

UNDERGROUND WATER QUALITY OF ROCK MINING IN ISHIAGU, EBONYI STATE, NIGERIA

*Qualidade da Água da Mina de Crushrock em Ishiagu,
Estado de Ebonyi, Nigéria*

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Abstract

Physicochemical and bacteriological analysis of underground water of Crush Rock mining pit in Ishiagu, Ebonyi State Nigeria were carried out to determine the pollution level and the potability of the groundwater due to mining and human activities. The results were compared with standards for water pollution and World Health Organization for drinking water. The results showed that total dissolved solids (TDS), total alkalinity, calcium and sodium, which had concentration ranges of 126-986ppm, 200.18-615.55ppm, 7.8-30.10ppm and 64-88ppm respectively, were above standards. However, the mean concentration of dissolved oxygen (DO) (1.2-3.20ppm) was below the standard. Other parameters measured were found to be within the permissible acceptable standard. *Pseudomonas*, *Chromobacterium*, *Bacillus*, *Escherichia*, *Staphylococcus*, *Flavobacterium*, *Micrococcus*, *Citrobacter* and *Achromobacter* species were identified as the major bacteria isolated from the underground water. The study revealed that the underground water from Crush Rock mining pit in Ishiagu Ebonyi State, Nigeria require some chemical and physical treatment as it is unsafe for human consumption.

Keywords: Underground water; Potability; Pollution; Bacteria.

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Resumo

Análises físico-químicas e bacteriológicas da água da mina de Crush Rock em Ishiagu, estado de Ebonyi, na Nigéria, foram feitas para determinar o nível de poluição e potabilidade da água subterrânea, devido à mineração e às atividades humanas. Os resultados foram comparados com os padrões da Organização Mundial da Saúde. Os resultados mostraram que o total de sólidos dissolvidos (TSD), alcalinidade total, cálcio e sódio tinham concentrações variando, respectivamente, entre 126 a 986 ppm, 200,18 a 615,55 ppm, 7,8 a 30,10 ppm e 64 a 88 ppm estiveram acima dos padrões. Entretanto, a concentração média de oxigênio dissolvido (OD) variava entre 1,2 a 3,2 ppm, abaixo do padrão. Outros parâmetros medidos foram encontrados dentro do aceitável permitido. *Pseudomonas*, *Chromobacterium*, *Bacillus*, *Escherichia*, *Staphylococcus*, *Flavobacterium*, *Micrococcus*, *Citrobacter* e *Achromobacter* foram identificadas como as principais espécies de bactérias isoladas da água. O estudo revelou que a água da mina de Crush Rock requer tratamento químico e físico, para poder ser consumida pela população, já que nas condições atuais ela não é potável. **Palavras-chave:** Água subterrânea; Potabilidade; Poluição; Bactérias.

Introduction

Underground water is a body of water occurring in the subsurface especially in the zone of saturation where all the pores and cracks are filled with water. During the percolation of groundwater, it takes along dissolved organic and inorganic materials. Microorganisms are frequently trapped on the surface water and as the water percolates some of the microorganisms will find their ways into the groundwater.

Global industrialization, Africa inclusive, has resulted in increased demand for this natural resources, water and this is more severe in the third world countries like Nigeria. The discharge of untreated or fairly treated wastes into ecosystems brings about structural, physical and chemical changes which often affect the biota (1) The physicochemical attributes of any water body are prime factors which influence its overall productivity, reproduction, and growth performance (2). Of notable importance are pH, transparency, temperature, dissolved oxygen, suspended solids, biochemical oxygen demand and dissolved ions, of which, play critical role in determining the suitability of the water for aquatic life as well as for other human uses (3). Any alteration of these water parameters, either through anthropogenic activities or natural disaster, often results in concomitant alteration of the aquatic life. WHO (4) described water not only as a giver of life but also as a source of many human diseases. The status of biological communities, particularly bacteriological quality, in water is of direct interest to microbiologists, hydrobiologists, public health officers, town planners, statisticians, engineers etc., as it serves as a measure of the extent of pollution in the system.

Monitoring the pollution level of water bodies in the developed world has been a continuous process (5,6, 7), but the pollution level of Nigeria's water has not been adequately monitored. The scourge of water and soil pollution on our people cannot be over emphasized and had made studies directed towards such investigations to be of utmost importance in alleviating the accompanying undesirable impact on the populace. Furthermore, the awareness such studies would create would be invaluable to our national government and other international organization in the realization of a healthy populace. This is of utmost importance and interest, especially now that there is global call on governments to give priority attention to environmental protection efforts in their countries (4,6 8).

