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The Environmental and Health Implications of Quarrying Activities in the Host Community of Oba-Ile in Akure, Nigeria



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ABSTRACT

Background: Blasting is used for the extraction of hard rocks using explosives and has easy operation and high efficiency. The explosives used in blasting are combined chemical substances, which enter the environment after detonation. This study aimed to investigate the effects of the chemicals released into the environment in blasting.

Methods: Water and soil were collected from inside and outside the quarry. Heavy metals and other deleterious constituents were assessed for AAS, and the results were compared with the WHO standards (domestic water use) and FAO (classification of soil macro- and micronutrients). The impact of mining on water and soil was evaluated by comparing the samples of the inside/outside the quarry.

Results: The mean pH of the water samples of the inside and outside the quarry was 5.52 and 5.47, respectively. Manganese and chromium in both water samples were WHO standard, while lead and cadmium were not detected in these samples. The mean pH of the soil samples of the inside and outside was 5.98 and 6.0, respectively. The heavy metals in the soil samples were FAO standard.

Conclusion: Quarrying adversely affects the environment. The EIA and strict implementation of the outlined mitigation measures should be enforced to guarantee sustainability.

1. Introduction

A quarry is a surface mine that produces enormous quantities of construction materials (e.g., gravel and limestone) for industrial applications [1]. For quarrying to take off, the landscape is drastically altered, and the ecosystem is totally disrupted by the clearing of vegetation, while surface hydrology, groundwater levels, and flow paths are also diminished [2]. The magnitude and nature of the environmental impact of quarry operation depends on the type of the extracted rocks, environment surrounding the quarry, size of the quarry, and geography and geology of the area [3, 4]. Aigbedion and Iyayi discovered a declining trend in the crop output of the farms within a close radius to quarries, concluding that the phenomenon was most probably associated with the dust pollution of the crop leaves and flowers, disrupted photosynthesis, and reduced yield [5]. The adverse effects of quarrying activities on crop

health and yield and human health could be inversely proportional to rural livelihood. According to Bradshaw and Chadwick, livestock growth and the development and productivity of livestock could be affected by the shocks induced by the blast noise and vibration [2].

In general, the effects of dust emission from quarries have micro-spatial and regional dimensions. The air pollution and ground vibration arising from blasting, crushing, and emission of noxious gases adversely affect human health and wellbeing. Undoubtedly, the most contentious environmental impact experienced by the residents living in the proximity of quarries and surface mines are those caused by blasting [6, 7].

Quarry activities also produce an ever-growing number of abandoned quarry pits, which are quickly filled with water and become suitable habitats for freshwater snails that act as an intermediary host for *Schistosoma haematobium*, eventually contributing to the prevalence of urinary



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disorders and other diseases that carry the organisms. This issue leads to the increased susceptibility of the rural populace to various health challenges [8]. Furthermore, suspended particulate matters are considered to be another major pollutant emanating from quarrying operations.

Quarrying is the most common mining method in Nigeria due to the abundance of granite and limestone deposits and the simplicity of the method to recover these materials compared to other available minerals. Ondo State is one of the states in Nigeria with rich granite deposits, which have attracted various investors to earn the state revenue, immensely contributing to the growth and development of the state. However, the adverse effects of such activities have been confirmed on the environment, which may lead to immediate/accumulative, physical, chemical, biological or mental environmental and health hazards [9, 10].

The present study aimed to investigate the environmental audit of quarrying areas in Nigeria.

2. Materials and Methods

2.1. Sample Collection

The study area was Oba-Ile in Akure North local Government Area of Ondo State, which is located between the longitude of 7°16'0" N-7°17'0" N and latitude of 5°14'30" E-5°15'30" E. Water and soil samples were collected at strategic points within and outside the quarry for laboratory analyses, and the results were compared with the international standards of the World Health Organization (WHO) and water and soil samples standards of the Food and Agriculture Organization (FAO).

The water samples were collected from 10 sampling points in different water bodies within and outside the quarry site and placed inside washed and rinsed sampling bottles. The water samples were collected from the ponds at crushing and drilling points, two streams, and a borehole within the quarry. In addition, water samples were collected from two wells, two streams, and a pond within 200 meters from the quarry. Soil samples were strategically collected from 10 different locations; five samples were obtained from within the quarry, and five were collected from outside the quarry for impact comparison purposes. The soil samples were collected from the crushing and drilling points at the road link between the crushing and drilling points and a farm within the quarry, as well as the farms within 250 meters from the quarry.

