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Challenges of Quarrying Activities for Sustainable Quality Water Resources in Abakaliki and Environs

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Abstract:

This paper examines the challenges of quarrying activities on sustainable quality water resources in Abakaliki and environs and the socio-economic implications of the effects on the people in order to find strategies to mitigate the effects. Data collection yielded 7 water samples and administration of 400 copies of questionnaires, interviews and photographs from 5 quarrying sites and one control site. Water samples were analyzed for physico-chemical properties at PRODA, Enugu. Analyses of data were by descriptive statistics, correlation and Principal Components Analysis (PCA). The result showed that the methods of quarrying and crushing of the rock lumps were generating dust and acidic waste water pollutants through runoff into the surrounding surface water bodies. PCA identified that pollution makes the water hard, low in oxygen and contains heavy metals above permissible limits. Parameters like Pb, As, Fe, Cu, Zn, Cd which contributed in pollution of the waters were found to affect aquatic plants, animals, human health and the ecosystem. Remediation was advanced as plausible mitigation measure to stem the increasing pollution trend, ensure safety of the environment, man and the attainment of the SDGs.

Keynotes: Quarrying, pollution, remediation, surface water quality, sustainable resources

Introduction

Quarrying activities for rocks, sand, gravel, and limestone for road beds, to make building stones, (Hussain, 2001, Cunningham and Saigo, 2005; Liman, 2016) are environmental polluting industries in Abakaliki and environs. The gains of quarrying activities notwithstanding, the impacts on water resources are quite enormous in view of the utter disregard for environmental limits, low knowledge and compliance to environmental laws. (Anosike and Ajayi, 2003; Oguntoke, Aboaba and Gbadebo, 2009). There widespread contamination of drinking and cooking water sources by guinea worm (Drancunculiasis) in Abakaliki area causing physical disabilities and resultant loss of income, (Anosike and Ajayi, 2003; Eze, 2005; Nnamani and Nnabueze, 2012; Okpara, 2015; Horton, 2019 and Chukwuma, 2019) makes the challenge of quarrying activities to quality water resources vexatious.

Quarrying in Abakaliki area discharge waste water into surface water (Okafor, 2006); an unfriendly environmental practice which is common in Nigeria and other developing countries (Anyadike, 2006). Quarrying activities also discharge dust and silt particles that settles on surface water used for drinking and other domestic chores in a community (Vermeulen and Whitten, 1999; Lameed and Ayodale, 2010) as witnessed in Zamfara state of Nigeria (Ikenna, 2010). Furthermore, runoff from quarries often have enhanced levels of metals such as arsenic, copper, lead, iron, cadmium, cyanide and nickel which pollute surface water, poisoning fish, plants and drinking water supplies (Pickering and Owen, 1995 and Whitehead, 2007). In Minna, Nigeria, extensive quarrying of sand/gravel resulted in the considerable variations in the concentration of geo-chemical and bacteriological pathogens in surface water, (Lawal, 2011).

Abakaliki, has potential water deficit extending for over four months Phil-Eze (1983), and inaccessibility to surface water (Chime, 1984). Accordingly, Elechi (1983) remarked that the greatest source of health problem in Abakaliki is the scarcity of water and the low quality of the available amount caused by guinea worm. In recent time, the challenges of quality potable water supply were addressed by the opening up of boreholes that regrettably run dry during the dry season. Because of inadequate supply of water in the area, any activity such as quarrying that compromises sustainable quality water resources in Abakaliki and its environs affects their livelihood and may force the people to rely on guinea worm infested water resources for their water supply and sanitation.

Previous environmental studies looked generally, at the environmental effect of quarrying in Nigeria (Mallo, 2010), general socio-economic effects of quarrying activities (Liman (2016), the impacts of quarrying in Ishiagu area (Chimbo 2008), while Aloh (2004) and Ibe and Agukoronye (2008) explored the health and crop profitability at quarry sites respectively. However, the studies under reference did not examine the effects of quarrying activities on the sustainable quality water resources which even in limited quantity are found to be very important for the socio-economic wellbeing in Abakaliki area.