Following the various industrial (especially rock mining), agricultural and commercial activities taking place in Ebonyi State, South-East Nigeria, this work is aimed at evaluating the effects of crush rock in Ebonyi State Nigeria.

Materials and Methods

Three sampling points were selected which were made up of one from the center and two from the banks. One and half liter of polythene containers with screw stoppers were used for collection of the samples. The containers were thoroughly washed with detergent after soaking them overnight and finally they were rinsed with deionised water. At the sampling point, each labeled container was rinsed with the sample. The sample was collected by stirring the 'spot and the container

was lowered to about 15cm depth to collect representative water sample. The samples were transported to the laboratory within 2-4 hours and stored at 40°C prior to analysis.

The temperature of the water was determined with a digital mercury thermometer and the turbidity of the water sample was determined with turbidimeter (9). Conductivity was determined by the method in Philips manual of laboratory conductivity meter (10). Total dissolved solid (TDS) was indirectly determined using the equation: $TDS = \text{Conductivity} / 2$ (11). The total suspended solids (TSS) were determined by calling up the program number (20) for total suspended solids on the Shimadzu UV – 160A-recording spectrophotometer at 400 nm. Following standardization with distilled water as blank, the samples were then introduced and the values read off as displayed on the screen (11). The pH was determined using Corning digital 112-pH meter.

Sulphate, chloride, sodium, potassium, alkalinity, silica, and dissolved oxygen content were determined by the methods outlined in standard methods for examination of Water and Waste Water (12). Calcium ion (hardness) was estimated by application of the method report in Hachwater Analysis Hand Book (11, 13).

The trace / heavy metals (Pb, Zn, Fe, Cd and Cu) content were assayed with Atomic Absorption Spectrophotometer, Unicam 969 in an air-acetylene flame.

Bacteriological investigation was carried out by pour plate method on a nutrient agar which was prepared according to the manufacturer's instruction, and was sterilized in the autoclave at 121° for 15 min. one milliliter of each water sample was transferred with sterile pipette into sterile petri dishes. The agar was poured into each of the petri dishes. The petri-dishes were rocked gently to mix the agar and the water sample. The plate was later incubated at 37°C for 24-48 hours for bacteria. At the end of the incubation, the colonies that developed in plates were counted with colony counter. The isolates were further characterized and identified by carrying out Gram staining, catalase, citrate, oxidase and some other biochemical tests.

Results

Table I summarized the physical properties of underground water of crush mining while tables II and III present chemical properties and the heavy metal values of the groundwater respectively. The seasonal variation of physicochemical qualities of the underground water is presented in table IV. The Results show that pH of the water sample lies between 7.5 and 8.2, and temperature was in the range of 26.1–27.1°C while turbidity, conductivity, total suspended solid (TSS), total dissolved (TDS) and dissolved oxygen had ranges of 0.5-179.4 {NTD}, 253-1800 ppm, 4.01-26.4 ppm, 126-986 ppm, and 1.2-3.20 ppm respectively. Similarly, the range of potassium (0.03-0.57 ppm), calcium (7.8-30.10 ppm), silica (2.120-3.590 ppm), sulphate (37.80-115.00 ppm), chloride (42.76.21 ppm), sodium (64.88 ppm) and alkalinity (200.18-615.55 ppm). The heavy metal contamination was low as their values ranged from 0-0.062 ppm from iron, 0-0.042 ppm for lead, 0-0.014 ppm for cadmium, 0-0.005 ppm and 0.009 for copper.

Table V showed that bacteria species made up of Gram positive and Gram negative organisms were isolated from the underground water. They included *Pseudomonas*, *Chromobacterium*, *Bacillus*, *Escherichia*, and *Staphylococcus* species. Others were *Flavobacterium*, *Micrococcus*, *Citrobacter* and *Achromobacter* species. The prevalence of bacterial organisms isolated was presented in table IV. *Pseudomas* and *Bacillus* species had the highest prevalence of 100% occurring in all the samples screened, and *Escherichia coli* and *Chromobacterium* species had prevalence of 91.6% and 66.6% respectively. This was followed by *Staphylococcus* species (50%), *Flavobacterium* species (41.7%), *Micrococcus* and *Achromobacter* species had 33.3% each, while the least prevalent organism was *Citrobacter* species with 25% occurrence.

