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Comparative Analysis of Physicochemical and Microbial Parameters of Water Samples from Oro-Obor and Ayo Rivers in Enugu South, Enugu State, Nigeria

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Abstract: *Comparative analyses of water samples from Oro-Obor and Ayo Rivers respectively were carried out on selected physicochemical and microbial parameters. Based on weekly sampling at four different times, at three staggered points along the course of each river, the samples were tested using the Association of Official Analytical Chemists standard methods. The range of mean results between Oro-Obor River and Ayo River are as follows: pH (5.31-5.49), Temperature (28.52-28.27 ^{o} C), Conductivity (79.44-120.58µS/cm), Total Dissolved Solids (31.11-51.67mg/L), Turbidity (91.35-9.94 NTU), Colour (30.75-8.58 pt/co), Dissolved Oxygen (10.68-9.79mg/L), Biochemical Oxygen Demand (3.24-3.44 mg/L), Chemical Oxygen Demand (154.28-146.41mg/L), Total Hardness (105.97-101.53mg/L), Nitrate (19.48-25.00 mg/L), Lead (0.028-0.023mg/L), Copper (0.014-0.015 mg/L), Zinc (0.090-0.397mg/L), Iron (0.368-0.815mg/L), Total Viable Count (145,833-525,000cfu/ml), Total coliform count (54,167-66.667cfu/ml). Overall water quality shows that both rivers are polluted and highly unfit for use as potable water. It was also discovered that Oro-Obor River is more polluted than Ayo River.*

Keywords: *Comparative Analysis, Pollution, Water, Standard.*

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I. Introduction

According to the Joint Monitoring Programme (JMP) for Water Supply and Sanitation set up by the World Health Organization [1] and United Nations Children's Fund, formerly United Nations International Children's Emergency Fund (UNICEF), safe drinking water is "water with microbial, chemical and physical characteristics that meet WHO guidelines or national standards on drinking water quality". One of the prevailing problems among developing countries is inadequate provision of water resources that meet up with the WHO guidelines on drinking water quality. Anthropogenic pollution of industrial origin remains one of the major environmental problems implicated in water resources management. In Nigeria, as with other developing countries, the problem is compounded by poor hygienic education, fragile economic base, and ineffective environmental regulatory policies and enforcement.

Oro-Obor and Ayo Rivers criss-cross many communities in Enugu South Local Government Area, including the areas bordering Okpara Coal Mine. Coal, fossilized hydrocarbon is associated with environmental pollution. Though the mining activities in the area stopped about 45 years ago, the post-mining coal drainage continues to be a source of organic, heavy metals and miscellaneous contaminants of aquatic environment. Some studies have been done on the physicochemical profile of the water bodies around the Okpara Coal Mine, but they were mostly narrowed to Nyaba River with little or no regard to other water bodies within the vicinity of the mining environment. Coal mines contain a combination of non-renewable metal, mineral and aggregate resources in quantifiable amounts, which are exhaustible with time. Globally, mines are known to be contaminated by heavy metals [2]. Mine operations, being recognized as important sources of heavy metals in the environment [3], are considered an environmental degrading venture. Although anthropogenic-induced metal pollution is associated with a lot of industrial activities such as petroleum exploration, exploitation and utilization, fertilizer application to agricultural soil, battery industries, mining and processing of coal remain probably the major source of environmental pollution by heavy metals and organic wastes [3]. This situation is exacerbated when the mining operations are carried out without post-operation environmental impact assessment. This is the case with the coal mining in Okpara Mine, where the lack of post-mining remediation measures has resulted in the contamination of associated water bodies.

II. Material And Methods

2.1 Sources of Data Collection

For effective execution of this study, two main sources of data were used namely: Secondary and Primary sources of data.

2.1.1 Secondary Data Collection

Secondary data for this study were sourced from text books, newspapers, magazines, periodicals, maps, public libraries, internet, articles, reports etc.

