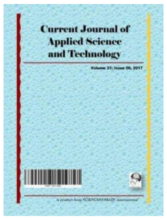

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Assessment of Groundwater Quality around Abandoned Quarry Ponds near Lower Benue Trough, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author FCNM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and managed literature searches. Authors GCO, ECO and EOM did the analyses of the study. All authors read and approved t the final manuscript.

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ABSTRACT

A field study was conducted on the Assessment of Ground Water Quality Around Abandoned Quarry Ponds near Lower Benue Trough, Nigeria and to establish how the Ponds were influenced by past quarrying activities. Water samples were collected from the four abandoned quarry ponds

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measured fifty meters (50 m) (165 ft) deep. These were labeled ABP1, ABP2, ABP3, ABP4, while the wells were labeled HDW (hand dug wells) measured eighty meters (80 m) (264 ft) deep and BH (borehole), measured two hundred eighty meters (280 m) (924 ft). *In-situ* measurements were done with HORIBA U-10 Water Quality Checker to determine pH, temperature, total dissolved solids, turbidity, conductivity, and salinity. Descriptive statistics, Pearson correlation (r) and test of homogeneity (ANOVA) were used to analyse data. There were no wide variations in the levels of the physicochemical parameters of water samples from the abandoned quarry ponds and wells. pH levels ranged between 6.800 and 8.000 (7.200±0.225), temperature ranged between 29.000 and 29.400 (29.067±0.0667) °C, turbidity ranged between 5.00 and 20.00 (10.83±2.71) NTU, total dissolved solids (TDS) ranged between 500 and 1020 (720±103) mg/L, total suspended solids (TSS) ranged between 50 and 800 (525±106) mg/L, Salinity ranged between 5.00 and 15.00 (10.00±1.83) $^0/_{00}$, conductivity ranged between 50.0 and 500.0 (183.7±69.1) µS/cm, CaCO3 ranged between30.0 and 500.0 (355.0±92.2) mg/L, Nitrate ranged between8.00 and 25.00 (13.83±2.52) mg/L, Sulfate150.0 and 280.0 (215.0±18.4) mg/L while Sodium 205.0 and 300.0 (255.8±15.5) mg/L. There was significant variation in concentrations of the physiochemical parameters measured [$F_{(19.27)} > F\ crit_{(2.37)}$] at P< 0.05 and sodium, conductivity, Sulfate and Calcium Carbonate were the most responsible for the observed inequality. Nitrate correlated positively with turbidity(r=0.942), and sulfate correlated positively with total dissolved solids (r=0.942) while turbidity correlated positively with total dissolved solids, (r=0.930) and (r=0.964) at P<0.01. Study findings include increased levels of the physiochemical parameters in the hand dug wells which are therefore a grave danger to consumers. The near surface water table and rock over-breaking due to uncontrolled blasting are enhancing pond water and groundwater interaction, and the resultant groundwater pollution in the study areas. Therefore, the quarry operators must reclaim the pits before departing or provide for the reclamation.

Keywords: Abandoned quarry ponds; geo-environmental hazards; physiochemical parameters; uncontrolled blasting.

1. INTRODUCTION

Rock formation and shapes are attractive places to observe. They can also be educational in nature. Some quarries are notable for their interactive activities and others have museums and studios that are open to the touring public. One such place is Rock of Ages Mine located in Barre, Vermont. According to Lewis [1] Rock of Ages is more than 100 years old.

Quarrying is a very old technology, used since the time of the ancient Egyptians for the limestone used in their immense pyramids, temples and monuments. Quarrying from an open pit has always been less expensive and less hazardous than mining in underground tunnels and vertical shafts [2]. Some quarries used in Roman times, including the Carrara quarry in Tuscany, are still in production and contain inscriptions and artifacts that provide useful information for archaeologists and historians [2]. Quarries present several hazards to engineers and workers. Cutting into a face can cause dangerous rock falls and flying stone fragments. Quarry pits can also fill with water in areas where groundwater lies near the surface, and water is continually pumped out of quarry pits in order to keep them clear of it. In some quarries, stone cutting continues underneath the water surface by dredging.

Quarries pose environmental problems. Quarrying operations create dust, which becomes a nuisance to the environment in addition to the noise of demolition work that is necessary. Excavating quarries destroys natural landscapes and wildlife habitats. To service quarries, roads must be built and during operations a constant stream of construction and excavation vehicles to and fro the site produces noise and air pollution from dust. Quarries can be exploited as long as the limestone deposit remains intact. Eventually, when they go out of production they must be abandoned. Quarries that are no longer in operation pose dangers to hikers and trespassers who see a quarry pool as an inviting place for a swim; ignoring dangerously cold water and the many underwater hazards that are often present like hitting ones head on the rock covered by water, jumping into sharp stone edges etc.

Abandoned quarry pits originally established through uncontrolled blasting threatens life and safety of human beings and other organisms. Some quarry operators in the lower Benue areas do not conduct proper mapping or exploration of a proposed site prior to excavation and mining. These could lead to failure of other engineering structures such as buildings, roads, bridge, and dams in their vicinity. They threaten habitants and ecosystem. According to Lameed and Ayodele [3], forest ecosystem of unexploited plot of quarry is seriously disturbed by quarry activities. The pits may be used for waste dumping or contain contaminated pool of water, thus becoming sources of groundwater pollution and breeding place for mosquitoes. These abandoned mine ponds require reclamation to account for sustainable mining practices in Nigeria.

In this study abandoned quarry ponds in Lokpa-Ukwu and Lekwesi in Abia State are investigated (Fig. 1) to establish whether they influence on the quality of underground water in the nearby surroundings and possible mitigation.

2. MATERIALS AND METHODS

2.1 Study Area

Agriculture used to be the only occupation of the people of the study area. This is induced by the rich soil which stretches from the northern to the southern part of the area. Subsistence farming is prevalent and about 70 per cent of the population is engaged in it [4]. A few farmers also produce on a large scale. Farming in the study area is determined by seasonal distribution of rainfall. The main food crops grown are yam, cassava, rice, cocoyam and maize while the cash crops include oil-palm, cocoa, banana and various types of fruits. Most farms are now occupied by quarry operations. The attention of the farmers is no longer in farming operations rather in mining activity which leads to destruction of farmland due to blind mining activities.