This study therefore aims to fill this lacuna by examining the challenges of quarry activities on sustainable quality water resources in Abakaliki and environs, determine the socio-economic implications of the effects of quarrying activities on the people and proffer strategies for its effective mitigation in Abakaliki and environs.

The Study Area

The study area is Abakaliki and environs which lies between latitudes 06 14' 32' N to 060 24' 32'' N and longitudes 08^0 01' 47'' E to $08^0$11' 14'' E. The quarrying industries are found in Enyadilogu, Ezzagu Iboko, Umuaghara and Ezza inyimagu villages (see Fig. 1) where the geology (Asu River Group) formed during the lower Cretaceous age (Albain) (Ugwueze, 2000; Aneke, 2007) gave rise to tectonic earth movements that resulted in minor folding, faulting, fracturing and fissuring, followed by igneous activity that deposited granite, limestone, lead, zinc, copper and cadmium mineralization in the area (Umeji, 2002).

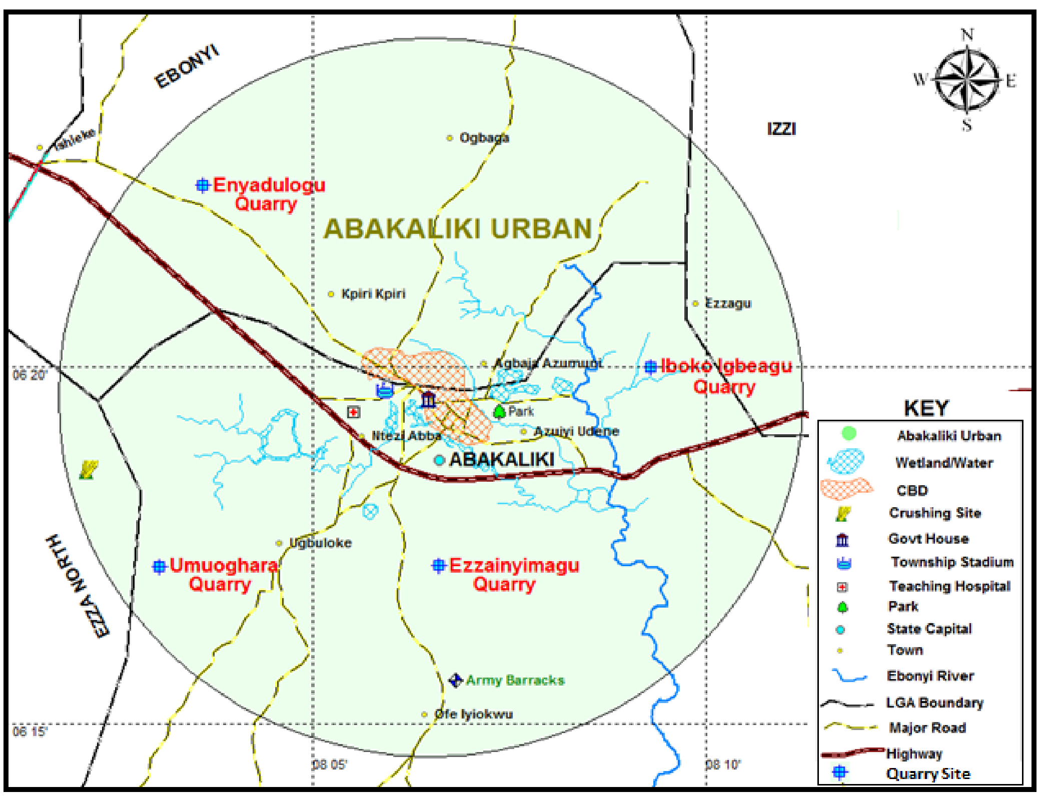

Fig. 1: Study Area showing Locations of Quarrying/Crushing sites in Abakaliki and Environs

