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# Physicochemical Parameters and Quality Index of Water Samples from Okobo Coal Mine Site

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## Abstract
Pollution from human activities such as mining is one of many pressures affecting surface water systems and resources. Physicochemical parameters of water samples from Okobo mine site and its environs were investigated following standard methods and procedures for sampling and evaluation. The parameters analysed were pH, alkalinity, dissolved oxygen (DO), chloride, total dissolved solid (TDS), hardness, nitrate and sulphate. These were expressed using Water Quality Index (WQI) a value that reflects overall quality of water at a given location and time. WQI transform complex water quality data into information that determine whether the water is safe for human consumption and the biotic environment. In this work WAWQI was used to estimate the water quality. The results obtained showed that WQI for upstream is >100 while the downstream value is < 1, an indication that the downstream water is safe for human consumption.
**Keywords:** Physicochemical properties, Water Quality Index, Pollution, Coal mine

## Introduction

Coal is one of the cheapest source of energy but a major contributor to the emission of greenhouse gases with $CO_2$ having the highest impact on the environment [1, 2]. Coal mining is a process by which coal minerals are extracted from underground. The process involves the removal of the vegetation on the overlying soil housing million tons of the biologically inert overburden dumps in form of rocks [3]. During this process, very large amount of hazardous extraction chemicals or contaminated waste rocks are released and disposed of into the environment [4] or abandoned on the mining site. The vulnerability of the ecological environment of these exploited areas cannot be overemphasized. The losses of water resource, ground subsidence, air/water pollution and other environmental issues associated with the mining of coal is more prominent. Life productivity of coalmine can extent close to a century which make related environmental problems continue gradually, forming a cumulative effect [1].

Progressive growth in population and human activities constitute a threat to freshwater system and the resources on which life depend as mining often causes severe pollution of soil or groundwater and other drinking water sources. This event contributes to the degradation of agricultural land and drinking water resources [1, 5]. A study by [6] revealed that the ground water in the mining district of Johannesburg, South Africa, is heavily contaminated and acidified as a result of oxidation of pyrite contained in the mine tailing dumps and has elevated concentration of heavy metals.

Acid mine drainage (AMD) is an age long pollution stream formed as a result of particles oxidation combining water and air. It is a stream of acidic effluent resulting from a sulphide enriched mines [7]. It is the most significant environmental problem raising from mining activities. Its effects on the environment is pronounced especially the destruction of aquatic life, distortion of crop growth, shortening of design lifespans of civil infrastructures and others [8]. Pollution of surface and groundwater, degradation of soil quality and aquatics is also evident [9]. Apart from the numerous negative impacts on the environment, flooding is also common due to inability of the surrounding to absorb water effectively [1]. Water and soil contamination caused by acid mine drainage is a significant environmental problem in some parts of the world, particularly in densely populated developing countries where human habitats are in close proximity to mine site [10].

Coal mine wastes show variable mineralogy due to the diverse nature of coal bearing strata and discharge waters with variable chemistry [11]. The method for comparing the water quality of various water resources are based upon parameters such as temperature, pH, turbidity, fecal coliform, dissolved oxygen, biochemical oxygen demand, total phosphates, nitrate and total solids [12]. Many studies have examined the relationship between these parameters. The methods, qualities and locations of the studies showed varied results [13,14,15]. While there have been improvements in coal mining methods, practices and technologies in recent years, significant environmental risks such as environmental degradation, soil, air and water pollution still remain [3,7].

## Materials and Methods

### *Study area*

Okobo community is a small settlement in Enjema District of Ankpa Local Government Area (7°22′14″N7°37′31″E) North Central, Kogi state, Nigeria with reserves of up to 380 million tonnes of coal. Coal mine wastes differ due to diverse nature of mineralogy, nature of coal bearing strata and discharge water with variation chemistry.

This current study is on the quantitative determination of physicochemical parameters and quality index of water sampled from Okobo coal mine site.

