”. The value was allowed to stabilize and recorded as the turbidity of the sample.

Colour: The colour of the sample was determined using Lovibond Comparator. The comparator has a chamber containing two tubes. Also it has a rotary colour-match controller. The first tube was filled with distilled water, and the second tube was filled with the sample. The colour-match control knob was rotated to match with the sample. And the value was recorded as the colour of the sample

Total Suspended Solids (TSS): The total suspended solid of the sample was determined using filtration technique (APHA 2004). Millipore paper was dried to a constant weight at 105 ^{o}C in an oven and cooled to room temperature in a desiccator. The weight was recorded as Wp. The dried filter paper was folded and filtration apparatus was set up. The water samples were mixed thoroughly and exalctly100 mL of the sample was poured into the funnel containing the filter paper and filtered. The filter paper was carefully removed using forceps and dried to constant weight at 105 ^{o}C and Cooled again to room temperature. The filter paper and its contents were weighed and the value recorded as W_T. TSS was calculated from equation 1.

$$TSS\ (mg\ L^{-1}) = \frac{W_T - W_P}{Volume\ of\ sample} \times 100\% \qquad (1)$$

W_T = weight of filter paper and its content;
W_P = weight of filter paper alone

Total Alkalinity: The total alkalinity of the sample was determined using Acidimetric Indicator End-Point Technique from equation 2. Exactly 100 mL of the water sample was poured into a clean 250 mL conical flask. And 3-5 drops of indicator (mixture of methyl red and bromocresol green in 95.0 % pure alcohol) was added. The solution was titrated with 0.0200 M H_2SO_4. The colour changed from blue to pink-red at the end-point and the value was recorded as the volume of acid consumed (A mL).

$$Total\ Alkalinity\ (mg\ L^{-1}) = \frac{A}{B} \times\ 100\% \qquad (2)$$

Where A = mL of 0.02 M H_2SO_4 consumed; B = mL of sample.

Chloride Ions: Argentometric Method was applied in the determination if chloride in the water samples. The principle employed in this method is that Chloride is determined in a neutral or slightly alkaline solution by titration with standard silver nitrate, using potassium chromate as an indicator. Silver chloride is quantitatively precipitated before red silver chromate is formed. This was done following the method adopted by Gav *et al.* (2017). A volume of 100 mL of the sample was measured into a 250 mL conical flask and 1-2 drops of $K_2Cr_2O_4$ indicator were added. The colour of the sample then changed to yellow. The sample was titrated against standard 0.0100 M $AgNO_3$ until persistent brick red colour appeared. The concentration of chloride in the sample was computed from equation (3)

$$Chloride\ ion\ (mg\ L^{-1}) = B.R. \times 35.45 \times \frac{1000}{Amount\ of\ sample\ taken\ (mL)} \qquad (3)$$

Where B. R. = Burette Reading (Volume of $AgNO_3$ used); M = Molarity of $AgNO_3$

Sulphate Ions: Spectrophotometric method was used in the determination of sulphate ions in the samples. The principle is that Sulfate ions are precipitated as $BaSO_4$ in acidic media (HCl) with Barium Chloride. Light absorbance of the $BaSO_4$ suspension is measured by a photometer and the SO_4^{2-} concentration is determined by comparison of the reading with a standard curve. The method reported by Gupta (2007) was adopted with little modifications. Sulphate standard solutions of 4.00, 6.00, 8.00, 10.0 and 12.0 ppm were prepared from the standard sulphate solution in a 100 mL beaker. The samples of 100 mL volume were also taken in a beaker; 20.0 mL buffer solution was then added and mixed well. Exactly one spatula of $BaCl_2$ is added with stirring and continued for a minute. A blank solution is prepared in the same way using distilled water and placed in the spectrophotometer for blanking. The standard solutions were then placed in the spectrophotometer and the absorbance was duly noted at 380 nm using UV spectrophometer. The absorbance of the samples was also recorded. A graph of absorbance vs. sulphate concentration is plotted to give a straight line passing through the origin. From the graph, concentration of sulphate in the samples are found out.