The geography of Abakaliki and environs is succinctly captured by Ogbonnaya (2018) in which the relief is undulating with low ridges ranging between 350m and 400m asl and wide valleys of 75 m asl on average, (Ofomata, 2002). Located in the Cross River drainage basin with Ebonyi River as the main river, there are many tributaries but two major ones are Iyi-udene and Iyi-Okwu streams (Chime, 1984). The climate is Koppen Am climate of high temperature of 27^0C to 32^0C, (Anyadike, 2002) while total annual rainfall range from 1700mm to more than 2000mm. The soil is has hydromorphic (Ofomata, 1975), while the vegetation is of derived Savanna zone, (Ofomata, 1975, and Abegun, Adegoke, Onwumere and Dahiru, 2003) in which the dominant plant species are *Hyperrhenia spp, Andropogon spp.*, *Pennistum purpureum, Sammanea saman. Ceiba pentandra*, *Butyrospermum paradoxica*, *Parkia biglobosa, Pentaclethra mycrophyla* and *Adansonia digitata*, (Abegun, et al, 2003). Based on the National Population Commission 2006 Final Population Figures, the projected Population of Abakaliki is 193,793 made up of 102,330 females and 96,463 males.

Research Methodology

The empirical survey research design was adopted in this study. Ordinary simple random sampling was used to select 4 wards from each LGA from where four major quarrying sites and the crushing sites were located as shown in Table 1. Out of population of 161,241 persons (INEC, 2015); Yamane (1967) formula was used to obtain sample size of 400 persons and proportionately shared among the wards to select the respondents. Precisely 11 workers (2 from the crushing sites, 5 medical personnel, 4 residents living near quarry sites) in addition to the Chairman, Tipper drivers, and 2 permanent staff of Directorate cadre in the Ministry of Commerce and Industries, Ebonyi state, making a total of 423 persons were administered with questionnaires and 10 respondents were interviewed.

The primary data was obtained through a field work during which a total of 7 water samples were taken from where water pumped out of quarry pits or rain water runoff accumulated at the quarry and Crushing sites. The water samples were analysed at PRODA, Enugu for Physico-Chemical properties of acidity, Chemical Oxygen Demand (COD), Sulphate (SO_4), pH, Conductivity, Total Hardness (TH), Phosphate (PO_4) Nitrite (NO_3), Dissolved Oxygen (DO), Biochemical Oxygen

Demand (BOD), Odour, Colour, Lead (pb), Cadmium (Cd), Zinc (Zn), Copper (Cu), Arsenic (As) and Iron (Fe). Secondary data was obtained from articles, journals, seminar papers, textbooks, newspapers and magazines, handbooks, University libraries, internet and State government official records of the Ministry of Commerce and Industry, and Ministry of Health. Photographs of quarrying activities in sample sites were taken.

Table 1: Co-ordinates and Codes of the Quarry/Crushing Sites

S/N	Name of sites	Codes	Latitude	Longitude	L.G.A
1	Sharon	SH	6º 20' 24" N	8º 8' 47" E	Izzi
2	Umuaghara	UM	6º18' 19" N	8º 2' 31"E	Ezza North
3	Enyadilogu	EN	6º22' 40" N	8º 8' 47"E	Ebonyi
4	Archinwangboko	ARC	6º 17' 5" N	8º 6' 46" E	Abakaliki
5	Crushing site 1 (Umuaghara)	CRS 1	6º18' 12" N	8º 2' 16" E	Ezza North
6	Crushing site 2 (Umuaghara)	CRS 2	6º 18' 25" N	8º 2' 23" E	Ezza North
7	New Layout (Control)	NL	6º 19' 59" N	8º 6' 56" E	Izzi

Source: Field Work. 2015

Descriptive statistics, Principal Component Analysis (PCA), Bar charts and Coefficient of variation were used to identify the major parameters affected by quarrying in the water resources of Abakaliki and environs. Finally, the Pearson Product Moment correlation coefficient analysis was used to highlight the socio-economic implications of the effects of quarry industries on water in the study area.

Result of Analysis:

Presently, quarrying activities in the study area are carried out in Ezza Inyimagu (Archinwamgboko) in Abakaliki L.G.A., Umuaghara in Ezza North L.G.A., Enyadilogu in Ebonyi L.G.A and Iboko Igbeagu (Sharon) in Izzi L.G.A. The method of quarrying is purely artisanal in which most work done is by human labour with crude and obsolete equipment. Water that accumulate in pits either as a result of rainfall or underground water seeping from the remains of the rock mass are evacuated with water pumping machines and channelled or emptied into adjacent land whether cultivated or not from where it ends up in surface water/stream.