2.1.2 Primary Data Collection

Primary data were collected by the researcher himself from three different locations of the two rivers at four consecutive times for the purpose of statistical analysis. Water samples were collected from point source and two different community locations along the course of the two rivers respectively. During the analysis of the water samples, test for each parameter was performed three consecutive times to minimize any laboratory error of the results. In the case of Oro-Obor River, water samples were collected at point source (A), located at the entry point of Okpara Coal Mine, Akwuke.. Also at the confluence point of Oro-Obor River with Nyaba River, Point (B) located at Akwuke and at Amechi-Uwani/Amechi Uno location, Point(C), water samples were collected. For Ayo River, water samples were collected at point source located at the base of Udi Hill. The second sample was collected at Amechi location, point (B), and the last sample was collected at Ugwuaji location, point (C).These samples collected were subjected to laboratory analysis to establish their physicochemical and microbial profiles needed for this study . Also primary data for this study were generated from personal communication with members of the various rural communities that depend on these rivers for their domestic and artisanal uses. The physicochemical parameters analysed in this work include: colour, pH, electrical conductivity, turbidity, total dissolved solids, dissolved oxygen, biological oxygen demand, chemical oxygen demand, nitrate, total hardness, lead, copper, iron and zinc. The bacteriological parameters analysed were, total coliform count and total viable count

2.2 Sample Collection

Samples were collected from three selected community locations along the route of Oro-Obor river at point source in Akwuke, with coordinates: N06^{O} 24.16', E007 ^{O} 26.942 ' (elevation 816.1m); at the confluence point of Oro-Obor River with Nyaba River at Akwuke, N06^{O} 22.714', E007 ^{O} 27.896 ' (elevation 626.9m) and at Amechi-Uwani/Amechi-Uno point N06^{O} 21.922', E007 ^{O} 31.795 ' (elevation 469.5m). In the case of Ayo River, samples were collected at the point source (base of Udi Hill) at Akwuke, N06^{O} 23.756', E007 ^{O} 29.641 ' (elevation 592.4m); along its route at Amechi, N06^{O} 23.557', E007 ^{O} 28.170 ' (elevation 681.2m) and at Ugwuaji, N06^{O} 24.908', E007 ^{O} 31.645 ' (elevation 526.8m). The samples were collected in sterile sample bottles cleaned with the same water several times. Samples were collected once a week for four consecutive weeks. The samples were labelled for easy identification before taking them to the laboratory.

2.3 Experimental Procedure

Physiochemical and microbial parameters were analysed using standard methods as reported in Association of Official Analytical Chemists (AOAC, 2005).

Colour was determined using Lovibond Comparators. Water sample was introduced into the lovibond cell and the standard disc rotated clockwise. The colour in platinum/cobalt unit was read off against the matched standard colour. The nitrate concentration was determined by the colorimetric method after treating the water sample with sodium salicylate to obtain sodium nitrosalicylate whose colour intensity was proportional to the concentration of nitrate in the water sample. Turbidity was determined by Direct Reading Engineering technique using turbidimeter. The probe of the instrument was dipped into the water sample in a 50ml beaker, and the turbidity was read against a standard in Nephlometric Turbidity Unit (NTU). The pH TDS, conductivity and temperature were also determined by the same Direct Reading Engineering Technique using Hanna multiparametric analyizer. The probe of the unit was dipped into a 50ml beaker containing the water sample and the desired mode called up by pressing the corresponding soft button. The value displayed on the Liquid Crystal Display (LCD) panel was taken as the true value of the parameter.

The trace metals; Lead, Copper, Zinc and Iron were determined using Atomic Absorption Spectrophotometer (AAS). Appropriate hallow cathode lamp was inserted for each metal as the sample was aspirated into the unit after calibration. The bio-load of the water samples were determined using serial dilution techniques while characterization of the microbes was done by macroscopic and microscopic examination of colonial morphology, Gramm-stain and biochemical reactions. Total Hardness was determined by titrimetric method while Dissolved Oxygen was determined by Winkler titrimetric method. Biochemical Oxygen Demand was determined as the difference of DO_1 (initial dissolved oxygen at 20^0C) and DO_5 (dissolved oxygen after 5 days incubation at 20^0C) while Chemical Oxygen Demand was determined by oxidizing the water sample in a defined manner, refluxing with concentrated sulphuric acid and potassium dichromate.