Nitrate Ions: The concentration of nitrate ion (NO_3^-) in the water samples was determined using colorimetric method (ASTM, 2007). Exactly 50.0 mL of filtered water sample was measured into an evaporating dish and was evaporated to dryness. After this, it was cooled and 1.00 mL phenoldisulphonic acid was added. The phenoldisulphonic acid and residue were rubbed with a glass rod and the contents of the evaporating dish were transferred to a 50.0 mL volumetric flask with 35.0 mL of distilled water. After which 4.00 mL of ammonium hydroxide was added to develop the yellow colour. The solution was diluted to volume with distilled water. The blank determination was carried out on all reagents used.

The yellow colour of the sample against the reagent blank was measured with a spectrophotometer at 410 nm using the calibration curve obtained from the curve of absorbance against 1.00, 2.00, 3.00, 4.00 and 5.00 ppm standard nitrate solution.

Phosphate Ions (PO_4^{3-}): Stannous Chloride method was used**.** The principle involves the formation of Molybdophosphoric acid and its reduction by stannous chloride to intensely colored molybdenum blue. The concentration of phosphates can be measured by measuring the intensity of the blue colored complex formed as they are directly proportional. The method reported by Gupta (2007) was adopted without modification. Standard solutions of 1.00, 2.00, 3.00, 4.00, 5.00 ppm were prepared using the standard phosphate solution in a 100 mL beaker. The samples of 100 mL volume were also taken in a beaker. Exactly 4.00 mL of Antimony Molybdate Reagent (AMR) and 0.500 mL of stannous chloride were added to the standard solutions and the samples were allowed to stand for 10 minutes. A blank solution was prepared in the same way using distilled water. The blank solution was placed in the spectrophotometer for blanking. The standard solutions were then placed in the spectrophotometer and the absorbance was duly noted. The absorbance values of the samples were then found out. A graph of absorbance vs. phosphate concentration is plotted to give a straight line passing through the origin. From the graph, the concentrations of phosphate ion in the samples were determined.

Fluoride (F^-) Determination: The fluoride levels was measured potentiometrically using an ion selective electrode (Orion model 25100) coupled to a multimeter (Xplorer GLX model PS-2002), and with the use of a Total Ionic Strength Adjustment buffer (TISAB I) in the ratio of 1:1 (ASTM, 1996).

Calcium in Water: The concentration of calcium was determined by Single acid wet oxidation (APHA 1998). Exactly 100 mL of the sample was measured into a 150 mL beaker and 5.0mL of conc. HNO_3 was added. The solution was evaporated to near dryness on a hot plate, caution was taken so that the sample does not boil .This was done by the use of low to medium heat. The beaker and the contents were allowed to cool and the contents filtered into 100 mL volumetric flask to remove silicate and other insoluble materials and the filtrate was made up to the mark with distilled water. The solution was stored in 125 mL polypropylene bottle after which the concentration was determined by Atomic Absorption Spectrophotometer. (Lamp current: 10 mA, Fuel Acetylene, support: nitrous oxide, flame stoichiometry: reducing, wavelength: 239.9 nm).

Magnesium in Water: The concentration of magnesium was determined by Single acid wet oxidation (APHA 1998). Exactly 100 mL of the sample was measured into a 150 mL beaker and 5.0mL of conc. HNO_3 was added. The solution was evaporated to near dryness on a hot plate, caution was taken so that the sample does not boil .This was done by the use of low to medium heat. The beaker and the contents were allowed to cool and the contents filtered into 100 mL volumetric flask to remove silicate and other insoluble materials and the filtrate was made up to the mark with distilled water. The solution was stored in 125 mL polypropylene bottle after which the concentration was determined by Atomic Absorption Spectrophotometer. (Lamp current: 4 mA, Fuel Acetylene, support air, flame stoichiometry oxidizing, wavelength: 202.6 nm.