The demographic characteristics of our questionnaire respondents show that there are 250 male and 150 female while 75% of them are married. Majority (60%) have lived in the area between 30 to 40 years while 25% have lived for 20 to 29 years. The educational attainment of the respondents show that 11% attained tertiary level of education, 25% hard secondary education, 34& had First School Living Certificate while 30% had no formal education. Over 55% of the respondents are farmers, 20% are traders, 15% are quarry workers while only 5% are civil servants.

On the use of surface water resources in the area, our result shows that 85% of the people drink the water raw, 90% use it for cooking, 100% use it for washing while 96% use it for bathing.

The result of water analysis in Table 2 shows also the maximum permissible limits of the water parameters of Nigerian Industrial Standard, European Union and WHO used to compare the result of the parameters. The physical properties of water samples analysed are total solid content, dissolved solids, and suspended solids while the chemical properties analysed are acidity, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Dissolve Oxygen (DO), Total Hardness, Conductivity, pH, Sulphate, Phosphate, Nitrate (NO_3) Iron (Fe), Copper (Cu).

The results show that there are clear variations of total solids between the sampled stations and the control station. The total solids of the sample stations are either too far below or above that of the control station. The highest (76 mg/l) total solid is recorded in CRS.1 while the least (2mg/l) is in ARC. The DS levels in surface water varied between 3mg/l at ARC and 160mg/l at SH. When compared to NL (the control station), with 12mg/l, the level at ARC is 4 times less while the level at SH is 13 times more. The dissolved solids for all the sites are however far below the Nigerian industrial standard. A comparison of the quarry sites with the control site (NL), shows that there are more total solids in UM, EN, CRS1 and CRS2, with 20mg/l, 19mg/k, 79mg/l and 32mg/l, respectively, than at the control site (NL) with 13mg/l. These higher TS values imply that quarrying activities have effect on the surrounding water bodies of the sites and therefore a challenge to provision of sustainable quality water to the people.

Table 2: Result of Analysis of Physico-Chemical Properties of Water Samples in various locations in Abakaliki and Environs in Comparison with the Nigerian Industrial Standard (NIS), EU and WHO

	PARAMETERS	THE CONTROL STATION	SAMPLE STATIONS						RANGE	MEAN	STANDARD DEVIATION	MAXIMUM PERMISSIBLE LIMIT FOR DRINKING WATER	REGULATOR
		(NL) NEW LAYOUT	**(UM) UMUAG - HARA**	**(ARC) ARCHINWA – MGBOKO**	**(EN) ENYAD-LOGU**	**(SH) SHARON**	**(CRS1) CRUSHING SAMPLED SITE 1**	**(CRS2) CRUSHING SAMPLED SITE 2**					
1	TS (Mg/l)	13	20	2	19	5	79	32	2-79	26.17	25.65	NA	

2	DS (Mg/l)	12	12	3	14	160	46	26	3-160	43.5	53.83	500	WHO
3	SS ((Mg/l))	1	8	Nil	Nil	Nil	33	6	0-33	8.0	12.39		
4	Acidity (Mg/l)	0.8	0.9	1	1	1.3	1.5	0.8	0.8-1.5	1.08	0.24	6.5-8.5	√ EU(2016)
5	COD (Mg/l)	7.80	6.30	8.20	7.80	7.30	6.50	4.90	4.90-8.20	6.83	1.092	NA	
6	$S^0$4 (Mg/l)	5.50	4.50	4.10	4.90	6.5	Nil	3.50	0-6.5	3.92	1.012	100	
7	PH	7	7	7	7	7	7	5	5-7	6.67	0.75	6.5-8.5	√
8	Conductivity (us/cm)	300	242	237	284	320	290	244	237-320	269.5	30.67	1000	
9	TH (Mg/l)	300	670	1200	930	320	340	660	320-1290	701.16	336.03	150	√