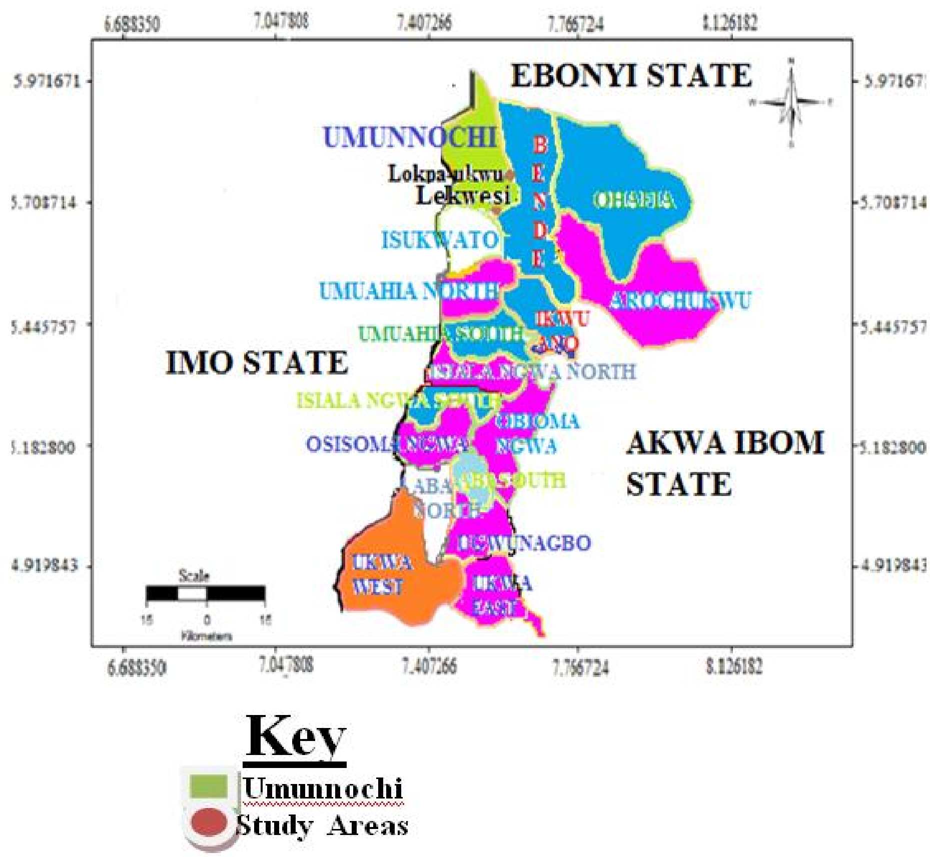

Fig. 1. Map of Abia state showing Lokpa-Ukwu and Lekwesi in Umunnochi local government area

The area is a water scarce region and has played host to mining activities for more than four decades. An annual rainfall of over 180-290 cm is recorded and wet season begins in middle April and reaches a peak of up to 300 cm in July or September. The wettest month is July and dry season begins in late November through March.

Mean monthly temperature range between 26-30°C, while humidity is about 60% and have been studied by several authors [5]. The characteristic dendritic drainage pattern of the argillaceous and other fine grained sediments is not uncommon with Lekwesi and Lokpa-Ukwu. The Ishiagu and environs are well drained with the general river flow trending NE-SW. Majority of the rivers in Lekwesi and environs align in this direction with the exception of those in the NW part which tend to flow in northeast southwest direction, [6].

The intrusive area is characterized by thick and dense vegetation typical of the tropical rainforest. The fine-grained soil; mostly clay, shale, silt and mixtures of these and sands support luxuriant plant growth. The presence of abundant trees, shrubs and grasses is responsible for the dense vegetation found in these areas. The vegetation however is denser in the parts directly overlain by the Asu-River Group that is, mainly Ishiagu, Lekwesi and Lokpa). The general relief of this study area is characterized by hills and valleys. Majority of the hills and valleys align in the NW-SE direction, and conform to orientation of the folds from the Santonian orogenic deformation.

2.2 Sampling

Water samples were collected using 1liter amber glass bottle fitted with a screw cap and lined with foil from the four abandoned quarry ponds of approximately fifty meters (50 m) (165 ft) deep and fifteen meters wide were labeled ABP1, ABP2, ABP3, ABP4, while the wells were labeled HDW (hand dug wells) of about eighty meters (80 m) (264 ft) deep and BH (borehole), measured two hundred eighty meters (280 m) (924ft). Samples were transported to the laboratory in ice-chest to maintain their integrity.

Replicate samples were collected from six sampling points (abandoned quarry ponds, and wells) in the study areas. Sampling was randomized in such a way as to cover the axis of the study area. However abandoned quarry pits selected were proximally closest to the point of the hand dug wells followed by borehole. Distance of ponds to residential areas was estimated using car mileage. Ponds dimensions were measured with tape and the depth probed with logging tool and by GPS measurements. Residential areas considered close to quarry ponds are those not exceeding 2 km interval.

2.3 Experimental Procedures

The temperature and the pH of water samples collected at the study area were measured with Suntex TS-2 PH/MV/Temp Meter. The samples collected were measured for conductivity, salinity and total dissolved solids with HACH CO 150 Conductivity meter. The turbidity and total suspended solids were measured with the HACH DR/2000 Spectrophotometer. The readings were recorded.

The SPSS© Version 17.0 and MS Excel 2007 packages were employed in the analysis of data. The Pearson correlation coefficient (r) was used to determine the influence of parameters detected on the ponds on the hand dug well. Furthermore, descriptive statistics and one-way analysis of variance (ANOVA) was used to determine spatial variance equality in means of the parameters variables at $P< 0.05$, and subsequently, structure of group means was detected using means plots.