Analytical Procedures for Soil Analysis

Soil pH: The study adopted the method reported by Ifenna and Osuji (2013), without modification. In this method, 20.0 g soil sample was mixed with 40.0 mL distilled water in 1: 2 ratios. The suspension was stirred intermittently with glass rod for 30 minutes and was left for one hour. The probe of the pH meter was inserted into supernatant for two minutes and pH was recorded.

Electrical Conductivity: The method described by Wagh (2011), for the determination of electrical conductivity of a soil sample was adopted. This was determined using an Equiptronics digital electrical conductivity bridge for which 20.0 g soil was added in 40.0 mL distilled water. The suspension was stirred intermittently for half an hour and was kept for 30 minutes without any disturbances for complete dissolution of soluble salts. The soil was allowed to settle down and the conductivity cell was inserted in the solution and the EC values were read and recorded.

Moisture Content: The moisture content of the soil was carried out as thus: The weight of a pan was taken and recorded as C, the soil sample was poured into a wash basin and the soil lumps broken down.. The sample was spread evenly over the bottom of the pan. The weight of the pan and its contents were taken immediately and recorded as Wt. of Wet Sample A. The container and the sample were placed in the oven set at 110 °C ± 5 °C. The sample was dried to a constant weight. The sample was weighed after every 30 minutes until two consecutive weights were recorded. The hot sample was weighed and recorded as Wt. of dry Sample B. Values were calculated using equation 4.

$$Moisture\ content = \frac{Initial\ weight - oven\ dried\ weight}{Weight\ of\ initial\ weight} \times 100 \quad (4)$$

Determination of Bulk Density: The determination of the bulk density of the soil was obtained using the Core Method (ASTM, 2007).

The core was driven into the ground and the intact core was removed. After collection, the soil core was weighed and the mass (g) reported the in 2 decimals. The soil core sampler was 10.0 cm in diameter and 10.0 cm high. The volume of the soil sample was calculated using the equation: $V = \pi r^2 h$, where V = volume (cm^3), r = the radius of the core sampler (cm) and h is the height of the core sampler (cm).The soil core was oven dried and weighed and the value reported (in gram) to 2 decimal places. The soil was removed from the core sampler and the container was cleaned. The mass of the oven-dried soil was determined by subtracting the weight of the core sampler from the weight of the core sampler + dry soil. The weight of the oven dried soil was recorded in 2 decimal places. The weight of the moist soil was also calculated by subtracting the weight of the core sampler from the weight of the moist soil + core sampler and recorded to 2 decimal places. Using the weight of the moist sample and oven-dried sample, the amount of water that was removed by drying was calculated and recorded in 2 decimal places. The bulk densities of the samples were calculated using the formula ($Db = M/V$) and recorded as the value of bulk density, where; M = mass of water that was removed by drying and V= Volume of the core sampler.

Nitrogen in Soil: The total amount of nitrogen in the soil sample was determined using regular macro-Kjeldahl method (ASTM, 2007). Exactly 5.00 g of soil sample was weighed into 500 mL Macro Kjeldahl flask and 20.0 mL of distilled water was added. The flask was swirled for a few minutes, and allowed to stand for 30 minutes. Exactly 1.00 g of the K_2SO_4 - HgO mixture and 10.0 g of K_2SO_4 with 30.0 mL of Conc H_2SO_4 (18.0 M) were added through a pipette. The flask was heated cautiously at low heat on the digestion stand. After the water has been removed and frothing has ceased, the heat was increased until the digest became clear. The mixture was then boiled for 5 hours. The heat was regulated during the boiling such that the H_2SO_4 condensed about half way up the neck of the flask. The flask was cooled and 100 mL of water was slowly added to the flask. The digest was transferred into another clean Macro Kjeldahl flask (750 mL). All the sand particles in the original digestion flask were retained and washed with 50.0 mL of distilled water 4 times and the aliquot was transferred into the same flask. Exactly 50.0 mL H_3BO_3 indicator solution was added into 500 mL Erlenmeyer flask through pipette which is then placed under the condenser of the distillation apparatus. The 750 mL Macro Kjeldahl flask was attached to the distillation apparatus. And 150 mL of 0.100 M NaOH was poured through the distillation flask by opening the funnel stopcock. The condenser was kept cooled (below 30.0 °C) by allowing sufficient cold water to flow through and regulate heat to minimize frothing and prevent suck-back. Exactly 150 mL distillate was collected and then the distillation was stopped.