10	$P0_4$ (Mg/l)	2.639	2.324	2.870	2.668	3.111	3.267	2.460	2.324-3.267	2.78	0.34		
11	$N0_3$ (Mg/l)	0.622	0.525	0.097	0.339	0.141	3.258	0.392	0.097-3.258	0.792	1.11	50	
12	DO (Mg/l)	16.72	19.67	12.78	29.50	15.73	29.50	29.50	12.78-29.50	22.78	7.01		
13	BOD (Mg/l)	8.92	13.37	4.58	21.7	8.92	23	25.8	4.58-25.8	16.23	7.80	6.0	√ WHO
14	Odour	Nil	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless				NA	
15	Colour	Brownish Black	Colorless	Colorless	Colorless	Brownish black	Milky	Light brown				NA	
16	Pb (Mg/l)	0.075	12.20	5.80	7.85	0.075	32.10	20.95	0.075-32.10	13.17	10.60	0.1	√
17	Cd (Mg/l)	0.012	0.029	0.050	0.16	0.012	0.022	0.018	0.012-0.16	0.049	0.051	0.003	√

18	Zn (Mg/l)	4.85	11.15	5.26	6.80	4.85	1.62	1.15	1.15-11.15	5.14	3.35	3	√
19	Cu (Mg/l)	0.028	0.95	1.43	1.090	0.028	0.95	0.94	0.028-1.43	0.90	0.43	1	√
20	As (Mg/l)	0.010	0.040	0.028	0.026	0.010	0.011	0.016	0.010-0.040	0.02 2	0.011	0.01	√
21	Fe (Mg/l)	1.45	16.50	11.65	18.60	1.45	15.22	18.70	1.45-18.70	13.6 9	5.96	0.3	√

Source: PRODA laboratory analyses (2016).

With reference to the chemical characteristics of the water samples, Table 2 indicates that the levels of BOD, DO, Copper, Cadmium, Iron, Arsenic, Lead and Zinc are far above the control site and the permissible limits in most cases while the levels of COD and Nitrate were less than the control sites. For example, BOD is very high when compared to the WHO standard of 6.0(mg/l) ranging from 4.58(mg/l) at SH site to 25.8(mg/l) at CRS 2. Apart from ARC site with BOD 4.58(mg/l), all other sample sites have BOD in excess of WHO permissible limit of 6.0(mg/l). Again, the DO of CRS 1 (25.5mg/l), CRS 2 (29.50mg/l), UM (19.67mg/l) and EN (29.50mg/l) sites are more than that of NL (16.77mg/l). Also, all the sites have water hardness more than the NIS (2007) limit of 150mg/l.

A simple dimensionless summation of the values of laboratory results between the control site and the quarrying sites was displayed in Fig. 3. The result shows that the water properties in the sample sites of UM, ARC, EN, SH, CRS1 and CRS2 are more than that of the control site NL and those in UM, ARC, EN and CRS2 more than double that of the control site NL. This denotes clearly that more quantities of the parameters are released into water resources as a result of the quarrying activities, thus challenging the provision of sustainable quality water to the people. In order to identify the offending properties, the laboratory result was subjected to PCA.

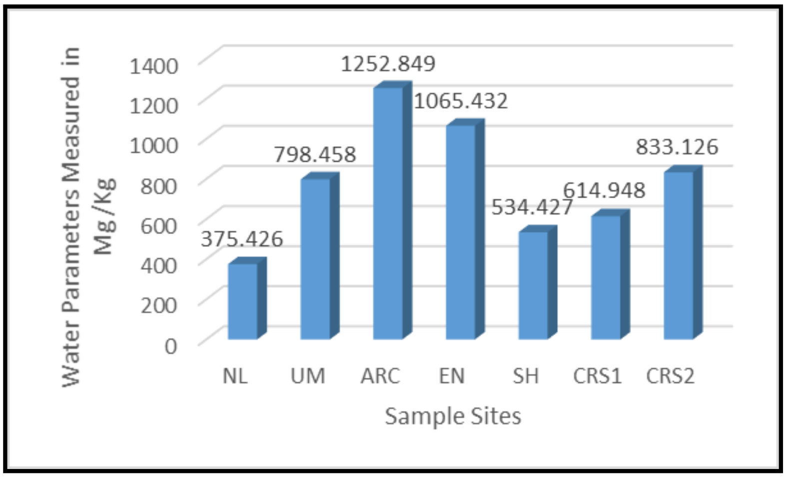

Fig 3: Difference in Water Properties between the Sample Sites and Control Site

In the application of Principal Components Analysis (PCA), correlation matrix was first established. The reason being that the variables were different in scale as suggested by (Kaipuzcu and Denes, 1987) and equal in importance (as suggested by Chaffield and Cothus, 1980). The resulting correlation matrix (Table 3) shows a series of significant correlation, some positive and some negative, some weak and some strong at $p = 0.05$ confidence level.