3. RESULTS AND DISCUSSION

3.1 Results

There were no wide variations observed in the concentrations of the physiochemical parameters of abandoned mining ponds and groundwater samples in the study area (Lekwesi and Lokpaukwu). pH levels ranges between 6.80 and 8.00, conductivity ranged between 50.00 and 500.00 µS⁄cm, total dissolved solids (TDS) ranged between 500.00 and 1020.00 mg/L, Calcium Carbonate ($CaC0_3$) ranged between 30.00 and 500 mg/L, total suspended solids (TSS) ranged between 50.00 and 800.00 mg/L, and Salinity ranged between 5.00 and $15.00^0/_{00}$,turbidity ranged between 5.00 and 20.00 NTU However, Nitrate ranged between 8.00 and 25.00 mg/L, Sulfate ranged between 150.00 and 280.00 mg/L, Sodium ranged between 2050.00 and 300.00 mg/L while temperature ranged between 29.00 and 29.40°C. Of the physiochemical parameters measured, ABP 2 was the only one with highest concentration of all the physiochemical parameters. Maximum pH and total dissolved solids of 8.00and 1020.00 mg/L respectively were recorded in ABP2and Conductivity 500 mg/L was recorded in ABP4.Minimum pH values of 6.8 were recorded in ABP1and 4, HDW, BH and Minimum total dissolved solids values of 500.00 mg/L were recorded in ABP1, HDW, and BH (Appendix 1).

Fig. 2 shows that maximum Calcium Carbonate ($CaC0_3$) and total suspended solids (TSS) 1000.00 mg/L and800.00 mg/L respectively were recorded in ABP2 while Salinity 15.00 $^0/_{00}$, was recorded in ABP2 and BH. Minimum values (30.00and 50 mg/l) were recorded in BH while Salinity 5.00$^0/_{00}$, was recorded in ABP 1 and HDW. Maximum and minimum turbidity levels of 20.00 and 5.00 NTU were recorded in ABP2,ABP1, HDW and BH respectively while maximum and minimum Nitrate, and Sulfate levels of 25.00 mg/L, 280.00 mg/L, 8.00 mg/l and 150.00mg/l were recorded in ABP2, and BH respectively (Fig. 3). However, Fig. 4 shows that maximum sodium and temperature of 300.00 mg/l and 29.40° Crespectively were recorded in ABP 3 and 4 while minimum Sodium 205.00 mg/L was recorded in BH and minimum temperature of 29.00° Cwere recorded in ABP1-3, HDW and BH.

A test of homogeneity in spatial mean variance of the parameters at P<0.05 revealed significant difference [$F_{(19.27)}$> F crit $_{(2.37)}$]. A further structure of group means that utilized HDW as predictor variable revealed that in ABP1, ABP2, ABP3 and ABP4, sodium (220.00) and conductivity (50.00) were most responsible for the observed significant differences (Figs. 5, 6, 7 and 8). However in BH, Sulfate (150.00) and Calcium Carbonate (30.00) was most responsible for the observed difference (Fig. 9).

The correlation test of the physiochemical parameters measured in abandoned ponds (ABP), hand dug well (HDW) borehole (BH) waters samples of Lekwesi and Lokpa-Ukwu in Abia State.The parameters measured, nitrate correlated positively with turbidity, and sulfate correlated positively with total dissolved solids while turbidity correlated positively with total dissolved solids (r=0.942), (r=0.930) and (r=0.964) at P<0.01 respectively (Appendix 2).

The linear regression scatter plot (Fig. 10) shows that the relationship between in total suspended solids (TSS) and sulfate is statistically significant (P<0.01). The positive correlation (r = 0.964) indicates that when TSS increases, sulfate also tends to increase. The model summary table reports the strength of the relationship between the model and the dependent variable (Sulfate) shows a multiple correlation coefficient, R, that is low (R=0.942), indicating weak relationship. The coefficient of determination, R^2, shows that less than half the variation in TSS is explained by model the (R^2=0.888).

The ANOVA table (Appendix 3) shows the regression and residual sums of squares that are highly unequal (9011.225 and 1138.745, respectively). This indicates that much more than half of the variation in TSS is explained by the model. The significance value of the F statistics which is less than 0.01 (Sig. f = 0.005) indicates that the variation explained by the model is due to chance.

The coefficient's table (Appendix 3) states that the expected Sulfate = .163X TSS concentration 129.210 = 129.373– .163 of TSS concentration. The test of normality of the error term (Fig.11) reveals a regression standardized residual plot that skewed to the right.

The linear regression scatter plot (Fig. 12) shows that the relationship between in nitrate and turbidity is statistically significant (P<0.01). The positive correlation (r = 0.930) indicates that when nitrate increases, turbidity also tends to increase. The model summary table (Appendix 2) which reports the strength of the relationship between the model and the dependent variable (Turbidity) shows a multiple correlation coefficient, R, that is low (R=0.930), indicating weak relationship. The coefficient of determination, R^2, shows that less than half the variation in nitrate is explained by model the (R^2=0.864).

The ANOVA table (Appendix 2) shows the regression and residual sums of squares that are highly unequal (190.833 and 30.000, respectively). This indicates that much less than half of the variation in nitrate is explained by the model. The significance value of the F statistics which is less than 0.01 (Sig. f = 0.007) indicates that the variation explained by the model is due to chance. The coefficient's table (Appendix 2) states that the expected Turbidity =1.000nitrate concentration –4.000 = –3.000 – 1.000 of nitrate concentration. The test of normality of the error term (Fig. 13) reveals a regression standardized residual plot that is slightly skewed to the right.

The linear regression scatter plot (Fig. 14) shows that the relationship between in turbidity and total dissolved solids (TDS) is statistically significant

(P<0.01). The positive correlation (r = 0.964) indicates that when total dissolved solids (TDS) increases, turbidity also tends to increase. The model summary table (Appendix 3) which reports the strength of the relationship between the model and the dependent variable (Turbidity) shows a multiple correlation coefficient, R, that is low (R=0.964), indicating weak relationship. The coefficient of determination, R^2, shows that less than half the variation in TDS is explained by model the (R^2=0.928).

