Evaluation of the Impacts of Limestone Mining on Soil and Water Quality in Okpella, Edo State, Nigeria

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Abstract- This research evaluated the impacts of limestone mining on soil and water quality in Okpella, Edo State. Nigeria. Samples of water and soil were collected from the quarry and processing plant of BUA Cement Company and from residential areas in close proximity to the company. Control samples were also collected from residential area within Okpella. Physico-chemical analysis was carried out on soil and water samples to evaluate the impacts of limestone mining on the quality of water and soil in the study area. The water samples collected from the mine site were alkaline with a mean pH value of 8.6. The mean electrical conductivity of water from the mine was 674µS/cm. This value is due to the high amount of dissolved salt in the water samples. The concentration of heavy metals like iron, manganese, copper and chromium were slightly above WHO and NSDWQ Standards while zinc, nickel and lead were within the maximum permissible limits. Also, the soil samples taken around the mine were of high concentration of phosphate, sulphur, potassium and calcium as compared to the elemental composition of the control samples. Concentration of heavy metals such as iron, zinc, copper, nickel and cobalt were higher than the maximum allowable limits of FAO/WHO while manganese, lead and chromium concentrations were within the limits. Soil and water bodies are essential natural resources that play crucial roles in maintaining the sustainability of an environment. Therefore, environmental experts and relevant authorities that can help to develop a tailored plan to address the implications of heavy metal contamination in the soil and water bodies of the host community of BUA Cement Company must be involved.

Indexed Terms- Heavy Metals, Quarries, Vegetation, Water

I. INTRODUCTION

Mining process has undeniably brought affluence and employment prospects in mining areas, but concurrently has led to widespread environmental degradation and the erosion of traditional values in society (Oluku, and Asikhia, 2021). Mining creates large disturbances that significantly impact soil, vegetation and fauna and result in habitat fragmentation and loss (Owolabi, 2020; Ogunro and Owolabi, 2022).

Limestone is a carbonate sedimentary rock, consisting of calcium carbonate and in some cases magnesium carbonate as a secondary component (Ganapathi and Phukan, 2020). Limestone is a highly prized industrial rock raw material. It is a raw material that pivots cement production in several countries. In Nigeria, limestone is one of the most commonly extracted minerals becauseof its use in cement production. The most widely adopted method of limestone mining is through opencast with bench formation (Ganapathi and Phukan, 2020). Olotu *et al* (2022) investigated the effect of limestone extraction in Okpella and its environs. Environmental degradation due to limestone exploitation has seriously affected crop yield in Okpella as a result of sealing up the plant leaf and reducing the photosynthesis rate Olotu *et al* (2022). The detrimental effect of limestone mining on the vegetation in Okpella area was noted by Osazuwa *et al* (2016).

1.1 Water Quality and Mining

Water is largely used in mining for mineral processing, dust control, slurry transport, and to meet workers' needs. Mining can deplete surface and groundwater supplies. Water is considered polluted when it is altered in composition or condition directly or indirectly as a result of activities of man so that it becomes unsuitable or less suitable for any or all the functions or purposes for which it would be suitable in its natural state (Owolabi and Opafunso, 2017). Changes in water quality resulting from mining activities include increase of water turbidity, concentrations of major ions and trace elements. In tropical countries like ours, the high temperature partially accounts for the water dissolving more materials.

1.2 Soil Quality

Soils are precious natural resources widely used as environmental indicators and their chemical analysis provide significant information on the assessment of anthropogenic activities of an area (Amadi *et al.*, 2017). Soils are dynamic and diverse natural systems that lie at the interface between earth, air, water, and life (Needelman, 2013). Li *et al.*, (2005) observed that soil quality is not only one of the most important environmental factors in developing sustainable ecosystem, but concerning the yields and safety of agricultural produce.