Table 3: Correlation Matrix of Water Sample Parameters in the Study Area

	Acidity	As	BOD	Cd	COD	Conductivity	Cu	DO	DS	Fe	NO3	Pb	pH	PO4	SO4	SS	TH	TS	Zn
Acidity	1																		
As	-.626	1																	
BOD	-.039	-.289	1																
Cd	-.218	.311	.185	1															
COD	.262	.174	-.652	.509	1														
Conductivity	.750	-.671	.043	.053	.250	1													
Cu	-.407	.542	.090	.383	.135	-.769	1												
DO	.021	-.266	.987**	.310	-.523	.092	.142	1											
DS	.551	-.655	-.239	-.394	.058	.821*	-.955**	-.273	1										
Fe	-.486	.416	.682	.405	-.395	-.596	.721	.697	-.862*	1									

NO3	.712	-.391	.461	-.221	-.219	.250	.072	.496	-.036	.206	1								
Pb	.266	-.268	.722	-.260	-.607	-.145	.285	.702	-.330	.565	.847*	1							
pH	-.773	.456	-.388	.231	.137	-.299	-.053	-.429	-.021	-.115	-.991**	-.799	1						
PO4	.928**	-.725	-.162	-.181	.395	.693	-.324	-.102	.547	-.576	.545	.130	-.644	1					
SO4	-.405	.239	-.516	.198	.324	.146	-.425	-.533	.381	-.474	-.901*	-.940**	.885*	-.320	1				
SS	.626	-.332	.472	-.337	-.351	.141	.080	.482	-.073	.247	.984**	.893*	-.962**	.439	-.914*	1			
TH	-.584	.592	-.354	.500	.484	-.656	.777	-.302	-.684	.311	-.504	-.360	.481	-.365	.191	-.527	1		
TS	.526	-.396	.690	-.193	-.449	.152	.104	.701	-.127	.399	.955**	.947**	-.921**	.354	-.916*	.961**	-.521	1	
Zn	-.341	.851*	-.443	.285	.333	-.211	.077	-.406	-.200	.025	-.418	-.514	.470	-.511	.499	-.391	.268	-.495	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

From Table 3, the variable acidity correlates very strongly, significantly and positively with $P0_4$ (0.928); As (arsenic) correlates strongly and positively with Zn (0.851) while Cu (Copper) correlates strongly, significantly and negatively with DS (dissolved solids) (-0.955). All these strong intercorrelation necessitates that we subject the result to PCA to enable clear identification of major parameters to deal with.

Result of the Principal Components Analysis (PCA) of the water sample parameters

The result of PCA of the water sample data showed that the extent of association between a variable and a component is indicated by the component loadings. The loadings have much the same meaning as correlation coefficients. The eigenvalue was used to determine the total explained variance in the component matrix and the number of the significant components extracted was also determined by the number of specification of the minimum eigenvalue greater or equal to unity according to Kaiser (1959). The output of the unrotated PCA was ill-defined thereby making interpretation difficult. In order to sharpen the loadings and refine our analysis, we subjected the PCA to varimax rotation. The result is presented in Table 5 below.

In the rotated component loadings of water samples, there are 6 significant variables in Component 1. The variables with high positive loadings are NO_3, Pb, SS and TS. The variables with high negative loadings are pH and SO_4 which have loadings of -0.971 and -0.894 respectively. These variables with negative loadings under component I are inversely related to the four variables with positive loadings named above. Together the 6 variables explain 33.984% of the total variance with an eigenvalue of 6.46. This Component I denotes an index of the ***magnitude of pollution*** level of water resources around the quarrying industries in Abakaliki and environs.