The ANOVA table (Appendix 3) shows the regression and residual sums of squares that are highly unequal (297101.887 and 22898.113, respectively). This indicates that more than half of the variation in TDS is explained by the model. The significance value of the F statistics which is less than 0.01 (Sig. f = 0.002) indicates that the variation explained by the model is due to chance. The coefficient's table (Appendix 3) states that the expected TDS =36.679 nitrate concentration 285.963 = 322.642 – 36.679 of turbidity concentration. The test of normality of the error term (Fig. 15) reveals a regression standardized residual plot that is slightly skewed to the right.

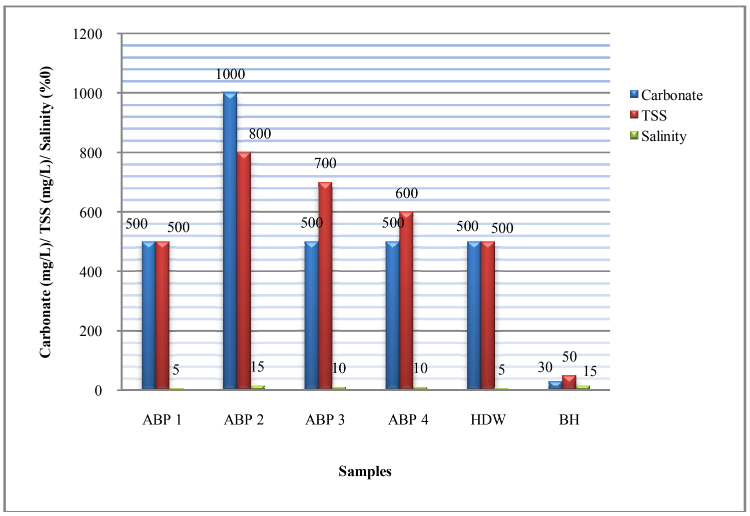

Fig. 2. Spatial variations in calcium carbonate (mg/L)/ TSS (mg/L)/ salinity (%0) concentrations in mining ponds of Lekwesi and Lokpa-ukwu

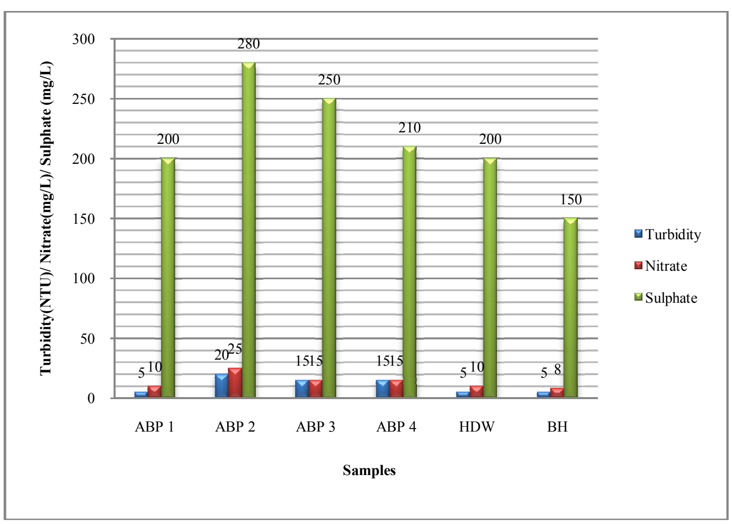

Fig. 3. Spatial variations in turbidity (NTU)/ nitrate (mg/L)/ sulphate (mg/L) concentrations in mining ponds of Lekwesi and Lokpa-ukwu

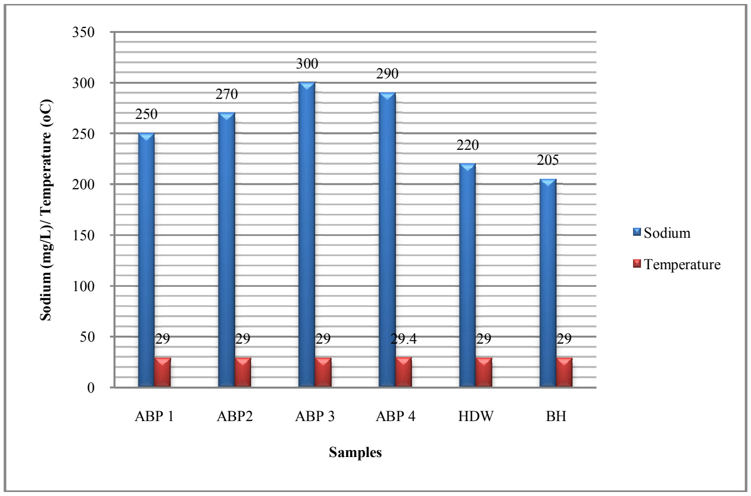

Fig. 4. Spatial variations in sodium (mg/L)/ temperature (°C) concentrations in mining ponds of Lekwesi and Lokpa-ukwu