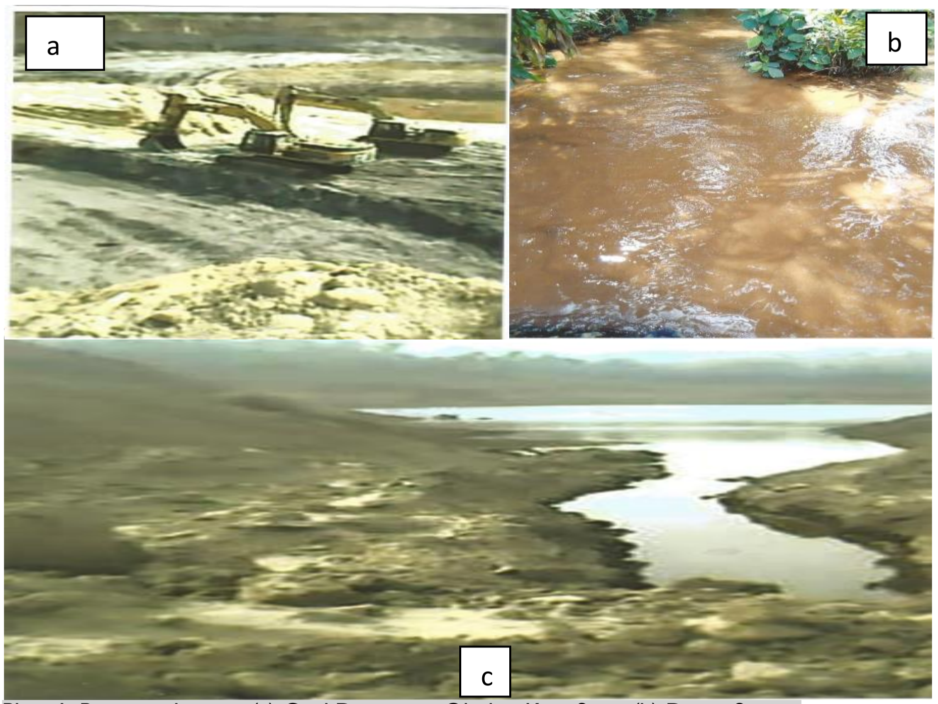


Plate 1: Pictures showing (a) Coal Deposit in Okobo, Kogi State (b) Down Stream Water Samples from Okobo (c) Outburst of Water from Coal Mine Site

Physiochemical parameters such as pH was determined in-situ with Hanna multiparameter pH meter as described by [16]. Nitrate, sulphate, chloride and total dissolved solids were determined by standard method adopted by [17]. Total alkalinity, dissolved oxygen (DO) bio-chemical oxygen demand (BOD) were determined using the procedures described in [18].

### *Water quality index*

A Water Quality Index (WQI) is a means by which water quality data is summarized for reporting to the public in a reliable manner. It is similar to the UV index or an air quality index, and it tells us, in simple terms, what the quality of drinking water is from a drinking water supply [12,19]. It reduced the numerous of water quality parameters in a simple and useful arithmetical value [20]. Water Quality Index for the water body under study was evaluated sing the technique of Weighted Arithmetic Index (WAI). The method has been widely used by the various scientists and WQI was calculated using the equation adopted from other authors [12, 21, 22]:

$$WQI = \sum qiwi / \sum wi \qquad (1)$$

The quality rating scale (qi) for each parameter was calculated using the expression:

$$qi = 100\,[\,(Vi - Vo/Si - Vo)] \qquad (2)$$

Where $Vi$ estimated concentration of ith parameter in the analysed water is, $Vo$ is the ideal value of this parameter. For pure water, $Vo$ = 0 (expected pH =7.0 and dissolved oxygen (DO) = 14.6 mg/L), $Si$ is recommended standard value of ith parameter. The unit weight (wi) for each water quality parameter was calculated using the following formula:

$$Wi = 1/Si \qquad (3)$$

## Results and Discussion

The rating of water quality according to this WQI is given in Table 1.