The NH_4-N in the distillate was determined by titrating with 0.01 M standard HCl using 25.0 mL burette graduated at 0.1mL intervals. The colour changed from green to pink at the end point and the percentage of Nitrogen (% N) content in soil was calculated.

Phosphorus in the Soil: The determination of Phosphorous in the soil sample was done using Olsen's Method. (ASTM, 2007). Exactly 2.00 g of air-dried soil sample (passed in a 2 mm sieve) was weighed into a 125 mL Erlenmeyer flask and 5.00 mL of 18.0 M of sulphuric acid was added with 0.400 g of ammonium persulfate and boiled until a final volume of about 10.0 mL was reached. The solution was filtered and made up with distilled water to 40.0 mL. And 5.00 mL of Antimony Molybdate was added to the solution, followed by the addition of 2.00 mL of ascorbic acid. The blank and standard solutions were subjected to the same treatment as above. After about 10-20 minutes, the absorbance of the sample, standard and blank solutions were measured with Ultra violet spectrophotometer at a wavelength of 680nm. The calibration curve was obtained for a standard solution of 1.00, 2.00, 3.00, 4.00 and 5.00 ppm phosphate and the concentration of the samples were obtained from the calibration curve using the absorbance of the samples.

Determination of Exchangeable Cations (K, Na, Ca & Mg) **in soil:** The determination of exchangeable cations (K, Na, Ca and Mg) in the soil sample was done using APHA 3030 AAS Method. Exactly 2.50 g of soil sample was treated with 25.0 mL of neutral 1.00 M CH_3COONH_4. The mixture was stirred for 15 minutes and filtered. Sodium, potassium, calcium and magnesium were determined from the filtrate by Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

The result of the physicochemical parameters such as temperature, colour, turbidity, pH, conductivity, total dissolved solid, total suspended solids, calcium, magnesium, chloride, sulphate, fluoride, alkalinity, nitrate and, phosphate in water samples collected from the two water sources (Anchimodo and Eyari) around the Owukpa Coal mining site with their standard deviations are presented in Table 2.

Table 2: Mean Values of Physichochemical parameters of Water Samples

S/No	Parameters	Anchimodo Water Sample	Eyari Water Sample	Water Control Sample
1	pH	6.20 ± 1.0	4.70 ± 0.20	4.65±0.50
2	Temp. (°C)	28.9 ±0.48	28.3 ± 1.6	29.3 ± 0.85
3	TDS (mg/L)	8.00 ± 1.0	8.67 ± 3.8	5.50 ± 0.71
4	EC (µS/cm)	12.3 ± 1.5	13.0 ± 6.1	9.00 ± 1.4
5	Turbidity (NTU)	1.20 ± 0.23	0.513 ± 0.74	1.93 ± 0.38
6	Colour (TCU)	7.00 ± 3.5	4.00 ± 4.4	16.0 ± 2.8
7	TSS (mg/L)	2.33 ± 0.58	1.33 ± 0.58	3.50 ± 0.71
8	Total Alk. (mg/L)	9.33 ± 2.5	2.00 ±1.0	3.00 ± 2.8
9	Cl^- (mg/L)	2.70 ± 0.22	3.17 ± 1.4	1.62 ± 0.48
10	SO_4^{2-} (mg/L)	1.15 ± 0.78	4.86 ± 5.5	1.17 ± 0.080
11	NO_3^- (mg/L)	0.0200 ± 0.010	0.0300 ± 0.035	0.0100 ± 0.00
12	PO_4^{3-} (mg/L)	0.0100 ± 0.00	0.0130 ± 0.0058	0.100 ± 0.00
13	F^- (mg/L)	0.0300± 0.010	0.0400 ± 0.044	0.0100 ± 0.00
14	Ca (mg/L)	0.440 ± 0.067	0.470 ± 0.29	0.310 ±0.077
15	Mg (mg/L)	0.260 ± 0.083	0.110 ± 0.16	0.200 ± 0.014