Component II has an eigenvalue of 4.863 and explains additional 25.592% of the total variance in the data set. The significant variables with positive loadings are Cu, and TH, while the significant variables with negative loadings are Conductivity and DS. This Component II denotes ***water hardness*** resulting from the waste water of quarrying industries within the study areas. Component III explained additional 19.081% of the total variance in the data set with an eigenvalue of 3.625. It has significant positive loading of 0.932 and 0.923 on BOD and DO respectively. It denotes ***high oxygen depletion*** when compared available oxygen for aerobic aquatic microbial organisms. In component IV, only Cd and COD are highly loaded and positively with eigenvalue of 2.028 to explained additional 10.675% of the variance in the original data set.

Table 5: Rotated Component Matrix of Water Sample Parameters

Rotated Component Matrix[a]

Water Parameters	Component				
	1	2	3	4	5
Acidity	.697	-.590	-.273	.227	-.202
As	-.242	.583	-.106	.053	.766
BOD	.297	.018	.939	-.051	-.164
Cd	-.232	.222	.339	.871	.150
COD	-.102	-.001	-.609	.785	.057
Conductivity	.148	-.909	.008	.356	-.160
Cu	.175	.958	.038	.223	.024
DO	.341	.029	.923	.104	-.140
DS	-.117	-.934	-.241	-.115	-.208
Fe	.184	.678	.688	.042	.177
NO3	.975	-.104	.167	-.016	-.099
Pb	.788	.207	.469	-.294	-.172
Ph	-.971	.127	-.079	-.026	.182
PO4	.532	-.477	-.401	.296	-.491
SO4	-.894	-.303	-.216	.113	.222
SS	.964	-.058	.181	-.178	-.047
TH	-.383	.806	-.256	.370	-.023

TS	.886	-.040	.425	-.117	-.139
Zn	-.288	.082	-.214	.155	.917
Eigenvalues	**6.457**	**4.863**	**3.625**	**2.028**	**2.027**
% of Variance Expl	**33.984**	**25.592**	**19.081**	**10.675**	**10.668**
Cum %	**33.984**	**59.576**	**78.657**	**89.332**	**100.000**

Extraction Method: Principal Component Analysis. Significant loadings =+/- 0.70

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

COD being strongly positive denote the presence of ***heavy metals*** in the quarry waste water. Finally, Component V has As and Zn with high significant positive loadings of 0.766 and 0.917 respectively; an eigenvalue of 2.027 and explains 10.668% of the total variance in the data set. Together with other components, the five components explained 100.000% of the variance in the original data set. Component V is an indication of the ***hazardous pollutants*** of the waste water from quarrying industries in Abakaliki and environs.

The PCA model application has successfully transformed the nineteen physico-chemical parameters of water into five (5) components defined by the variables having the highest loading as shown in Table 6. The five variables isolated namely Nitrate (NO3), Copper (Cu), Biological Oxygen Demand (BOD), Cadmium (Cd) and Zinc (Zn) with their relative percentage contributions are the main challenges of quarrying activities in the provision of sustainable quality water resources to the people of Abakaliki and environs.

Table 6: The Relative Strength of the Underlying Dimension of Water Pollutants

Components	Nature of Challenge	Component Defining Variables	Relative contribution of components (%)	Cumulative contribution of components (%)
I	Pollution level of water	Nitrate (NO_3)	33.984	33.984
II	Water Hardness	Copper (Cu)	25.592	59.576
III	High Oxygen Depletion	Biochemical Oxygen Demand (BOD)	19.081	78.657
IV	Heavy metals	Cadmium (Cd)	10.675	89.332
V	Hazardous Pollutants	Zinc (Zn)	10.668	100.000

The Socio-Economic Implications of the Challenges of Quarrying Activities on Sustainable Quality Water Resources in the Study Area