**Table 1: Water Quality Rating as per Weight Arithmetic Water Quality Index Method**

| WQI Value | Rating of Water Quality | Grading |
|---|---|---|
| 0-25 | Excellent water quality | A |
| 26-50 | Good water quality | B |
| 51-75 | Poor water quality | C |
| 76-100 | Very poor water quality | D |
| Above 100 | Unsuitable for drinking purposes | E |

[19]

**Table 2. Standard for Drinking Water and Unit Weight of the Water Quality Parameters**

| Parameters | Units | Standard Values | Recommending Agencies | Unit weights ($w_i$) |
|---|---|---|---|---|
| pH | | 6.5-8.5 | WHO | 0.133 |
| Alkalinity | $mgL^{-1}$ | 200 | WHO | 0.005 |
| DO | $mgL^{-1}$ | 5 | BIS | 0.20 |
| Chloride | $mgL^{-1}$ | 250 | ICMR | 0.004 |
| TDS | $mgL^{-1}$ | 500 | WHO | 0.002 |
| Hardness | $mgL^{-1}$ | 300 | BIS | 0.003 |
| Nitrate | $mgL^{-1}$ | 45 | BIS | 0.022 |
| Sulphate | $mgL^{-1}$ | 500 | WHO | 0.002 |

**Table 3: Result of Physico-chemical Parameters of Water Samples from Okobo Coal Mine**

| Parameters | U | M | D | C | $EC_1$ |
|---|---|---|---|---|---|
| pH | 6.43±0.03 | 3.66±0.01 | 3.41±0.01 | 3.50±0.01 | 5.00±0.02 |
| Alkalinity | 35.0±1 | 30.0±1 | 85.0±1 | 45.1±0.1 | 75.2±0.2 |
| DO | 8.53±0,01 | 8.44±0.01 | 3.56±0.01 | 23.0±0 | 8.43±0.01 |
| Chloride | 189±0 | 140±1 | 245±1 | 182±0 | 120±1 |
| TDS | 2.0±0 | 4.0±0 | 5.95±0.1 | 4.01±0.01 | 1.00±0 |
| Hardness | 16.0±0.7 | 23±1.4 | 47.0±1.4 | 20.0±0 | 23.0±1 |
| Nitrate | 1.32±0.01 | 1.23±0.04 | 1.32±0.02 | 1.11±0.01 | 1.05±0.1 |
| Sulphate | 1.63±0.04 | 4.11±0.01 | 1.64±0.01 | 2.45±0 | 2.50±0 |

*Foot note: U = Up Stream, M = Mid Straem, D = Down Stream, EC1 = Control $_1$ (Eva Water), C=Control = Ogaji*

**Table 4. Calculation of Water Quality Index in Upstream**

| Parameters | Measured value | Standard value | Unit weights ($w_i$) | Quality rating Scale ($q_i$) | WQI |
|---|---|---|---|---|---|
| pH | 6.43 | 6.5-8.5 | 0.133 | 85.7 | 11.40 |
| Alkalinity | 35.00 | 200 | 0.005 | 170.6 | 0.09 |
| DO | 8.53 | 5 | 0.20 | 75.6 | 34.12 |
| Chloride | 189.00 | 250 | 0.004 | 0.40 | 0.30 |
| TDS | 2.00 | 500 | 0.002 | 5.30 | 0.0008 |
| Hardness | 16.00 | 300 | 0.003 | 350 | 0.016 |
| Nitrate | 1.32 | 45 | 0.022 | 2.90 | 0.0006 |
| Sulphate | 1.63 | 500 | 0.002 | 0.30 | 0.064 |
| | | | $\sum wi$ =0.371 | $\sum qi$ =358.3 | $\sum wiqi$ =46.0514 |