II. MATERIALS AND METHODS

2.1 Geology and Description of the Study Area

According to Ogunyele *et al.*, (2018), Okpella lies within the basement complex and the cretaceous to recent sediment of South Western Nigeria, the area falls within the Anambra and Afikpo basin which formed the sedimentary cycle. The area is the eastern extension of the Upper Proterozoic Igarra Schist Belt, South-western Nigerian Basement Complex. Okpella is located between latitude N07^{o} 16' and N07^{o} 22' and longitude E06^{o} 18' and E06^{o} 23' in the North-eastern part of Edo State, Nigeria (see Figure 1 and Plate 1).

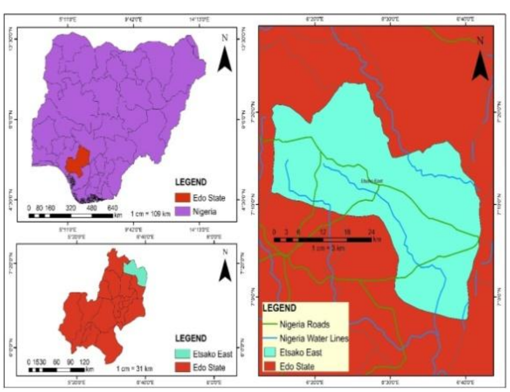

Figure 1: Map of the Study Area

Plate 1: Aerial Photography of Okpella Cement Processing Plant and Mines showing the sample collection points

2.2 Data Collection and Sampling

a. Field visit and Sampling

Collection of representative soil and water samples in the study area.

Eighteen (18) water samples (surface and groundwater) and twelve (12) soil samples were collected from the quarries and immediate environments using random sampling method in accordance to standard sampling procedure.

2.3 In-Situ and Laboratory Analysis

The pH multi-meter was used to measure the physical parameter of the water sample. Electrical Conductivity was determined by switching the pH meter to EC mode and Total Dissolved Solid (TDS) determination by switching the pH meter to TDS mode. Heavy metal concentrations of the samples were determined in the laboratory

III. RESULTS AND DISCUSSIONS

Table 1: Mean Values of Surface and Groundwater Physico-Chemical Compositions of the Study area

Parameters	pH	EC	Col.	Turb.	Sal.	TSS	TDS	COD	HCO_3	Na	K	Ca	Mg	Cl	P	NH_4N	NO_2	NO_3	SO_4
Unit		μS/cm	TCU	NTU							mg/l								
WHO	6.5-8.5	1000	3	5	N.S	5	1000	N.S	100	200	10	75	20	200	N.S	N.S	0.2	10	200
NSWDQ	6.5-8.5	1000	15	5	N.S	5	500	N.S	100	200	10	75	20	250	N.S	N.S	0.2	50	100
Mine site																			
L1	8.4	765	N.D	N.D	360	N.D	300.3	22.3	480.1	2.37	1.12	7.46	4.47	177	0.29	0.24	0.06	0.37	1.79
L2	8.5	764	N.D	N.D	340	N.D	358.1	23.5	442.9	2.49	1.15	6.83	4.83	211	0.32	0.25	0.07	1.94	1.86
L3	8.7	727	N.D	N.D	330	N.D	352.7	28.0	322.0	0.86	0.43	7.42	1.51	105	0.13	0.21	0.04	0.18	1.52
L4	8.6	711	N.D	N.D	320	N.D	380.3	25.2	427.6	3.72	1.34	5.42	5.33	319	0.51	0.28	0.11	2.76	2.17
L5	8.7	715	N.D	N.D	320	N.D	382.3	21.7	316.4	2.87	1.32	5.08	5.10	247	0.35	0.27	0.08	2.42	1.86
L6	8.4	712	N.D	N.D	310	N.D	347.7	18.1	275.7	1.92	0.51	4.82	2.88	123	0.15	0.22	0.05	0.25	1.65
L7	8.7	675	N.D	N.D	310	N,D	338.8	18.2	268.3	2.14	0.85	4.80	3.05	123	0.27	0.24	0.05	0.32	1.65
L8	8.7	603	N.D	N.D	270	N.D	284.1	27.4	266.3	1.35	0.68	4.70	2.71	89	0.27	0.48	0.09	1.41	1.96
L9	8.6	574	N.D	N.D	260	N.D	248.3	21.4	426.7	1.09	0.52	5.11	2.64	88	0.21	0.37	0.07	1.32	1.17
Mean	8.6	674	N.D	N.D	310	N.D	332.5	22.9	358.4	2.09	0.88	5.74	3.61	165	0.28	0.28	0.07	1.22	1.74