2.1.1. Preparation of the Soil and Water Samples

Air-dried soil samples were ground and sieved using a two-millimeter mesh [11], stored in polythene bags, and labeled before analysis. The water samples were preserved as prescribed by the American Public Health Association (APHA) in terms of different parameters [12]. The samples aimed for physicochemical parameters were stored in a pre-washed two-liter keg, and the samples aimed for heavy metals were stored in a pre-washed one-liter keg and fixed to the pH of < 2. Some physicochemical parameters (e.g., temperature, pH, and dissolved oxygen [DO]) were determined in situ at the site of sample collection. The samples were preserved in ice chests and transferred to the laboratory where they were further refrigerated at the

temperature of 40C until the analysis of the other physicochemical parameters.

2.2. Determination of Heavy Metals in the Water Samples

Initially, the effluent samples were digested with conc. HNO₃ and pre-concentrated before analysis using an atomic absorption spectrophotometer (AAS). Afterwards, 100 milliliters of the well-mixed samples was measured into a 250-milliliter beaker, and 10 milliliters of the concentrated HNO₃ was added. The solution was evaporated to near dryness on a hot plate under medium heat and was not allowed to boil. The beaker with the content was allowed to cool to the room temperature, after which another 10 milliliters of the portion of conc. HNO₃ and five milliliters of H₂O₂ were added. The beaker was immediately covered with a watch glass, returned to the hot plate, and heated under a gentle reflux action, and the process continued until a whitish residue was obtained. The residue was dissolved in five milliliters of the concentrated HNO₃ and a quantity of distilled water. After cooling, the solution was filtered through a Whatman No. 42 filter paper into a 25-milliliter volumetric flask and made to the mark with distilled water. Finally, the solution was transferred into a polythene bottle prior to the AAS analysis. Per every batch of the samples, reagent blanks were prepared.

Calcium and magnesium ions in the water samples were measured using the EDTA titration method. To do so, two milliliters of 1 M NaOH solution was added to 50 milliliters of the water sample, followed by a small quantity of a murexide indicator. The pink color of the solution appeared, and the solution was titrated with 0.01M EDTA solution to turn purple at the endpoint [13]. The titer value indicated the calcium hardness alone and was used to calculate Ca²⁺ (mg/l), and Mg²⁺ was calculated based on the difference in the titer values of total hardness and calcium hardness.

2.3. Analysis of Heavy Metals in the Soil Samples

Dry soil samples were analyzed in terms of lead, zinc, chromium, and magnesium concentrations using the AAS after sample digestion. To do so, two grams of the samples were dried to a constant weight and digested with a nitric-perchloric hydrofluoric acid mixture (1 ml:1 ml) [11]. After cooling to the room temperature, five milliliters of saturated boric acid was added to the complex with HF, which would otherwise attack the glassware. The digests were filtered into 50-milliliter standard flasks using a Whatman No. 1 filter paper and made up to the marks with distilled water. The concentration of each heavy metal in the sample solution was measured against the serially diluted mixed standard solutions containing the heavy metals within linear concentration ranges. At this stage, we used an AAS (a bulk scientific model 500A) with a deuterium background corrector, a hollow cathode lamp, and an electronic computing system.

2.4. Cation Exchange Capacity

The cation exchange capacity (CEC) is a measure of the quantity of the readily exchangeable cations neutralizing the negative charge in the soil, which was evaluated in this study [11].

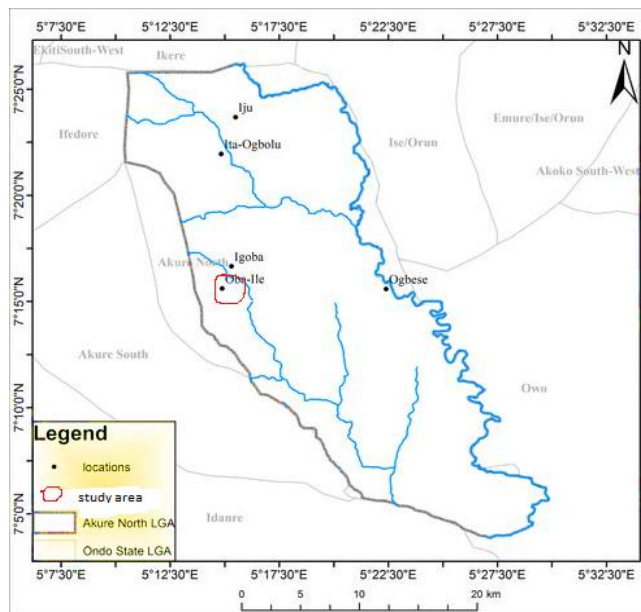


Figure 1: Location of Study Area

3. Result and Discussion

3.1. Water Samples Analysis

The parameters assessed in the water samples were pH, lead, chromium, cadmium, and manganese. The mean pH of the collected water samples from the within and outside of the quarry was 5.52 and 5.47, respectively (Tables 1 and 2), which indicated that quarry operations within the study area had no significant impact on the pH of water ($P=0.792$).