$$Total\ WQI = \sum wiqi / \sum wi = 124.1277$$

**Table 5. Calculation of Water Quality Index in Mid-Stream**

| Parameters | Measured value | Standard value | Unit weights ($w_i$) | Quality rating Scale ($q_i$) | WQI |
|---|---|---|---|---|---|
| pH | 3.66 | 6.5-8.5 | 0.133 | 48.8 | 6.49 |
| Alkalinity | 30.00 | 200 | 0.005 | 15 | 0.075 |
| DO | 8.44 | 5 | 0.20 | 168.8 | 33.76 |
| Chloride | 140.00 | 250 | 0.004 | 56 | 0.224 |
| TDS | 4.00 | 500 | 0.002 | 0.8 | 0.0016 |
| Hardness | 23.00 | 300 | 0.003 | 7.66 | 0.023 |
| Nitrate | 1.23 | 45 | 0.022 | 2.73 | 0.06 |
| Sulphate | 4.11 | 500 | 0.002 | 0.082 | 0.0016 |
| | | | $\sum wi$ =0.371 | $\sum qi$ =299.872 | $\sum wiqi$ =40.635 |

$$Total\ WQI = \sum wiqi / \sum wi = 109.528$$

**Table 6. Calculation of Water Quality Index in Down Stream**

| Parameters | Measured value | Standard value | Unit weights ($w_i$) | Quality rating Scale ($q_i$) | WQI |
|---|---|---|---|---|---|
| pH | 3.41 | 6.5-8.5 | 0.133 | 0.454 | 0.06 |
| Alkalinity | 85.00 | 200 | 0.005 | 0.425 | 0.002 |
| DO | 3.56 | 5 | 0.20 | 0.712 | 0.142 |
| Chloride | 245 | 250 | 0.004 | 0.98 | 0.004 |
| TDS | 5.95 | 500 | 0.002 | 0.012 | 0.0024 |
| Hardness | 47.00 | 300 | 0.003 | 0.157 | 0.0047 |
| Nitrate | 1.32 | 45 | 0.022 | 0.293 | 0.065 |
| Sulphate | 1.64 | 500 | 0.002 | 0.003 | 0.006 |
| | | | $\sum wi = 0.371$ | $\sum qi = 3.144$ | $\sum wiqi = 0.2856$ |

Total $WQI = \sum wiqi / \sum wi$ =0.7698

Table 3 presents the physicochemical parameters of water samples from Okobo coal mine environment. From the table, the upstream (U) water pH is near neutral (6.43). As the water moved down stream (D), the pH decreased with M and D having values of 3.66 and 3.41 respectively. The pH of the water is below the allowable limit recommended for surface water [23]. Low pH recorded downstream can be attributed to the influence of acid mine drainage (AMD), oxidation of pyrite and possible acidic lateritic soil. Many streams impacted by AMD have a pH value of 4 or lower. Plants, animals and fish are unlikely to survive in such stream, [24]. [25] reported low pH of 2.8 in water body within the vicinity of Iva Valley and Okpara coal mines in Enugu State, Nigeria. Determination of acidity is significant as it contributes to corrosiveness of water [26].

Alkalinity of the water sampled ranged from 30 to 85mgL$^{-1}$. The highest value was obtained down the stream. Alkalinity value obtained was lower than the permissible limit recommended by [23]. Elevated value of alkalinity in water resources is due to the presence of salts of weak acids, carbonate and/or the presence of ammonium and hydroxides [27].