Control (Okpella Town)																		
L10	6.5	172	N.D	1.7	190	4.3	228.6	4.1	182.7	1.79	0.78	5.10	3.11	106.8	0.28	0.68	0.11	1.83	2.64
L11	6.5	284	N.D	3.6	180	7.6	212.3	8.1	103.7	0.82	0.22	4.68	1.56	54.1	0.16	0.30	0.06	0.17	0.77
L12	6.6	344	N.D	N.D	130	N.D	90.7	8.2	140.8	0.85	0.34	4.81	1.72	70.8	0.16	0.36	0.06	0.57	0.89
L13	6.5	353	N.D	N.D	150	N.D	141.7	2.6	151.3	0.82	0.33	2.07	1.58	101.4	0.22	0.25	0.04	0.18	1.46
L14	7.0	372	N.D	N.D	260	N.D	171.7	5.2	268.3	3.68	1.41	3.14	5.48	317.7	0.51	0.26	0.11	2.76	2.17
L15	7.1	343	N.D	N.D	160	N.D	175.0	8.1	183.4	2.13	0.83	2.09	3.03	121.3	0.27	0.24	0.05	0.32	1.65
L16	7.0	351	N.D	1.5	170	4.2	187.0	12.2	101.4	1.78	0.76	2.81	3.11	106.5	0.28	0.68	0.11	1.82	2.84
L17	7.1	573	N.D	3.4	150	7.4	170.0	2.5	150.3	0.82	0.21	1.91	1.54	52.8	0.15	0.30	0.05	0.17	0.77
L18	8.4	343	N.D	N.D	160	N.D	174.0	8.0	232.4	1.07	0.51	1.95	2.62	88.4	0.21	0.37	0.07	1.32	1.17
Mean	7.0	348	N.D	2.55	170	5.87	172.3	6.6	168.3	1.53	0.60	3.17	2.64	113	0.25	0.38	0.07	1.02	1.60

N.D depicts Not Detected, N.S depicts Not Stated, WHO depicts World Health Organisation, NSDWQ depicts Nigerian Standard for Drinking Water Quality

Table 2: Values of the Heavy Metals of the Surface and Groundwater samples of the study area

Parameters	Fe	Mn	Zn	Cu	Cr	Cd	Ni	Pb	V	THC
WHO	0.3	0.1	4.0	2.0	0.05	0.003	0.07	0.01	0.005	NS
NSWDQ	0.3	0.2	3.0	1.0	0.05	0.003	0.02	0.01	0.005	NS
Minesite										
L1	0.43	0.15	0.21	0.09	0.03	0.01	0.01	0.02	0.01	N.D
L2	0.28	0.14	0.19	0.87	0.03	0.01	0.01	0.01	0.00	N.D
L3	0.55	0.19	0.33	0.13	0.06	0.03	0.02	0.04	0.01	N.D
L4	0.11	0.05	0.07	0.04	0.02	0.01	0.00	0.01	0.00	N.D
L5	0.23	0.12	0.18	0.08	0.02	0.01	0.01	0.01	0.00	N.D
L6	0.55	0.17	0.29	0.11	0.05	0.02	0.01	0.03	0.01	N.D
L7	0.51	0.16	0.21	0.11	0.05	0.02	0.01	0.02	0.01	N.D
L8	0.42	0.16	0.21	0.09	0.03	0.01	0.01	0.02	0.00	N.D