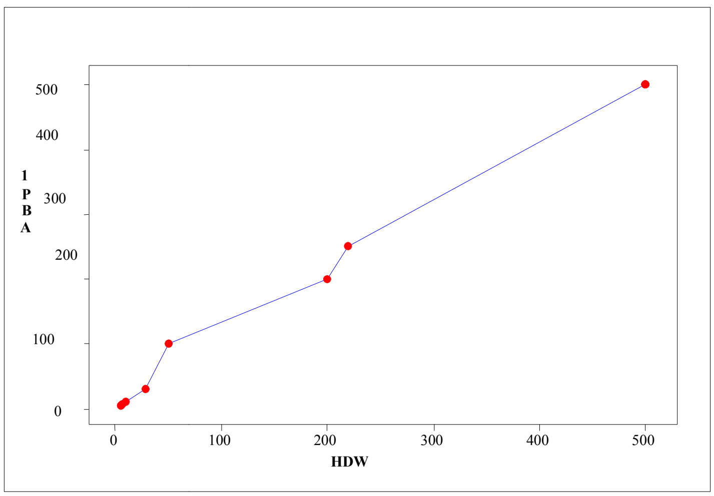

Fig. 5. Plot physiochemical parameter between HDW and ABP1

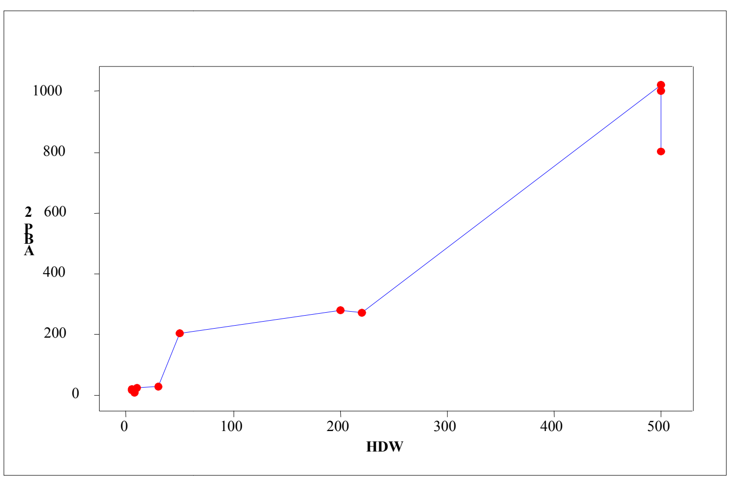

Fig. 6. Plot of the physiochemical parameter between HDW and ABP2

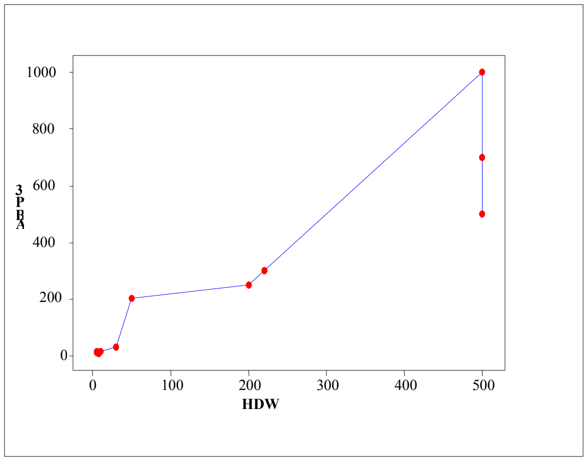

Fig. 7. Plot of the physiochemical parameter between HDW and ABP3

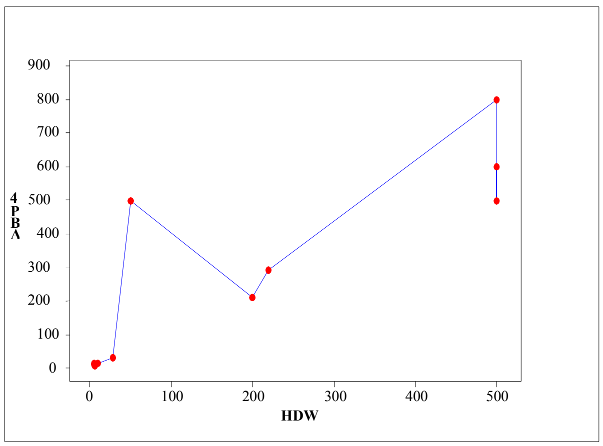

Fig. 8. Plot of the physiochemical parameter between HDW and ABP4

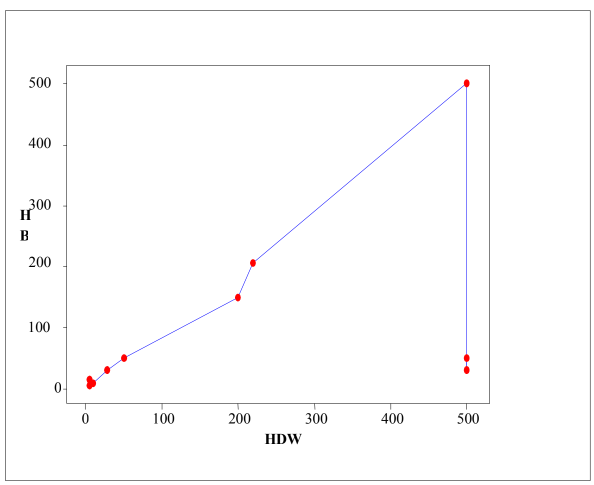

Fig. 9. Plot of the physiochemical parameter between HDW and BH

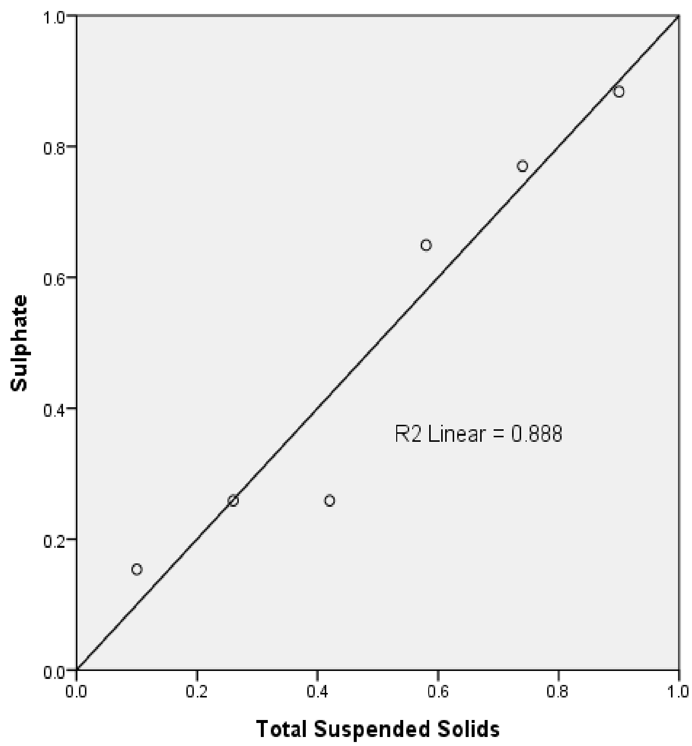