According to the WHO [14], pure water is neutral at the pH of 7 and temperature of 25°C; when opened to the carbon dioxide in the air, this equilibrium shifts to the pH of approximately 5.2. This confirms that the water samples collected from within and outside the quarry were within the expected ranges of stream waters. Stream water is near acidity to neutrality. According to the information in Tables 1 and 2, lead was not detected in the samples collected from outside and inside the quarry, indicating that quarry operations did not inject toxic lead into the environment.

In the present study, manganese was detected in the water samples collected from inside and outside the quarry with the ranges of 0-0.05 and 0-0.01 cmol(+)/kg, respectively. These values were far below the recommendations of the WHO, based on which the intake of manganese per day is within the range of 8-9 milligrams as an utterly safe level [15]. In the water quality analysis, chromium was detected in three out of five of the water samples collected from inside the quarry (mean: 0.152 cmol(+)/kg), while the samples collected from outside the quarry had the mean value of 0.236 cmol/kg. These values were below the standard of 0.05 mg/l, which is recommended for drinking water [13]. Notably, the variations in the mean values of the tested parameters in the water quality analysis of the samples collected from inside and outside the quarry were very close, which indicated that quarrying induced toxicity in the water bodies of the study area.

Table 1: Water Quality Analysis of Samples Collected from Inside Quarry

Parameters	Unit	Samples				
		1	2	3	4	5
pH	1:2 H ₂ O	5.45	5.21	5.61	5.21	6.12
Pb	cmol(+)/kg	ND	ND	ND	ND	ND
Ch	cmol(+)/kg	ND	ND	0.2	0.39	0.17
Cad	cmol(+)/kg	ND	ND	ND	ND	ND
Mn	cmol(+)/kg	0.01	ND	0.05	ND	0.01

Table 2: Water Quality Analysis of Samples Collected from Outside Quarry

Parameters	Unit	Samples				
		1	2	3	4	5
pH	1:2 H ₂ O	5.61	5.55	5.41	5.57	5.21
Pb	cmol(+)/kg	ND	ND	ND	ND	ND
Ch	cmol(+)/kg	0.28	0.14	0.32	0.34	0.1
Cad	cmol(+)/kg	ND	ND	ND	ND	ND
Mn	cmol(+)/kg	0.01	0.01	ND	ND	0.01

3.2. Soil Sample Analysis

The soil samples collected from inside and outside the quarry were analyzed in the laboratory to evaluate pH, sodium, calcium, magnesium, CEC, lead, cadmium, manganese, and chromium (tables 3 & 4). The pH values of the soil samples collected from within the quarry were within the range of 5.51-6.64 with the mean value of 5.98 (Table 3). On the other hand, the pH of the soil samples collected from far outside the quarry was within the range of 5.21-6.59 with the mean value of 6.0 (Table 4). The comparison of the mean pH did not reveal whether the quarry activities in the study area affected the soil.

According to the results of the present study, the variation of the mean difference in pH was not significant as it was within the optimal range for organic soil (5.5-6.0) [11], which is the pH range at which most nutrients are available in soil. The sodium and chemical analyses of the soil samples collected from within and outside the quarry were also performed to assess elements such as sodium, calcium, magnesium, manganese, lead, and CEC. The samples were also evaluated in terms of sodium, and the results indicated that samples A, B, C, D, and E (within the quarry) had the values of 2.13, 2.14, 2.03, 1.95, and 1.35 cmol(+)/kg, respectively, with the mean value of 1.92 cmol(+)/kg. On the other hand, the values of samples one, two, three, and four (outside the quarry) were within the range of 1.21-1.29 cmol(+)/kg, with the mean value of 1.24 cmol(+)/kg. The samples collected from within the quarry had higher values and mean values, which may be accredited to the use of explosives in rock blasting. The values of all the samples were within the range of the FAO classification for the very high levels of macro- and micronutrients.

3.3. Magnesium Analysis

According to the findings of the current research, samples A, B, C, D, and E had the magnesium concentration of 3.21, 4.21, 0.21, 1.2, and 0.75 cmol(+)/kg, respectively, with the mean value of 1.92 cmol(+)/kg. Based on the FAO classification of soil macro- and micronutrients, samples A and B were classified as soils with high nutrients, while samples C, D, and E were classified as soils with medium nutrients. In addition, samples one, two, three, four, and five (outside the quarry) had the values of 1.09, 2.52, 2.11, 2.32, and 1.22 cmol(+)/kg, respectively, with the mean value of 1.85 cmol(+)/kg. These values were within the range of medium-to-high macro- and micronutrients, indicating that the quarry activity in the study area did not affect magnesium concentration.