L9	0.27	0.14	0.19	0.08	0.02	0.01	0.01	0.01	0.01	N.D
Mean	0.37	0.14	0.21	0.18	0.03	0.01	0.01	0.02	0.01	N.D
Control(Okpella Town)										
L10	0.54	0.19	0.33	0.13	0.06	0.03	0.02	0.04	0.00	N.D
L11	0.11	0.05	0.07	0.04	0.02	0.01	0.00	0.01	0.00	N.D
L12	0.23	0.12	0.18	0.08	0.02	0.01	0.00	0.01	0.01	N.D
L13	0.55	0.17	0.29	0.11	0.05	0.02	0.01	0.03	0.01	N.D
L14	0.41	0.15	0.21	0.09	0.03	0.02	0.01	0.02	0.01	N.D
L15	0.11	0.06	0.07	0.05	0.02	0.01	0.01	0.01	0.00	N.D
L16	0.24	0.14	0.19	0.09	0.02	0.01	0.00	0.01	0.01	N.D
L17	0.42	0.15	0.20	0.09	0.03	0.01	0.01	0.02	0.01	N.D
L18	0.53	0.16	0.22	0.12	0.05	0.02	0.01	0.03	0.01	N.D
Mean	0.35	0.13	0.20	0.09	0.03	0.02	0.01	0.02	0.01	N.D

N.D depicts Not Detected, N.S depicts Not Stated, WHO depicts World Health Organisation NSDWQ depicts Nigerian Standard for Drinking Water Quality

3.1 Water

At the mine sites pH values ranged from 8.4 to 8.7, with a mean value of 8.6 while the pH values in Okpella town varied from 6.5 to 8.4, with a mean value of 7.0 (Table 1), implying that majority of surface and underground waters at the mine site and Okpella are alkaline. The EC of water samples taken from the mine site ranged from 574 µS/cm to 765 µS/cm, with a mean value of 674 µS/cm, while the EC of Okpella town ranged from 172 µS/cm to 573 µS/cm, with a mean value of 348 µS/cm (Table 1).This clearly shows that waters in mine sites are good conductor of electricity than the waters at the Okpella town.

Salinity of the water samples taken from the mine site ranged from 260 mg/l to 360 mg/l, with a mean value of 310 mg/l while the waters samples obtained from Okpella town ranged from 130 mg/l to 260 mg/l with a mean value of 170 mg/l (Table 1). The water in mine site is more saline compared to the water obtained from the Okpella town. Salts increase the ability of a solution to conduct an electrical current, so a high EC value indicates a high salinity level.

No colour was detected in all the water samples considered, indicating that the water samples have good colour. However, the inability to detect colour in the water samples may not denote that the water is pure; rather it may imply that colouration could be present in amounts below the detection limit (DL).Turbidity distribution in the study area range from 1.5 NTU to 3.6 NTU, with a mean of 2.55 NTU (Table 1). Turbidity values were not detected in all the samples collected from the mine while only four (4) samples taken from the Okpella community were detected. Turbidity values are generally low and meet the maximum permitted level of 5 NTU stipulated by WHO and NSDWQ.TSS values of water samples taken from Okpella varied from 4.2 mg/l to 7.6 mg/l, with a mean value of 5.87 mg/l (Table 1) indicating that the water samples meet the maximum allowable limit of 5 mg/l stipulated by WHO and NSDWQ.

TDS of the water samples taken from the mine site ranged from 248.3 mg/l to 382.3 mg/l, with a mean value of 332.5 mg/l while the waters samples obtained from Okpella town ranged from 90.7 mg/l to 228.6 mg/l, with a mean value of 172.3 mg/l (Table 1). TDS in water samples in the mine sites contain more dissolved solid compared to the samples in the town. These results indicate that the water bodies meet the maximum allowable limit of 1000 mg/l stipulated by WHO and 500 mg/l set by NSDWQ. COD of the water samples taken from the mine sites ranged from 18.1 mg/l to 28.0 mg/l, with a mean value of 22.9 mg/l while the waters samples obtained from Okpella town ranged from 2.5 mg/l to 12.2 mg/l, with a mean value of 6.6 mg/l. Water samples L1 to L9 representing the mine area have higher COD values while the Okpella community has lower COD value (Table 1).