III. Results And Discussion

The results are as presented on tables 1a and 1b below:

Table 1a: Summaries of the Mean Physicochemical and Microbial Parameters of Oro-Obor River at Different Sample Collection Points with their P-Values and Standards Organization of Nigeria (SON) Standards.

Parameters	Point A n= 4	Point B n = 4	Point C n = 4	Over all Mean n = 12	P-Values	SON Standards
pH	5.27 ± 0.590	5.31 ± 0.236	5.34 ± 0.199	5.31 ± 0.389	0.969	7.50
Temperature (°C)	28.44 ± 1.390	28.52 ± 1.319	28.60 ± 1.233	28.`52 ± 1.192	0.986	30.00
Conductivity (µS/cm)	109.15±51.848	78.33 ± 16.665	109.15 ± 51.848	79.44 ± 38.011	0.081	1000.00
TDS (mg/L)	17.50 ± 5.000	32.50 ± 5.000	43.32 ± 22.447	31.11 ± 16.531	0.069	500.00
Turbidity (NTU)	8.53 ± 6.710	114.88 ±25.425	150.68 ± 1.973	91.35 ± 64.535	0.000	5.00
1Color (pt/co)	7.25 ± 2.217	36.00 ± 9.416	49.00 ± 3.367	30.75 ± 18.989	0.000	15.00
DO (mg/L)	11.748 ± 3.088	9.86 ± 2.289	10.43 ± 4.370	10.68 ± 3.150	0.725	7.50
B``OD (mg/L)	3.45 ± 2.050	4.07 ± 1.670	2.20 ± 0.484	3.24 ± 1.622	0.276	6.00
`COD (mg/L)	128.74 ± 21.031	136.13 ± 10.716	197.99 ± 4.733	154.28 ± 34.781	0.000	200.00
Hardness (mg/L)	101.25 ± 1.594	103.33 ± 3.600	113.33±8.606	105.97 ±7.401	0.026	500.00
Nitrate (mg/L)	15.93 ± 2.020	21.26±17.120	21.27 ± 14.341	19.48 ± 11.996	0.802	50.00
Cu (mg/L)	0.007 ± 0.002	0.017 ± 0.006	0.018 ± 0.008	0.014 ± 0.007	0.051	1.00
Pb (mg/L)	0.001 ± 0.000	0.038 ± 0.036	0.044 ± 0.032	0.028 ± 0.032	0.113	0.01
Zn (mg/L)	0.007 ± 0.002 .	0.037 ± 0.018	0.225 ± 0.036	0.090 ± 0.103	0.000	5.00
Fe (mg/L)	0.074 ± 0.008	0.381 ± 0.073	0.644 ± 0.123	0.368 ± 0.255	0.000	0.30
TVC (cfu/ml)	87500±47871.4	137500±118145.4	212500 ± 193110.5	145833 ± 132215.96	0.445	100.00
TC (cfu/ml)	25000±50000	25000 ± 50000	112500 ± 75000	54167 ± 68947.7	0.108	0.00

Legend:

Point A= Sample collection at point source (Enrance point, Okpara Coal Mine) location.
Point B= Sample collection point at Oro-Obor/Nyaba Rivers Confluence location, Akwuke Community.
Point C= Sample collection point at Amechi Uwani/Amechi Uno Communities location.

Table 1b: Summaries of the Mean Physicochemical and Microbial Parameters of Ayo River at Different Sample Collection Points with their P-Values and SON Standards.