TABLE I: Physical properties of underground water of Crush Rock Mining

Date	Temp. °C	Turbidity (NTU)	Conductivity (ms/cm)	TDS (ppm)	TSS (ppm)	PH
Aug. 2002	28.0	179.4	250	126	4	8.1
Oct. 2002	27.4	150.1	1871	986	26.41	7.6
Dec. 2002	27.6	0.5	1650	814	18.32	7.7
Feb. 2003	27.6	19.2	1224	688	9.1	7.6
Apr. 2003	28.6	4.4	629	339	8.06	7.6
Jun. 2003	28.3	2.1	359	186	46.2	7.6
Aug. 2003	28.0	17.9	253	126	4.01	8.2
Oct. 2003	27.6	14.7	390	148	15.01	7.6
Dec. 2003	27.4	1.0	1453	718	9.26	7.5
Feb. 2004	27.5	19.0	860	480	9.01	7.7
Apr. 2004	26.1	4.4	609	301	8.0	7.6
Jun. 2004	26.8	2.1	360	181	4.61	7.6

TABLE II: Chemical properties of underground water of Crush Rock Mining

Date	SO ₄ ²⁺ (ppm)	Cl ⁻ (ppm)	Na ⁺ (ppm)	Alkalinity (ppm)	K ⁺ (ppm)	Ca ²⁺ (ppm)	Silica (ppm)	DO (ppm)
Aug. 2002	100.0	42.1	65	200.2	0.03	14.2	3.69	1.2
Oct. 2002	50.4	50.61	88	200.2	0.18	10.6	2.12	1.8
Dec. 2002	90.4	47.1	84	350.5	0.16	7.8	2.54	2.0
Feb. 2003	37.8	47.1	85	615.6	0.57	20.2	3.02	3.2
Apr. 2003	680	45.6	70	260.4	0.21	30.1	2.91	1.2
Jun. 2003	45.3	42.8	64	201.6	0.01	9.0	2.55	1.6
Aug. 2003	115.2	43.1	66	240.7	0.003	12.2	3.59	2.0
Oct. 2003	60.1	50.1	82	210.2	0.15	11.8	3.01	1.6
Dec. 2003	64.0	56.2	84	310.1	0.22	10.0	3.14	2.0
Feb. 2004	45.2	54.0	82	412.6	0.46	8.14	3.26	2.2
Apr. 2004	70	47.6	70	250.0	0.26	30.1	2.11	1.2
Jun. 2004	80.2	48.7	74	261.6	0.16	9.0	2.55	1.5

TABLE III: Heavy metal values of underground water of Crush Rock

Date	Fe (ppm)	Pb (ppm)	Cd (ppm)	Zn (ppm)	Cu (ppm)'
Aug. 02	0.01	0.02	0.02	0	0.01
Oct. 02	0.02	0.01	0.01	0	0.01
Dec. 02	0	0	0	0	0
Feb. 03	0	0.04	0	0.01	0.01
Apr. 03	0.01	0	0	0	0
Jun. 03	0.06	0.01	0	0	0.01
Aug. 03	0.01	0.02	0.01	0	0.01
Oct. 03	0.02	0.01	0	0	0.01
Dec. 03	0.01	0.01	0	0	0.01
Feb. 04	0.01	0.01	0	0	0
Apr. 04	0.02	0	0	0	0
Jun. 04	0.06	0.01	0	0	0.01

TABLE IV: Seasonal variation of physicochemical qualities of underground water of crush rock mining

Parameter	Dry Season N = 6			Rainy Season N = 6		T. level
	Mean	SD	Range	Mean	SD	
PH	7.62	0.08	7.5-8.20	7.8	0.35	-1.465
Temp.	27.52	0.09	26.1-27.10	26.73	0.55	2.065
Turbidity	9.32	9.26	0.5-179.40	61.97	101.71	-0.817
Conductivity	1229.5	527.93	253-1800	413.67	291.90	0.081
TSS	14.54	6.95	4.01-26.40	5.56	2.18	3.052
TDS	639.0	291.90	126-986	217.0	109.83	3.441
DO	2.13	0.56	12-3.20	1.6	0.4	2.023
Potassium	0.29	0.18	0.03-0.57	0.11	0.09	1.947
Calcium	11.42	4.56	7.8-30.10	17.1	11.37	-4.490
Silica	2.84	0.44	2.120-3.590	3.02	0.53	-0.191
Sulphate	57.99	18.54	37.80-115.00	76.17	35.66	-1.723
Chloride	50.85	3.67	42.76-56.21	43.82	1.55	3.135
Sodium	84.17	2.23	64-88	66.67	3.06	8.868
Alkalinity	349.83	153.64	200.18-615.55	234.25	29.93	1.972
Iron	0.02	0.02	0.0-0.062	0.03	0.03	-0.679
Lead	0.01	0.01	0.0-0.042	0.01	0.01	1.912
Cadmium	0.004	0.003	0.0-0.014	0.006	0.007	3.627
Zinc	0.001	0.002	0.0-0.005	0.001	0.002	0.0
Copper	0.006	0.003	0.0-0.009	0.006	0.005	0.420