Iron was the most abundant in the soil samples determined with values ranging from 0.11 mg/l to 0.55 mg/l as gotten from the mine, with mean concentration of 0.37 mg/l while the values for the control point (Okpella town) ranged from 0.11 mg/l to 0.54 mg/l with mean concentration of 0.35 mg/l (Table 2).

Table 3: Mean Values of the Soil - Chemical Compositions from the Study Area

Parameters Units(Mg/kg)	Mg	Al	P	S	K	Ca	Si
FAO/WHO	100	NS	NS	NS	NS	NS	NS
Mine site							
B1	0	21430	384	1441	7162	1421	39137
B2	0	17743	640	309	5801	62546	92034
B3	0	16332	856	1470	10344	41571	48133
B4	0	13716	82	168	6877	2184	25284
E1	0	13986	1201	1245	648	185679	28530
E2	0	14438	878	1076	5771	111892	31727
E3	0	15581	1063	2186	6148	142455	31439
E4	0	23589	227	1219	11024	1005	40607
Mean	0	17102	666	1139	6722	68594	42111
Control (Okpella Town)							
C1	0	15197	219	0	7718	1636	25278
C2	0	13994	391	399	11386	167	38135
C3	0	22235	653	1010	12261	1175	62931
C4	0	18029	307	411	19060	1374	42653
Mean	0	17364	393	455	12606	1088	42249

NS = Not Stated

Table 4: Mean Values of the Heavy Metals in the Soil Sample from the Study Area

Parameters	Fe Mg/kg	Mn Mg/kg	Zn Mg/kg	Cu Mg/kg	Cr Mg/kg	Ni Mg/kg	Pb Mg/kg	V Mg/kg	Co Mg/kg	As M/kg
FAO/WHO (2001)	5000	2000	300	100	100	-	50	NS	50	20
WHO (1996)	NS	NS	NS	NS	NS	35	NS	NS	NS	NS
Mine site										
B1	200367	482	2676	1003	112	2084	142	46	215	0
B2	98833	486	2409	1517	0	1335	69	107	220	0

B3	114351	465	2570	817	0	1530	0	78	337	0
B4	173918	810	2727	2874	0	2085	0	17	0	0
E1	120084	1078	1796	726	0	1070	0	0	0	0
E2	114311	901	1806	2237	0	1053	0	0	0	0
E3	164649	993	1636	876	0	1132	0	0	0	0
E4	267837	1704	2499	554	0	1571	0	0	725	0
MEAN	156794	865	2265	1326	14	1541	26	31	187	0
Control (Okpella Town)										
C1	259456	174	2494	996	0	1378	0	231	4622	0
C2	149865	478	2284	3168	214	1444	0	19	746	0
C3	165275	911	1817	907	0	1061	144	600	2958	0
C4	227071	937	1855	493	0	881	270	265	2944	0
MEAN	200117	625	2113	1391	54	1191	104	279	2818	0

N.S = Not Stated

3.2 Soil

Aluminium content in the mine soil ranged from 13,716 mg/kg to 23,589 mg/kg, with the mean value of 17,102 mg/kg while that of the control (Okpella town) ranged from 13,994 mg/kg to 22,235 mg/kg, with the mean value of 17,364 mg/kg (Table 3). The control mean value is slightly higher than that of the mine site. FAO/WHO (2001) maximum allowable limit for heavy metals shows that there is no set guideline for aluminium, nonetheless the recorded mean values depict a higher concentration of aluminium in the study area. The FAO/WHO (Food and Agriculture Organization/World Health Organization) does not provide a specific permissible limit for aluminium in soil.

Phosphate values gotten from the mine site were in the range of 82 mg/kg and 1201 mg/kg, with the mean of 666 mg/kg, also which of the Okpella town were between 219 mg/kg and 653 mg/kg, with a mean of 393 mg/kg (Table 3). The mine site mean value is significantly higher than that of the control. The FAO/WHO (Food and Agriculture Organization/World Health Organization) does not provide a specific permissible limit for phosphate in soil.