Parameters	Point A n = 4	Point B n = 4	Point C n= 4	Over all Mean n = 12	P-Values	SON Standards
pH	5.27 ± 0.150	5.51 ± 0.180	5.69 ± 0.281	5.49 ± 0.261	0.061	7.50
Temperature (°C)	27.80 ± 1.468	28.49 ± 1.336	28.52 ± 1.316	28.27 ± 1.292	0.712	30.00
Conductivity (µS/cm)	83.33 ± 6.665	125.00 ± 6.382	153.42 ± 34.406	120.58 ± 35.352	0.003	1000.00
TDS (mg/L)	33.33 ± 6.665	52.50 ± 5.000	69.17 ± 15.722	51.67 ± 17.894	0.003	500.00
Turbidity (NTU)	5.31 ± 1.285	7.72 ± 1.590	16.78 ± 4.511	9.94 ± 5.770	0.001	5.00
Color (pt/co)	6.50 ± 1.732	9.00 ± 0.000	10.25 ± 1.258	8.58 ± 1.975	0.006	15.00
DO (mg/L)	12.37 ± 3.254	7.65 ± 2.632	9.34 ± 0.795	9.79 ±3.018	0.064	7.50
BOD (mg/L)	3.50 ± 1.115	3.39 ± 0.665	3.42 ± 3.048	3.44 ± 1.731	0.996	6.00
COD (mg/L)	141.10 ± 20.357	189. 10 ± 4.228	109.03 ± 9.303	146.41 ± 36.366	0.000	200.00
Hardness (mg/L)	96.67 ± 2.357	102.50 ± 3.193	105.42 ± 3.696	101.53 ± 4.740	0.010	500.00
Nitrate (mg/L)	22.15 ± 23.170	24.06 ± 12.315	28.80 ± 12.788	25.00 ± 15.520	0.851	10.00
Pb (mg/L)	0.003 ± 0.003	0.031 ± 0.028	0.035 ± 0.040	0.023 ± 0.030	0.280	0.01
Cu (mg/L)	0.014± 0.006	0.016 ± 0.007	0.016 ± 0.010	0.015 ± 0.007	0.962	1.00
Zn (mg/L)	0.110 ± 0.056	0.441 ± 0.122	0.640 ± 0.056	0.397 ± 0.240	0.000	5.00
Fe (mg/L)	0.410 ± 0.093	0.842 ± 0.115	1.192 ± 0.271	0.815 ± 0.371	0.001	0.30
TVC (cfu/ml)	100000 ± 81649	162500 ± 75000	1312500 ± 1501318	525000 ± 978287	0.140	100.00
TC (cfu/ml)	25000 ± 50000	75000 ± 95743	100000 ± 141421	66.667 ± 98473	0.594	0.00

Legend:

Point A= Sample collection at point source (Basement of Udi Hill) location.
Point B= Sample collection point at Amechi Community location.
Point C= Sample collection point at Ugwuaji Community location.

3.1 Physicochemical Parameters

This study focussed on Oro-Obor and Ayo Rivers in Enugu South Local Government Area, Enugu State. The study analysed water samples from the two rivers for some physicochemical and microbial parameters viz: colour, pH, electrical conductivity, turbidity, total dissolved solids, dissolved oxygen, biological oxygen demand, chemical oxygen demand, nitrate, total hardness, Lead, Copper, Iron and Zinc, total coliform and total viable count. From tables 1a and 1b above, the rivers recorded acidic mean pH of 5.31 and 5.49 for Oro-Obor and Ayo rivers respectively. This is in agreement with previous report [4]. Naturally, any water body in contact with coal mine tailings tends to be acidic because of the relative high sulphur, volatile organic matter, and hydrocarbon contents. Acidic water has negative implications for the sustainability of both aquatic and terrestrial organisms. Intestinal ulceration is exacerbated in individuals constantly exposed to acidic water through dietary origin. Acid sensitive aquatic organisms are affected by acidic water conditions. Acidic water affects the gills of fishes thereby limiting their oxygen-carrying capacities. Heavy metals are more bioavailable in acidic water, thus making such water bodies unhealthy for human consumption. The pH of both rivers was out of the acceptable range of 6.50-8.50 for Standard Organisation of Nigeria (SON) [5]. Nganje et al (2010) reported a pH of 4.66 during the dry season and 4.22 during the rainy season for water bodies around Okpara Coal Mine in Enugu [6]. The slight variation in the pH of the present study from the previous studies could be attributed to spatial effects. With the passage of time, the pH increases towards neutrality as a result of many factors including dispersal of the mine tailings by mechanical weathering.