Fig.10. Regression scatter plot between total suspended solids (TSS) and sulfate

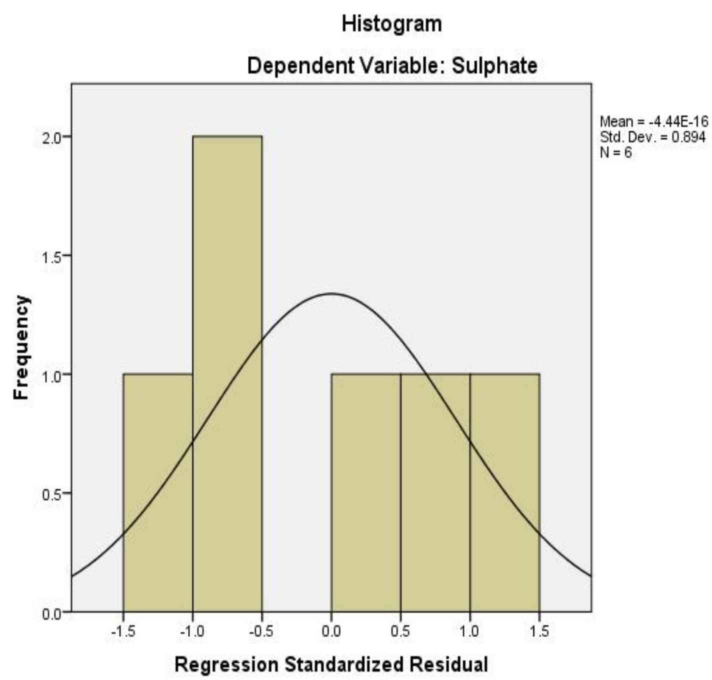

Fig. 11. Regression standardized residual plot between total suspended solids (TSS) and sulphate

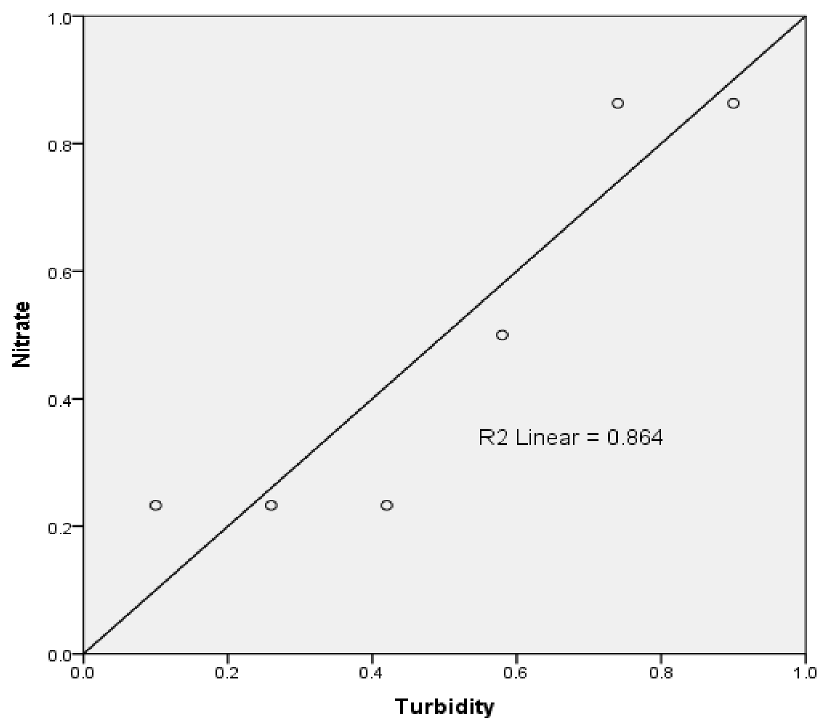

Fig. 12. Regression scatter plot between turbidity and nitrate

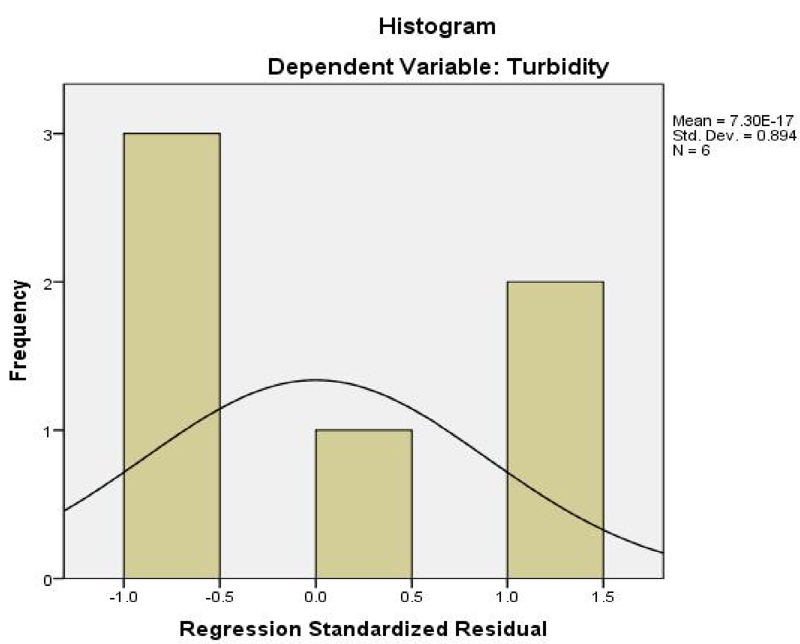

Fig. 13. Regression standardized residual plot between turbidity and nitrate

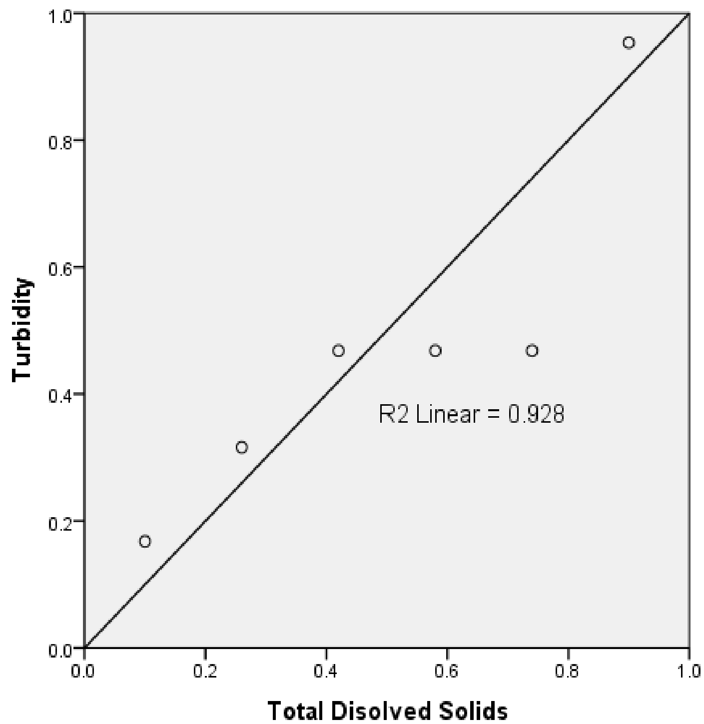

Fig.14. Regression scatter plot between total dissolved solids (TDS) and turbidity