pH: The mean pH values were found to be 6.20 ± 1.0, 4.70 ± 20 and 4.65± 0.50 for Anchimod, Eyari and Water control sample respectively. Anchimodo and Eyari are the two water sources around the Owukpa coal mining site. The control sample was obtained from river Okpokwu along Owukpa-Okpoga road. The results show that all the water samples were acidic; the control sample shows the highest level of acidity, followed by Eyari and then Anchimodo. These values are below the recommended value of 8.0 for drinking water (WHO, 2011). This condition is common with water sources within mining location due to possible acid mine drainage as explained by Awalla (2014) and Matthew *et al.* (2012).

Temperature: The mean temperature readings of the water samples from Anchimodo, Eyari and that of the control samples were 28.9 ± 0.48, 28.3 ± 1.6 and 29.3 ± 0.85 respectively. These values are less than the 30 °C permissible value for natural or raw water set by WHO (2011). Temperature defines the rate of chemical and biological processes that occur in water. Sustainability of living organisms also depends on water temperature. Some prefer cold temperatures; some prefer warmer conditions while most survive in the mild temperature as it affects their biological and ecosystem directly or indirectly.

Total Dissolved Solids: TDS is that part of the total solids that is dissolved in water. The mean value of TDS in the water sample from Anchimodo, Eyari and control sample are 8.00 ± 1.0, 8.67 ± 3.8 and 5.50 ± 0.71 mg/L respectively. These values are within the 1000 mg/L recommended by WHO (2011). The mean value of TDS has the highest value in Eyari, followed by Anchimodo and then the water control samples. This variation could be ascribed to the presence of chlorides, nitrates, calcium, phosphates and other ions in the water samples more than the control sample. In natural water, dissolved solids are composed of mainly Na^+ , K^+ , Ca^{2+} and Mg^{2+} (Prasanthi *et al.*, 2012).

Electrical Conductivity: The mean values of electrical conductivity for water samples obtained from Anchimodo, Eyari and control samples are 12.3 ± 1.5, 13.0 ± 6.1 and 9.00 ± 1.4 µS/cm respectively. These values are all less than the set standard by WHO (2011) with conductivity values of 1000 µS/cm. This finding is in agreement with Verma *et al.* (2012), who reported that EC is higher for water samples closed to mining sites than those far away or without direct contact with mining effluents.

Turbidity: The mean values of turbidity for the water samples from Anchimodo, Eyari and control samples are 1.20 ± 0.23, 0.513 ± 0.74 and 1.93 ± 0.38 NTU respectively. These values were within WHO standards of 5 NTU. Turbidity of water is seasonal dependent. Runoff water directed into the water bodies could result to increase in the turbidity value of a water sample as explained by Wu *et al.* (2008) and Awalla (2014).

Colour: The mean values of colour in the water samples from Anchimodo, Eyari and control samples are 7.00 ± 3.5, 4.00 ± 4.4 and 16.0 ± 2.8 respectively. The values of colour for Anchimodo and Eyari are below the WHO standard 15 TCU while that of control sample is above the set standard.

Total Suspended Solids: The result of TSS in the water samples (Anchimodo and Eyari) and control samples as presented in Table 2 are 2.33 ± 0.58, 1.33 ± 0.58 and 3.50 ± 0.71 mg/L respectively. These values are all less than the WHO standard limit of 500 mg/L. The value of TSS in the control sample is a little higher than the value of TSS for Anchimodo and Eyari.