Furthermore, a heavy inflow of water from Nyaba River at the confluence point with Oro-Obor River may have increased the volume of water that enters into Oro- Obor River, leading to increased dilution of the water sample and thus increasing the pH towards neutrality as recorded in this study. From the result of table 1b above, the overall mean turbidity value of Ayo River along different points was 9.94 NTU while Oro-Obor river (table 1a above) recorded an abnormal high value of 91.35 NTU which far exceeded the SON recommended guideline value of 5 NTU. High levels of turbidity can protect micro-organisms from the effects of disinfection and hence stimulate the growth of bacteria.

The colour measured in Platinum/Cobalt unit was higher in Oro-Obor River (table 1a above) with a value of 30.75 pt/co than in Ayo River (table 1b above) which has a value of 8.58 pt/co. The implication of a coloured water lies on its aesthetic value since colour is an organoleptic property. The electrical conductivities of the two rivers were 79.44µS/cm for Oro-Obor (table 1a above) and 120µS/cm for Ayo (table 1b above). These values were within the SON acceptable standard of 1000µS/cm.

From the results of table 1a and 1b respectively, the total dissolved solids of the two rivers were 31.11mg/L for Oro-Obor River and 51.67mg/L for Ayo River. These values were within the SON acceptable limit of 500.00mg/L. It can be said that the two rivers are relatively unpolluted with respect to conductivity and total dissolved solids.

High TDS waters may interfere with the clarity, colour and taste of water. High total dissolved solids indicate hard water and is reported to have effect on the taste and also indicate the presence of toxic minerals in drinking water [7].

The three oxygen related parameters viz: dissolved oxygen (DO); biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were within the SON acceptable limits except dissolved oxygen. The relative high dissolved oxygen of 10.68±3.150gm/L for Oro-Obor River (table 1a) and 9.79±3.018mg/L for Ayo River will (table 1b) support the growth of aquatic lives. The two rivers may be said to be unpolluted with respect to biochemical oxygen demand and chemical oxygen demand but polluted with respect to dissolved oxygen. The mean COD value of 154.28±34.781mg/L was recorded for Oro-Obor River (table 1a) while the COD concentration for Ayo River was recorded as 146.41±36.366mg/L. The mean BOD values of 3.24±1.622mg/L (table 1a) and 3.44±1.731mg/L (table 1b) were recorded for Oro-Obor River and Ayo River respectively. The COD and BOD concentrations of the two Rivers being studied are generally low and observed to be within the SON standard.

From tables 1a and 1b above, the hardness of water samples from both rivers of Oro- Obor and Ayo were 96.67mg/L and 102.50mg/L respectively. These values obtained were in agreement with previous report [8, 9]. The values were also within the SON acceptable limit of 500mg/L. The water bodies were therefore not polluted with respect to hardness. Water hardness is occasioned by carbonate and bicarbonate of calcium and magnesium. Their relative low concentrations as recorded were indications of low contents of carbonate and bicarbonate.

It was generally observed from the mean nitrate-nitrogen concentrations of all the water samples that nitrate pollution was present in both rivers. Ayo River showed highest nitrate concentration at point C sampling point which surprisingly recorded very high mean concentrations of 28.80 mg/L and failed to meet the SON recommended guideline value of 10.0 mg/L for drinking water quality. Since the local economy of the study area is agrarian in nature, the high concentrations of nitrate – nitrogen at Ayo and Oro-Obor rivers could be attributed to agricultural activities where nitrogen fertilizers are extensively used for maize, cassava and vegetable farming. The nitrate concentrations in both rivers, 22.15mg/L for Oro Obor (table 1a) and 24.06mg/L for Ayo River (table 1b) were higher than SON acceptable standard of 10.00mg/L. These observations have negative implications on the health of the rural inhabitants of the study area realizing the association of nitrates in the etiology of metamaglobinemia [10] and the formation of carcinogenic nitrosamines [11].

All the studied metals were observed to be present. The Lead content (table 1a) was 0.003mg/L in Oro-Obor River water sample and 0.031mg/L in Ayo River water sample. While the Oro-Obor value fell within the SON acceptable limit of 0.01mg/L, that of Ayo was significantly higher. Lead (Pb), has been implicated in the ethiology of functional diseases such as microcytic anaemia [12], inhibitory effects on delta-aminolevulinic acid dehydratase [13, 14]. From table 1a and 1b above, the copper content of Oro-Obor and Ayo River water samples were respectively 0.014mg/L and 0.016mg/L against SON standard limit of 1.00mg/L. Copper is an important micro nutrient associated with many metaloenzymes especially cytochrome-c oxidase. Cytochrome-c oxidase plays an important role in oxidative metabolism.