The pollution of the water resources of our study area has far reaching effect on the socio–economic life the people. Osinem, (2005) reported that industrial waste water, discharged untreated may pollute surface water such that fishing, forestry, crop production, animal husbandry and general ecosystem services may be drastically reduced. Notwithstanding its importance, water is the most poorly managed resource the world over (Amadi, 2012). From the component defining variables obtained and the report of our questionnaire administration and interviews held, we were able to deduce the socio-economic implications of the challenges of quarrying activities on sustainable quality water resources in the area. Given the effects of the quarrying activities on surface water bodies in the areas, we were able to deduce that there exists high pollution level that leaves the people with no choice than to make do with what is available. Copper (Cu) contributes significantly to water hardness and hard water gives adverse taste, destroys fabric when washed, causes irritation of skin and atopic eczema (Peter, 2016), consumes more soap during washing, hard to boil, clogs water pipes and leads to breakdown of water treatment plants (Kama, 2016). In addition, high oxygen depletion due to higher BOD than DO and Cadmuim (Cd) (Keilly, 1998; Aimee and Alexandra, 2004) results in not only poor yield of aquatic resources because of death of fish (Naveen, 2012) and other aquatic organisms but also loss of job for artisanal fishermen as Nwele (2016) confirmed. The high turbidity of the surface streams impedes photosynthesis causing breakdown of food chains and balance in the ecosystem (UNEP, 2008). The isolation of Zinc (Zn) is indicative of the presence of other heavy metals normally found in its association such as As, Pb, Cd etc (Graham, 2008) to affect the health of people directly when consumed to cause kidney failure, diarrhea, vomiting, cardiac abnormalities and cancer (NIS, 2007). These health challenges were confirmed to be rampant in the study area by Elom (2017), a health worker in one of the hospitals in the state capital.

The quarry activities which seems to put food on the tables of the indigenes by way of employment, is rather compounding their problems through poisonous surface water. Consequently, there is the need for mitigation of the level of surface water pollution in the study area. Addressing the five component defining variables will reduce to a very great extent the degree of water pollution and death of aquatic organisms in Abakaliki and its environs and make domestic water resources available and sustainable to the inhabitants.

Mitigation Measures

Mitigation measures are options used to either completely eliminate or minimize identified adverse impacts of an identified environmental challenge to as low as reasonably possible. Avoiding or at least reducing the flow of contaminated quarry waste water and the spread of dust particles in the first place is a goal in itself. Preventive measures should consequently seek to reduce the amount of contaminants being released into the water and the total amount of water leaving a quarry site. Unfortunately, prevention is not always possible due to some reasons like, technical hitches, negligence in the implementation of rules and regulations, enforcement, ignorance and local conditions (UNEP, 2010).

For effective mitigation, a preventive integrated management approach is required (Nigeria Industrial Standard (NIS), 2007). Our oral interview with some of the quarry workers proved that they were unaware of any law's guiding the disposal of quarry wastes water; the Standard

Organization of Nigeria and its water protection or management principles, nor do they have any knowledge of water quality standard. Further interrogation also revealed that the quarry workers were not aware of the chemical composition of the quarry pit water and its toxicity.

The overall objective of mitigation is to create a final solution that is protective of human health and environment (Martin and Ruby, 2004). Given the disposition of Abakaliki and environs, the active treatment remediation methods (UNEP, 2010), is advised for the simple reason that the sites are scattered and ownership is not centrally controlled. In view of this, government must step in to stem the level of pollution by applying the active treatment methods by the establishment of a central treatment plant for all quarry waste water and drainages. The active treatment here will involve chemical, biological and physical processes in nature. The chemical removal processes are by oxidation, reduction, coagulation, absorption, adsorption, hydrolysis, and precipitation; the physical removal processes include gravity aeration and dilution while the biological processes include biosorption, biomineralization, bioreduction, and alkalinity generation.

Conclusion

This paper has examined the challenges of providing sustainable quality water resources in the face of quarrying activities in Abakaliki and environs. Assessment of the water samples indicated that the concentrations of Fe, Pb, Zn, Cu, As and Cd in the water samples were not only higher than the baseline concentrations in the control site but also above the Nigerian Industrial Standards, WHO and EU set limits. This significantly pollutes the water and exposes the inhabitants to varying levels of water related diseases and pervasive economic losses due to use of hard and untreated water. Even though quarrying industries contribute significantly to the economic growth in the areas where they operate, it has been shown that their activities negatively affect the welfare of the people and the ecosystems. In order to meet the target 15 of the Sustainable Development Goal, we strongly suggest active mitigation by treatment of waste water in the area before discharge into nearby surface streams and undertaking of Environmental Impact Assessment before any new quarry may be approved in the study area.

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