The values of Potassium (K) in the mine site ranged from 648 mg/kg to 11,024 mg/kg, with the mean value of 6,722 mg/kg, the control point values were between 7,718 mg/kg and 19,060 mg/kg, with the mean of 12,606 mg/kg (Table 3).The mean values of potassium in the mine site is significantly higher than that of the control. The FAO/WHO (Food and Agriculture Organization/World Health Organization) does not provide specific permissible limits for potassium in soil.

The values of calcium recorded from the mine site ranged from 1,005 mg/kg to 185,679 mg/kg, with the mean value of 68,594 mg/kg while the values from the control points were between 167 mg/kg and 1,636 mg/kg and the mean of 1088 mg/kg (Table 3). The mean values of the concentration of calcium in the soil sample at the mine site and the control (68,594 mg/kg and 1088 mg/kg respectively) are significantly higher than the peak concentration of calcium in soil samples (570 mg/kg) recorded by Ogunlana *et. al.*, (2020).

Iron occurs in concentrations of 7,000 to 500,000 mg/kg in soils (Fageria*et. al.*, 2002). As shown in Table 4, iron (Fe) contents from the soil obtained from the mine site ranged from 98,833 mg/kg to 267,837 mg/kg, with the mean value of 156,794 mg/kg and that of the control point were between 149,865 mg/kg and 259,456 mg/kg, with mean value of 200,117 mg/kg. Comparison of iron contents in the mine soil samples with that of the control soil samples indicates that higher iron contents were recorded in Okpella town. Iron contents in all the soil samples far exceed the FAO/WHO (2001) permissible limit of iron in soil (5000 mg/kg).

Manganese (Mn) contents in soil gotten from the mine site were in the range of 465 mg/kg and 1704 mg/kg, with the mean of 865 mg/kg, the control point had values from 174 mg/kg to 937 mg/kg, with the mean value of 625 mg/kg (Table 4). These were higher than those obtained by Anjali *et. al.*, (2017) in their study in Sonepat, Haryana (India), where the concentration of manganese in the soil was found to be in the range of 104.15 to 214.90 mg/kg.

Copper (Cu) values from the mine site were between the range of 554 mg/kg and 2874 mg/kg, with the mean value of 1326 mg/kg, that of the control point were in the range of 493 mg/kg and 3168 mg/kg and the mean value of 1391 mg/kg (Table 4). The mean value shows that the mine site has a slightly higher concentration compared to the control. The concentrations of copper recorded in soils at the mine site and Okpella town were significantly above the FAO/WHO (2001) permissible limit of 100 mg/kg. The results obtained were significantly higher than the 6.55 mg/kg reported by Fosu Mensah *et. al*., (2018). Additionally,Iyaka and Kakulu (2012) discovered a mean Cu level of 467 mg/kg in the soils of an industrial area in Bida, Niger State.

The values of lead (Pb) in soil samples gotten from the mine site ranged from 69 mg/kg to142 mg/kg, with a mean value of 26 mg/kg while the values of Pb in soil samples at the control point ranged between 144 mg/kg and 270 mg/kg, with the mean value of 104 mg/kg (Table 4). This implies that Pb values are higher at the control. The concentration of lead in the soil was detected in only two (2) sampling points in the mine site and Okpella town. The lead concentration in the soil analysed around the mine was below the permissible limit (50 mg/kg) set by FAO/WHO (2001), while the control had a concentration above the permissible limit.

CONCLUSION

The physical and chemical properties of the water sampled show that water bodies are slightly alkaline. Water quality indicators assessed with physical and chemical parameters like phosphorus, electrical conductivity, turbidity and pH agreed to be unaffected by mining activities and population growth in the study area with almost all meeting the required limits stipulated by WHO and NSDWQ. Elevated levels of iron, cadmium, lead, vanadium, and manganese in water bodies can harm fish, invertebrates, and other aquatic organisms. It can disrupt their reproductive cycles, impair growth and development, and even lead to population decline.

Sequel to the findings of this study,soil conservation and management practices to improve soil fertility and structure must be prioritized. Environmental experts and relevant authorities that can help to develop a tailored plan to address the implications of heavy metal contamination in the soil must be involved.

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