TABLE V: Characterization and identification of bacteria isolates from water sample

Colony Characteristics	Cells shape & arrangement	Oxidase Test	Cream Reaction	Catalase Test	Citratic Test	Indole Test	Urease Test	M.R.	VP	Starch Hydrolysis	Motility	Endospore	H.S.	Gas	O/F Test	Gelatin Degradation	Nitrate Reduction	Lactose	Maltose	Sucrose	Mannitol	Glucose	Fructose	Xylose	Isolate
Cream coloured raised, wavy edge colonies spreading widely and dull appearance. Turned light brown later	Rods in chains and few in singles large cells	+	+	+	+	-	-	-	+	-	-	+	-	-	+	-	+	+	-	-	+	-	-	-	<i>Bacillus</i> species
Mucoid, convex, irregular surface with entire edge Diffuse greenish-blue pigment in N.A	Rods, Slender a few in pairs. Others in singles	-	+	+	+	-	-	-	+	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	<i>Parasporangium</i> species
Cream coloured colonies of flat & spreading with a rough edge	Rods	+	-	+	+	-	+	-	-	+	+	-	-	-	0	+	-	-	+	-	-	-	-	-	<i>Aeromonas</i> species

Discussion

It is difficult to find a river or other body of water whose natural regime has not been modified in one way or another by man's activity. At the same time, man really depends on water for domestic consumption, industrial, recreational and agricultural purpose and the quality of water for each purpose differs tremendously. The result of our study revealed that the mean pH concentration for dry (7.62) and rainy (7.8) seasons were within the range of 7-8.5 as set by WHO (14) for drinking water. pH which is below 7 can impart a sharp acid taste to water and can easily corrode the pipe borne plumbing (11). The temperature range of 26.1-27.1°C falls within the normal international standard for discharge into streams. The mean value of temperature was found to be higher in dry season (27.52°C) than the rainy season (26.73°C). The highest temperature values were recorded in the months of April (28.6°C) and June (28.3°C) 2003 while the least temperature value was in April (26.1°C) 2004. Similar findings were recorded in our earlier work (15). It is important to note that temperature exerts a marked effect upon the pollutional characteristics of a stream or water body since the amount of oxygen that a water body can carry is inversely proportional to the temperature of the water body. The temperature values for the study did not vary much in both seasons. A water body whose temperature rises above 33°C is generally considered unsuitable for public water supplies (16, 17, 18). Turbidity is one of the water characteristics, which although not harmful to the health of people using it but may affect its acceptability as a domestic supply. The international standard sets the maximum permissible level for turbidity at 25 units (19). The results indicated clearly that the rainy season mean turbidity value. (61.97 NTU) was higher than the dry season value (9.32 NTU). That is the rainy season value was above the international standard while the dry season value was below the WHO standard. The implication of the higher values of turbidity is that more energy and chemicals will be needed in rainy season than in the dry season at the treatment plant (16). The conductivity values were highest in the months of October, 2002 (1871 ms/cm) and December 2003 (1453 ms/cm). The least values of 250 ms/cm, 253 ms/cm, and 359 ms/cm were recorded in the months of August 2002, August

2003 and June 2003 respectively (Table 1). The lower mean values of conductivity observed in the rainy season (413.67ms/cm) when compared with dry season value (1229.5 ms/cm), had been attributed to the dilution effect of rains. These values are within the acceptable standard limits of 300 ms/cm (20, 16). Total suspended solids (TSS), total dissolved solids (TDS) and dissolved oxygen (DO) were higher in dry season than in rainy season. This is due to the dilution effect of rainy and reduced mining activities during the rainy season. The TSS was relatively good since its concentrations were within the minimum acceptable standard for domestic use and many industrial purposes. The value of TDS was however above the permissible international standard of 500 ppm. This is objectionable since water higher in dissolved solids should be viewed as potentially corrosive to well screens and other parts of well structure (21). The low range of DO (1.2-3.20 ppm) recorded during the study is an indication that the underground water of Crush Rock mining is not suitable for aquatic life. This is because under favorable environmental conditions, a minimum constant value of 5 ppm (DO), is satisfactory for sustenance of aquatic biota including fishes (15, 22). The total alkalinity reported in terms of their equivalent carbonate had range values of 200.18 - 615.55 ppm, with higher mean value of 349.83 ppm in dry season and lower value of 234.25 in rainy season. The total alkalinity concentrations exceeded the WHO standard throughout the sampling period. The concentrations of some parameters such as potassium, sulphate and chloride were found to be within the minimum acceptable and maximum allowable WHO standards for drinking and domestic purposes. Nduji *et al.* reported that chloride, sulphate and nitrate ion content of Nigerian surface and underground waters are negligible when compared with WHO standard (23). Other researchers made similar findings (11, 15, 16, 24, 25).