The concentration of zinc in both water samples from Oro-Obor and Ayo Rivers were within SON acceptable limit. For Oro-Obor River, (table 1a above) zinc has a concentration of 0.090mg/L while in Ayo River, (table 1b above) it has a concentration of 0.397mg/L. Zinc is a micro nutrient which at appropriate level helps in the regulation of vitamin A concentration in the blood. It is also a major component of insulin and is essential in the formation of protein. The most prevalent mining related metallic pollutant in this study was iron and was recorded(table 1a and 1b above) to have an overall mean values of 0.368mg/L and 0.815mg/L in the Oro-Obor River and Ayo rivers respectively. These values exceeded the SON recommended standard limit of 0.30mg/L. The recommended daily allowance for iron is 18.0mg per day in human being, above which it constitutes a health threat [15].

Iron (Fe) concentrations in the study area were found to be prevalent pollutant in all the water samples with the highest mean concentration of 1.192mg/L being recorded at point C of Ayo river. One of the sources of these high iron contents in the water bodies were observed to be the results of lateritic bare farmlands lying along and around the Ayo River and the other surrounding streams and rivers in the study area. Again, the soil nature of the study area is deep to moderately deep red in colour and is full of iron stones and quartz gravels. However, the major source of iron in the study area is most probably the pyrite and marcasite gangue found in the Enugu coal seams. When pyrite (FeS_2) is oxidized, iron is released. The iron coats the water surface as well as the sediments with the characteristic yellow or orange colour. Iron content of Oro-Obor River water sample was 0.410mg/L (table 1a) while Ayo River water sample had iron concentration of 0.842mg/L (table 1b). These values were significantly higher than the SON recommended standard value of 0.30mg/L. This certainly will have negative health implications as iron over-load is associated with polycythemia [16].

3.2 Bacteriological Parameters

Both Total Viable Count (TVC) and Total Coliform Count (TCC) in the two Rivers were above the SON standard values of 100cfu/ml and 0.00cfu/ml respectively.

These have negative public health implications as the coliforms are among the major microbes of pathological importance. Although the WHO guidelines recommend the complete absence of microbial indicators in any 100 ml of drinking water, however, Oro-Obo River (table 1a above) in this study recorded high numbers of both Total Faecal Coliforms and Total Viable Count colony counts of 54167cfu/ml and 145833 cfu/ml respectively. Ayo River(table 1b) also recorded high bacterial count. The total viable count was 525000cfu/ml while the total coliform count was 66.667cfu/ml. The concentrations of these microbial indicators in the water samples are indications of serious bacterial contamination

IV. Conclusion And Recommendations

Water quality impact from hard rock mines are often very difficult to predict. Despite modern technology, mining companies' impact predictions are very difficult to achieve. In the light of the situation, it is possible as explained in the study that surface water bodies located in the vicinity of mining operations have been widely implicated with mine pollution resulting in poor water qualities whose assessment parameters often differ significantly from the Standard Organisation of Nigeria or WHO recommended permissible limits. The long term environmental and health implications are often severe. As a proactive mitigation measure, new alternative sources of water supplies in the form of boreholes should be provided for the affected communities in Enugu South Local Government Area whose traditional sources of drinking water are endangered by the post coal mining activities and other negative environmental practices in the area. Farmers should be restrained from the use of modern synthetic nitrogen fertilizers but rather be encouraged to embrace the application of organic manure to farmlands as a way of reducing nitrate levels as well as its sediment deposits in the rivers. Rural farmers who engage in garden activities along the river banks of Oro-Obor and Ayo Rivers should avoid direct use of water from the two rivers. Instead, they should access water from boreholes located a little distance away from the river banks for the daily watering exercise of their crops to prevent introduction of heavy metals embodied in the rivers to the plants, animals and man through food chain.

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