Total Alkalinity: The mean value of total alkalinity for the water samples from Anchimodo, Eyari and the control samples are 9.33 ± 2.5, 2.00 ±1.0 and 3.00 ± 2.8 mg/L respectively. These values are less than the WHO standard of 120 mg/L. The concentration of total alkalinity is highest in Anchimodo, followed by the control sample. Eyari has the least value and this further buttress the acidic nature of the water samples from Eyari.

Chloride: The mean concentration of the chloride ion in the water sample from Anchimodo, Eyari and the control samples were recorded to be 2.70 ± 0.22, 3.17 ± 1.4 and 1.62 ± 0.48 mg/L respectively. The results are far less than WHO (2011) recommended concentration of 250 mg/L for natural water bodies. The chloride concentrations in the water samples (Anchimodo and Eyari) are also higher than the concentration of chloride in the water control samples.

Sulfate Ions: The mean concentration of sulphate ions in water samples (Anchimodo and Eyari) and the control samples were measured to be 1.15 ± 0.78, 4.86 ± 5.5 and 1.17 ± 0.080 mg/L respectively. These were all within the recommended limit of 250 mg/l by WHO. The high concentration of sulfate ions in Eyari compared to the control samples and Anchimodo is probably due to runoff received from the mining site. A similar observation was made by Wu *et al.* (2008), where they noted that proximity to the mining site and seasonal variation had an effect on the sulphate concentration of the river especially during the dry season.

Nitrate Ions: The mean concentration of nitrate ions in the water samples (Anchimod and Eyari) and the control samples were found to be 0.0200 ± 0.010, 0.0300 ± 0.035 and 0.0100 ± 0.00 mg/L respectively (Table 2). These values are far less than the WHO recommended standard of 50.0 mg/L. These low concentration values may be as a result of less human activities that would serve as common sources of nitrate contamination. These sources include fertilizers, livestock manure, feedlots, septic tanks and land application of municipal sludge as stated by Obi and Kocha (2007). The concentration of nitrate is highest in the samples obtained from Eyari, followed by Anchimodo and the control samples have the least nitrate concentration. This little variation could be ascribed to the discharge of effluent from the mining site into the water bodies. Verma *et al.* (2012) supported this statement by saying that the pond water has higher concentration of nitrates than well water and unsafe for drinking because of contamination by nearby mining activities.

Phosphate ions: The mean concentrations of phosphate ions in the water samples (Anchimodo and Eyari) and control samples were measured to be 0.0100 ± 0.00, 0.0130 ± 0.0058 and 0.0100 ± 0.00 respectively. These low concentration values may be as a result of less human activities that would serve as common sources of phosphate contamination. These sources include fertilizers, livestock manure, feedlots, septic tanks and land application of municipal sludge as stated by Obi and Kocha (2007).

Fluoride Ions: The mean values for the concentration of fluoride in the water samples (Anchimodo and Eyari) and the control samples were measured to be 0.0300 ± 0.010, 0.0400 ± 0.04 and 0.0100 ± 0.00 mg/L respectively. These values are less than the WHO (2011) recommended standard of 1.50 mg/L for natural water.

Calcium: The mean values of calcium in water samples (Anchimodo and Eyari) were measured to be 0.440 ± 0.067, 0.470 ± 0.29 and 0.310 ± 0.077 mg/L respectively. These values are less than the recommended value of 75.0 mg/L set by WHO (2011) for natural water. Calcium is an important constituent assisting in the normal functioning of a number of processes in the body, for instance, the nerve impulse transfer (Saha, 2017). The low concentrations of calcium found in all the analysed samples suggest that the water may not be contaminated with calcium from the mining site at the time of this study.

Magnesium: Magnesium is an important dietary element like calcium. Magnesium is present in large number of minerals and gets collected during rains or when water flow through beds containing such minerals. magnesium like calcium has an important role to play in the various biological processes (Ahmad *et al.*, 2015). The mean concentration of magnesium in water samples (Anchimodo and Eyari) and control samples are 0.260 ± 0.083, 0.110 ± 0.16 and 0.200 ± 0.014 mg/L respectively These values are less than the WHO recommended values of 30.0 mg/L for natural water, therefore the water sources sampled cannot be associated with magnesium contamination from mining activities at the time this study.