The survival of aquatic life depends on amount of oxygen dissolved in water. The values of dissolved oxygen (DO) in different stream of water body measured were 8.53, 8.44 and 3.56 mgL$^{-1}$ for upstream, midstream and downstream respectively. The value of DO decreases as the water move down the stream. The lower limit of DO recommended by [28] is 5.0 mgL$^{-1}$. The results show that the water was polluted downstream probably with die-off and decomposition of submerged plants and animals. The amount of DO in a given volume of water is a function of temperature and amount of other substances dissolved in it [24]. The chloride level in the water samples ranged from 140 mgL$^{-1}$ to

245 mgL-1. High chloride concentration in water can harm aquatic organisms by interfering with osmoregulation. Recent published research suggests that high chloride concentrations are harmful to many aquatic animals. [29] found chloride tolerance level for some brook trout species to be as low as 3.1ppm. [30] found that elevated chloride levels interfered with the processes by which bacteria break down nitrogen in suburban stream debris dams and naturally occurring barriers of stick rocks. Increase in chloride concentrations are thought to be due to anthropogenic or human caused through application of potash fertilizer on farm land.

Total dissolved solids (TDS) are a measure of all constituents dissolved in water includes $CO_3^{2-}$ , $Cl^-$, $SO_4^{2-}$ and $NO_3^-$ . The inorganic cations include $Na^+$, $K^+$ $Ca^{2+}$ and $Mg^{2+}$. TDS value of the upstream water was 2.00 mgL-1and it increased downstream (5.95 mgL-1). [31] stated that TDS was responsible for toxicity through increase in salinity, changes in the ionic composition of the water and toxicity of individual ions [32] indicated that the toxicity related to the ions in TDS is due to the specific combination and concentration of ions. The United States Environmental Protection Agency (USEPA) currently does not have a national criterion for TDS. According to [33] to date, 27 states have enacted a state-specific criterion. However, TDS limits and the designated uses vary greatly from state to state.

Total hardness of the various segments of water body studied varied from 16 to 47mgL-1. Water has been classified on the basis of hardness as follows: water having 0 - 75 mgL-1 as soft, 75 - 150 mgL-1 as hard and >300 mgL-1 as total hardness [34]. Base on this, the water sample in this study can be described as soft water.

The concentration of $SO_4^{2-}$ in the upstream, midstream and down were 1.63, 4.11 mgL-1 and 1.64 mgL-1respectively. According to [23], typical sulphate levels in fresh spring water are in the vicinity of 20 mgL-1 and range from 0 to 630mgL-1 in rivers. [35] reported $SO_4^{2-}$ value of 109.8mgL-1 to 250.98 mgL-1. $SO_4^{2-}$ value ranged from 783 mgL-1 to 794 mgL-1 was recorded by [36]. Due to high value of $SO_4^{2-}$ in water people can experience diarrhea and dehydration. Infants are often more sensitive to sulphate than adults.

Nitrate ion ($NO_3^-$) is the common form of nitrogen in natural waters. Nitrate levels in different part of the water body studied ranged from 1.28mgL-1 to 1.32 mgL-1. Nitrate concentrations over 5 mgL-1 in natural waters normally indicates man-made pollution, 200 mgL-1 is an extreme level [36, 37]. Permissible value for $NO_3^-$ for surface water is 45.0 mgL-1 [38]. Man-made sources of nitrates include fertilizers, livestock, urban runoff, septic tank and waste water discharges. In general, nitrates are less toxic to human than ammonia or nitrite, however at high levels nitrate will become toxic especially to infants [38].

The highest phosphate level was recorded at point D with a concentration of 0.90 mgL-1 while the lowest concentration was 0.25 mgL-1 recorded at point M of the water body. The elevated phosphate concentration in water have been linked to increasing rates of plant growth, changes in species composition and proliferation of planktonic, epiphytic and epibenthic algae, resulting in shading of higher plants [39].

## Conclusion

The physicochemical parameters of water samples from Okobo mine site and its environs were quantitatively determined. The results obtained revealed that upstream is most polluted with WQI >100. The downstream water has WQI <100, an indication of its safety for human consumption and the environment. However, a periodical assessment of water quality parameters should be carried out to avert any negative effect due to variation.

**Competing Interests**
Authors have declared that no competing interests exist

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