Table 3: Analysis of Soil Samples Collected from Inside Quarry

Parameters	Unit	Samples			
		A	B	C	D
pH	1:2 H ₂ O	6.64	6.39	5.51	5.56
Na	cmol(+)/kg	2.13	2.14	2.03	1.95
Ca	cmol(+)/kg	5.54	6.54	3.54	2.1
Mg	cmol(+)/kg	3.21	4.21	0.21	1.2
CEC	cmol(+)/kg	14.32	13.21	10.16	8.43
Pb	cmol(+)/kg	0.15	0.19	0.21	0.27
Mn	cmol(+)/kg	1.59	5.92	6.1	2.46

Table 4: Analysis of Soil Samples Collected from Outside Quarry

Parameters	Unit	Samples				
		1	2	3	4	5
pH	1:2 H ₂ O	6.59	6.22	5.21	6.07	5.93
Na	cmol(+)/kg	1.21	1.22	1.21	1.25	1.29
Ca	cmol(+)/kg	3.36	3.27	4.31	4.42	2.78
Mg	cmol(+)/kg	1.09	2.52	2.11	2.32	1.22
CEC	cmol(+)/kg	9.25	12.17	9.5	12.66	12.68
Pb	cmol(+)/kg	0.34	0.4	0.39	0.32	0.24
Mn	cmol(+)/kg	5.57	7.09	4.02	6.07	0.23

3.4. CEC Analysis

According to the results of the present study, samples A, B, C, D, and E had the CEC concentration of 14.32, 13.21, 10.16, 8.43, and 13.11 cmol(+)/kg, respectively, with the mean value of 11.85 cmol(+)/kg. Based on the classification of soil macro- and micronutrients, samples A, B, and E were classified as soil with high nutrients, while samples C and D were classified as soil with medium nutrients. As for the samples collected from outside the quarry, samples one, two, three, four, and five had the concentration of 9.25, 12.17, 9.50, 12.66, and 12.68 cmol(+)/kg respectively, with the mean value of 11.25 cmol(+)/kg. Based on the classification of soil macro- and micronutrients, samples one and three were classified as soil with high nutrients, while samples two, four, and five were classified as soil with medium nutrients, indicating that the samples collected from within and outside the quarry were within the range of medium-to-high soil nutrients for CEC. Therefore, the quarry operations in the study area did not adversely affect the CEC concentration.

3.5. Lead Analysis of the Soil Samples within the Quarry

According to the current research, samples A, B, C, D, and E had lead concentrations of 0.15, 0.19, 0.21, 0.27, and 0.23 cmol(+)/kg, respectively. Based on the FAO classification of soil macro- and micronutrients, samples A, B, C, D, and E were classified as soil with low nutrients. On the other hand, samples one, two, three, four, and five (outside the quarry) had values of 0.34, 0.40, 0.39, 0.32, and 0.24 cmol(+)/kg, respectively, which were within the range of low lead concentration.

3.6. Manganese Analysis

According to the results of the present study, soil samples A, B, C, D, and E had manganese concentrations of 1.59, 5.92, 6.10, 2.46, and 0.22 cmol(+)/kg, respectively. Based on the FAO classification of soil macro- and micronutrients, samples B and C were classified as soil with medium macro- and micronutrients, while samples A, D, and E were classified as soil with very low macro- and micronutrients. These samples were within the range of low-to-medium

manganese concentration. Similarly, samples one, two, three, four, and five (outside the quarry) had manganese concentrations of 5.57, 7.09, 4.02, 6.07, and 0.23 cmol(+)/kg, respectively. Based on the FAO classification of soil macro- and micronutrients, samples one, two, and four were classified as soil with medium macro- and micronutrients, while samples three and five were classified as soil with very low macro- and micronutrients.

4. Conclusion

The mechanical effects of rock blasting in quarrying operations using explosives have been investigated extensively, while no studies have been focused on the produced chemicals by these explosives [16]. This study aimed to evaluate the impact of the chemicals produced by explosives on soil and water bodies and the vicinity of the study area. According to the results, the studied elements in the soil and water samples from within the study area, where high concentrations of explosive chemicals are expected, did not exceed the permissible threshold by the WHO. Furthermore, the mean pH values of the water samples from within and outside the study area showed no significant difference ($P \leq 0.05$).

The explosives used in the study were a combination of ammonium nitrate and fuel oil (ANFO) as the column charge, while blended ANFO was applied as the bottom charge, which does not allow the generalization of the findings as it may differ in the areas where emulsion, gelatin, and other explosives are used. Therefore, it is recommended that the government, cooperate health organizations, and especially the companies carrying out stone extraction evaluate the effects of the gases released during explosive detonation and set regulations for the prescription of approved explosives that are environmentally safe.

Authors' Contributions

The corresponding author A.O.O., conceived the project. Both authors were involved in the field research, conducted the laboratory analysis of the samples, and analyzed the data. A.O.O., drafted the manuscript, and P.A.A., revised the manuscript. All the authors approved the final manuscript for publication.

Conflict of Interest

The Authors declare that there is no conflict of interest.

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