Physicochemical Parameters in Soil Samples

The result of the physicochemical parameters such as pH, moisture content, electrical conductivity, bulk density, nitrogen, phosphorus, cation exchange capacity calcium, and essential elements such as magnesium, sodium, potassium in the soil samples with standard deviations of the aforementioned parameters are presented in Table 3.

Table 3: Mean Values of Physicochemical Parameters and Essential Elements in Soil Samples

S/No	Parameters	Soil Analytical sample	Soil Control Sample
1	pH	4.32 ± 0.31	6.30 ± 0.85
2	E C (µS/cm)	0.0200 ± 0.029	0.0150 ±0.0071
3	Moisture content (%)	13.7 ± 2.36	20.3 ± 2.22
4	Bulk Density (g/cm^3)	1.50 ± 0.17	1.46 ± 0.028
5	N (%)	0.145 ± 0.11	0.395 ± 0.16
6	P (%)	0.0510 ± 0.32	0.125 ± 0.050
7	Ca (mg/kg)	6.57 ± 9.6	38.8 ± 1.9
8	Mg (mg/kg)	83.3 ± 24	195 ± 48
9	Na (mg/kg)	183 ± 19	88.4 ± 48
10	K (mg/kg)	17.3 ± 16	59.0 ± 28
11	CEC (meq/100g)	15.8 ± 10	23.2 ± 1.0

Soil pH: The pH was found to be 4.32 ± 0.31and 6.30 ± 0.85 respectively for both analytical and control soil samples obtained from Owukpa LGA around the Owukpa coal mining site. This is an indication that mining activity may have impacted on the environment. The sample was found to be more acidic than the control sample. This suggests acidity of all soil samples around the mining sites as compared to the control soil. This could be as a result of acid mine waste on the soil around the mining site. Similar results were reported for coal mining area by other researchers (Ezeaku and Ikemefuna, 2011; Biswas *et al.*, 2013; Oladipo *et al.*, 2014; Sufian and Jha, 2015).

Soil Electrical Conductivity: The mean value of EC of the soil analytical samples and soil control samples were found to be 0.0200 ± 0.029 and 0.0150 ± 0.0071 µS/cm respectively. These values are relatively low compared to FAO (2008) maximum limit of 10.0 (µS/cm). The electrical conductivity of the soil analytical samples is a little higher than the control samples this could be as result of dissolved higher concentration of sodium chloride or potassium chloride in the soil samples around the mining site than the control samples. A similar result was reported for coal mining area by (Oladipo *et al.*, 2014).

Soil Moisture Content: The mean value for the composition of moisture contents of the soil analytical samples and control samples were found to be 13.7 ± 2.36 and 20.3 ± 2.22% respectively. The results show that the moisture contents of the soil control samples are higher than the soil analytical samples. This may be because the soil around the mining site is exposed as a result of deforestation during the mining activity thereby encouraging the loss of water from the soil. The same result was reported by Abugu (2018) where the author reported that the soil temperature of the mining site was higher than the control soil samples.

Soil Bulk Density: The mean value of the bulk density of the soil analytical samples and control samples are 1.50 ± 0.17 and 1.46 ± 0.028 g/cm^3 respectively. There was a slight difference observed between the soil analytical and the control. The analytical sample was found to be higher than the control samples. This difference in the soil bulk density may be attributed to higher organic matter content in the analytical sample compared to the control samples. Tackele *et al.* (2015) reported that, soils under no agricultural activity normally have low bulk density and soils under cultivated land usually have high bulk density due to the differences in soil organic matter and less disturbances under the uncultivated land than in the cultivated land.