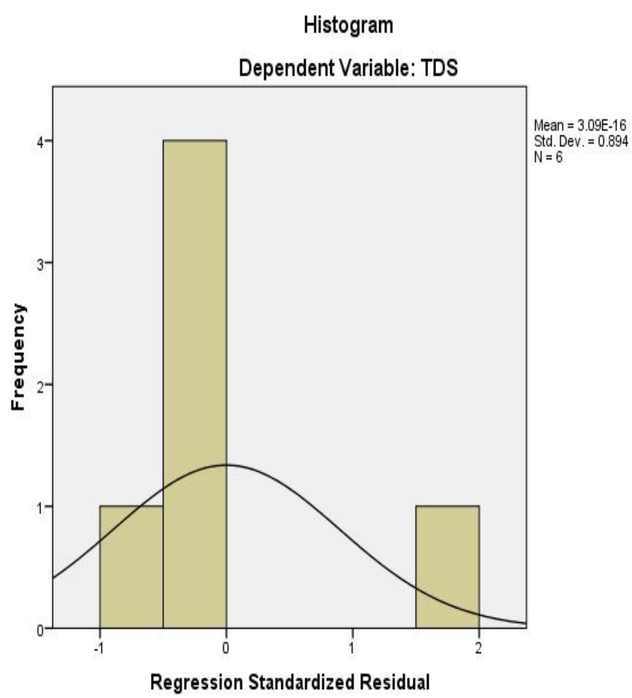

Fig. 15. Regression standardized residual plot between total dissolved solids (TDS) and turbidity

Table 1. Concentrations of the physiochemical parameters in the abandoned quarry ponds and wells sampled concentrations

Parameter	ABP 1	ABP 2	ABP 3	ABP 4	HDW	BH	WHO/EU
P^H	**6.8**	**8**	7	6.8	6.8	7.8	6.5-8.5
Conductiv	**100**	**202**	200	500	50	50	250
TDS	**500**	**1020**	1000	800	500	500	500
$CaCO_3$	500	1000	500	500	500	30	30
TSS	500	800	700	600	500	50	50
Salinity	5	15	10	10	5	15	5
Turbidity	5	20	15	15	5	5	5
Nitrate	10	25	15	15	10	8	50
Sulphate	200	280	250	210	200	150	500
Sodium	250	270	300	290	220	205	200
Temp	29	29	29	29.4	29	29	29

3.2 Discussion

There were narrow variations in the concentrations of the physiochemical parameters characteristics of groundwater sources in the aquifers of the region of the study area increasing future inputs could portend heavy pollutions in the aquifers. In the Hand Dug Well (HDW) water samples analysed, with the exception of Calcium Carbonate ($CaCO_3$), Total Suspended Solids (TSS) and Sodium (Na), the other parameters were equal or below the World Health Organization and European Union's maximum permissible limits for drinking water. The World Health Organization [7] and European Union [8] has 30 mg/l, 50 mg/l and 200 mg/l respectively as the permissible limits for drinking water. Hence, the results obtained from this research exceeded the WHO and EU drinking water standards for ABPs.

The possibility of seepage and subsequent contamination of the groundwater aquifer by surface pollutants have been severally identified by other authors [9]. Depth is an important factor in well contamination. The deeper the well the lowers the chances of contaminations, all other things being equal. Water containing contaminants may not move deep enough to reach deeper groundwater aquifers. Also, as contaminated water moves deeper, time and the amount of soil it passes through increase. This in turn increases opportunities for contaminants to be broken down by physical and chemical processes, taken up by micro-organisms and plants or bound to soil particles. Distance from the source of contamination is also important, the closer the sources, the greater the chances of the contaminations. This is in part due to the decreased time and amount of soil the contaminated water will move through. Also, well contamination is often caused by contaminated water moving down the outside or inside of the well casing, [10].

Total solids are dissolved solids plus suspended and settleable solids in water. In stream water, dissolved solids consist of calcium, chlorides, nitrate, phosphorus, iron, sulfur, and other ions particles that will pass through a filter with pores of around 2 microns (0.002 cm) in size, [11]. Suspended solids include silt and clay particles, plankton, algae, fine organic debris, and other particulate matter. These are particles that will not pass through a 2-micron filter. The concentration of total dissolved solids affects the water balance in the cells of aquatic organisms. An organism placed in water with a very low level of solids, such as distilled water, will swell up because water will tend to move into its cells, which have a higher concentration of solids. An organism placed in water with a high concentration of solids will shrink somewhat because the water in its cells will tend to move out. This will in turn affect the organism's ability to maintain the proper cell density, making it difficult to keep its position in the water column. It might float up or sink down to a depth to which it is not adapted, and it might not survive. A high concentration of total solids will make drinking water unpalatable and might have an adverse effect on people who are not used to drinking such water. Levels of total solids that are too high or too low can also reduce the efficiency of wastewater treatment plants, as well as the operation of industrial processes that use raw water. Total dissolved solids (TDS) are determined by filtering a water sample and measuring the residue upon evaporation of the filtrate, [11]. Sulfate, carbonate and sodium are the main constituents of TDS in the study area waters.

According to Soltanpour et al. [12], Nitrates and nitrites are nitrogen-oxygen chemical units which combine with various organic and inorganic compounds. The greatest use of nitrates is as a fertilizer. The formation of nitrates is an integral part of the nitrogen cycle in our environment. In moderate amounts, nitrate is a harmless constituent of food and water. Plants use nitrates from the soil to satisfy nutrient requirements and may accumulate nitrate in their leaves and stems. Due to its high mobility, nitrate also can leach into groundwater. If people or animals drink water high in nitrate, it may cause methemoglobinemia, an illness found especially in infants.