Concentrations of calcium and sodium were found to be well above the maximum acceptable WHO limit. The high values of calcium and sodium recorded may be attributed to the partial solubility of the calcium carbonate (CaCO_3) and other minerals that are component of the quarry stone (11, 26). This observation agrees with earlier findings of this work on increased level of alkalinity since carbonate had been known and

reported to increase alkalinity (27). There is no reliable standard for silica content in drinking water, however, the silica values of the samples ranged from 2.120 - 3.590ppm. Higher values of silica had been reported and were attributed to the silty nature of the soil or blasting activities of the rock or probably due to other redox activities (11, 28). Results obtained showed that the rate of accumulation of these heavy metals in the underground water did not vary as such among the samples examined. In all the samples examined, some metals were not detectable. Overall, seasonal variation of these metals shows that rainy season has relatively mean higher values for iron and cadmium than in the dry season. Copper on the other hand had higher mean value in the dry season than rainy season. Lead and Zinc did not display any seasonality throughout the study. All the values obtained in the present study are however below WHO standard limit (20), FEPA (29) and DPR (30). Although, these trace metals differ widely in their chemical properties, their relative concentrations and discharges and hence, their bioavailability are very important to terrestrial, aquatic and marine organisms in terms of toxicity (31). The emission of these heavy metals often result in extensive and persistent contamination of water and vegetation. The overall effects of the resultant emissions, on the living organisms including animals and humans are many and often life threatening. For example lead is known to produce developmental neurotoxicity and it has been shown that infants, children and pregnant women may be differentially sensitive to environmental lead exposure. Lead can cause abdominal pain, vomiting, drowsiness, convulsion, malfunction of the kidney, reproductive system, liver, brain and the central nervous system structural abnormalities, altered growth and functional deficits, sexual maturity and consequently death (11, 15, 32, 33, 34, 35). Zinc has low toxicity to man, but relatively high toxicity to fish (36). Thus, contamination of aquatic environments with larger quantities of zinc would cause massive death to fish (37). Although sterile water devoid of microorganisms rarely exist except in the laboratory (38), studies have shown that strategies abound for the treatment of water meant for human consumption to permissible level of microbial flora especially coliform (14,19,20). Thus, the present results suggest that the

underground water require further microbiological treatment if the water should be used as drinking water. The results corroborate the levels of microbial flora obtained in other works (11, 15, 26, 39). The presence of *Escherichia coli*, *Pseudomonas sp.*, *Chromobacterium sp.* in the water samples is indicative of fecal or related pollution due to either humans or animal (reptiles, birds and rodents) activities. *Staphylococcus* may have originated from human activities which is indicative of lack of personal hygiene of the miners. There was evidence of indiscriminate defecation and absence of drainage systems in the study area. The surface run off of waters into the mining probably seems to be the major source of the bacterial contamination. *Pseudomonas* and *Bacillus* were isolated from the water sample throughout the study and their consistent isolation could be associated with the physiological nature of the organisms usually in water where they can survive with very minimal nutrients as reported by Caincross et al. (40) and Ogbulie and Akujiobi (41). The trend in the isolation of these bacterial species reveals the characteristic microbial contamination of the underground water and the high incidence of some of them in the samples indicate the ability of these organisms to thrive in different environments.

Conclusion

From the chemical and bacteriological analysis of the underground water, it is evident that the underground water investigated is polluted as compared with standards. Therefore, it is not portable. The pollution level of the underground water is due to the mining activities, human and animals (reptiles, birds, and rodents) activities, water run off and improper refuse and sewage disposal around the mining area.

It is suggested that the state, local government, ministries or agencies responsible for the environmental health, minerals, labour etc. should make and enforce laws on mining, sewage and refuse disposal. Adequate drainage system should be provided to protect the pit and minimize the pollution of the water. It is strongly recommended that these waters should be treated before being used for drinking and other domestic purposes.

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