Soil Nitrogen: The value for the mean composition of nitrogen in the soil analytical samples and the soil control samples were determined to be 0.145 ± 0.11 and 0.395 ± 0.16% respectively. The nitrogen compositions of both soil analytical samples and soil control samples are low because nitrogen is one of the nutrients required for green coloration of plants. There is a bit difference in the nitrogen content of the soil analytical samples from the control samples. The nitrogen content of the later is greater than the former, this may be due to excavation of the topmost soil that contain soil nutrient during mining. The finding of this study is in agreement with Abugu *et al.* (2018) who reported that the concentration load of soil nutrients such as calcium, magnesium, sodium, potassium, nitrate, sulfate, phosphate and chloride were observed to be low in samples around the mining area than the control samples.

Phosphorus in the Soil: The values for the mean compositions of phosphorus in the soil analytical samples and soil control samples are 0.0510 ± 0.32 and 0.125 ± 0.050 mg/kg respectively. Phosphorus is one of the components of NPK fertilizer that increases the yield of crops, therefore is required in the soil in a composition higher that the values obtained for both the analytical and control samples in this study. For phosphate, 5.00 mg/kg is the recommended value by FAO (2008) for crop productions. Phosphorus exists in the soil inform of phosphate, thus, low amount of phosphorus in the soil is an indication of low fertile soil.

Calcium in the Soil: The mean concentrations of calcium in the soil analytical samples and soil control samples were determined to be 6.57 ± 9.6 and 38.8 ± 1.9 mg/kg respectively. These values are lower than the recommended value of 150 mg/kg by FAO (2008) for crop production. The mean value obtained from the soil control samples is higher than the mean value of the analytical samples.

Magnesium in the Soil: The mean values of the concentrations of magnesium in the soil analytical samples and soil control samples were determined to be 83.3 ± 24 and 195 ± 48 mg/kg respectively. These values are higher than the recommended limit of 50.0 mg/kg set by FAO (2008) for crop productions. The magnesium content of the soil control samples is higher than the soil analytical samples.

Sodium in the Soil: The mean concentrations of sodium in the soil analytical samples obtained from the Owukpa coal mining site and the control samples were found to be 183 ± 19 and 88.4 ± 48 mg/kg respectively. These values are less than the recommended value of 200 mg/kg by FAO (2008) for crop productions. The mean value of sodium in the soil obtained from the mining site is higher than the mean concentration of sodium in the soil control samples. This could be as a result of mineralization during mining and direct disposal of mining wastes on the nearby soil (Adegboye, 2012).

Potassium in the Soil: The mean concentrations of potassium in the soil samples obtained from the mining site in Owukpa, Ogbadibo LGA and the soil control samples were determined to be 17.3 ± 16 and 59.0 ± 28mg/kg respectively. These values are less than the recommended value of 100 mg/kg by FAO (2008) for crop productions. The mean concentration of potassium in the control samples is higher than the mean concentration of sodium in the soil samples obtained from the coal mining site. Potassium is required for plant growth thus is among the soil nutrients that are depleted in mining areas. This is in agreement with Biswas *et al.* (2013) who independently observed small concentration of potassium in mining area.

CONCLUSION

This study assessed the physicochemical characteristics of the two surface water sources for the Owukpa people in Okpokwu Loocal Government Area of Benue state as well as the soil in the vicinity of Owukpa Coal Mine. Results indicated that the water bodies are acidic as the values fell below the recommended limit of (8.00) WHO (2011). Other physicochemical parameters measured in the water samples were generally far less than the concentrations set by WHO (2011). The concentration of the soil physicochemical parameters generally fell far below the recommended values by WHO (2011). However, the values of magnesium (83.0 and 195 mg/kg for soil and control soil samples respectively) were much more than the concentration (50.0 mg/kg) given by WHO (2011).

RECOMMENDATION

The government and policy makers should take some proper steps by ensuring that Mining policy is up to date and applied accordingly in the mining site. Also, Effluent Treatment Plant (ETP) should be developed for waste treatment in the studied area. Farmers are also advised to use organic manure if they must farm on the studied soil due to acidic nature of the soil.

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