Pregnant women, adults with reduced stomach acidity, and people deficient in the enzyme that changes haemoglobin back to normal hemoglobin are all susceptible to nitrite-induced methemoglobinemia. The most obvious symptom of methemoglobinemia is a bluish color of the skin, particularly around the eyes and mouth. Other symptoms include headache, dizziness, weakness or difficulty in breathing. Babies with these signs should be immediately taken to hospital, [13]. If recognized in time, methemoglobinemia is treated easily with an injection of methylene blue. Prolonged intakes of high levels of nitrate are linked to gastric problems due to the formations of nitrosamines. N-nitrosamine compounds have been shown to cause cancer in test animals. Studies of people exposed to high levels of nitrate or nitrite have not provided convincing evidence of an increased risk of cancer. The inhabitants in the study area cannot escape this problem if necessary action is not taken and urgently.

Nitrates form when microorganisms break down fertilizers, decaying plants, manures or other organic residues. Usually plants take up these nitrates, but sometimes rain or irrigation water can leach them into groundwater. Although nitrate occurs naturally in some groundwater, in most cases higher levels are thought to result from human activities. Once taken into the body, nitrates are converted to nitrites. Infants below six months who drink water containing nitrate in excess of the maximum contaminant level (MCL) could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue baby syndrome. The current maximum contaminant level (MCL), is 10 mg/L or 10 ppm, [11]. EPA has set this level of protection based on the best available science to prevent potential health problems. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed nitrate as part of the Six Year Review and determined that the 10 mg/L or 10 ppm MCLG and 10 mg/L or 10 ppm MCL for nitrate are still protective of human health. The major sources of nitrates in drinking water are runoff from fertilizer use; leaking from septic tanks, sewage; and erosion of natural deposits.

Turbidity is a measure of the cloudiness of water- the cloudier the water, the greater the turbidity. Turbidity in water is caused by suspended matter such as clay, silt, and organic matter and by plankton and other microscopic organisms that interfere with the passage of light through the water [14]. Turbidity is closely related to total suspended solids (TSS), but also includes plankton and other organisms.

Turbidity itself is not a major health concern, but high turbidity can interfere with disinfection and provide a medium for microbial growth. It also may indicate the presence of microbes (11). The U.S. Environmental Protection Agency's (EPA) "Surface Water Treatment Rule" requires systems using surface water (or ground water under the direct influence of surface water) to (a) disinfect their water, and (b) filter their water or meet criteria for avoiding filtration so that at no time can turbidity go above 5 nephelometric turbidity units (NTUs). Systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month [11].

The USEPA has established the National Secondary Drinking Water Regulations (NSDWRs or secondary standards). These secondary standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. U.S. EPA [15] recommends secondary standards to water systems but does not require systems to comply.

It is used to indicate water quality and filtration effectiveness (such as whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause sickness/illness such as nausea, cramps, diarrhea, and associated headaches.

According to Loneragan et al. [16] Sulfate is a substance that occurs naturally in drinking water at various concentrations. Health concerns regarding high sulfate concentrations in drinking water have been raised because of reports that link it with an increased occurrence of diarrhea. Groups at potential risk within the general population from the laxative effects of sulfate are those that encounter an abrupt change from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations. Sulfate in drinking water currently has a secondary maximum contaminant level (SMCL) of 250 milligrams per liter (mg/L), based on aesthetic effects (i.e., taste and odor).

Sulfate is a necessary nutrient for plants, and therefore, for the stream community as a whole. However, it is not known to be limiting to the normal expression of aquatic life in aquatic ecosystems. It may also be a necessary nutrient for animals, e.g., in formation of chondroitin sulphate. Sulfate is a conventional pollutant. The toxicity exerted by sulfates is probably the sudden change of ionic concentration, i.e., the relative saltiness of the water, rather than other types of interference with organism metabolism [10]. If an organism can withstand the osmotic shock initially, it will probably continue to survive and function at a given sulfate level indefinitely. Sulfate is not a toxicant in the category of heavy metals, pesticides or other toxic natural or man-made substances, but rather is a common salt necessary for life at some concentration [13].

Undoubtedly, this result creates a great cause for public health concerns; especially as high consumption of sodium can have many negative effects, such as increased blood pressure and heart complication. Excessive sodium in the diet has many serious, dangerous side effects especially when the kidneys which naturally balance sodium levels cannot excrete sufficient sodium; it begins to aggregate in the blood as well as fluid build-up in people with congestive heart failure, cirrhosis or kidney disease [17].

Calcium carbonate depending on an individual may cause heartburn, constipation or gas and excessive intake of Calcium over time raises risk of kidney stones [18]. According to the National Institutes of Health Osteoporosis and Related Bone Diseases states that lack of calcium leads to Osteoporosis, unhealthy bones and improper functioning of central nervous system, blood vessels, heart and muscles.

High Total Suspended Solids in water body can often mean higher concentrations of bacteria, and metals in the water. As plants and animals decay, suspended organic particles are released and can contribute to the TSS concentration, (Fig. 5). These pollutants have negative health implications [19].

They are not only ingested by drinking contaminated waters, but can also be absorbed through wet skin, inhaled as it volatilizes during showering, laundering, or cooking and are further consumed when this water is used to prepare foods. This thus increases the risk of elevated concentrations in tissues of man and other animals. Inevitably man could suffer the greatest risk of bioaccumulation due to his position in the trophic chain; being a tertiary consumer in addition to his predisposition to other routes of entry into his body. Worse still, carcinogenicity is transgenic, as oncogens (cancer prone genes) could be inherited by filial generations [20].

The observed significant spatial variations in concentration of the physiochemical variables measured indicated that the wells sampled had different levels of occurrences and concentrations. The HDW, which had the highest concentration, is located very close to the abandoned quarry pits. Thus the concentration can therefore, be attributed to its proximity to the depth of HDW, and the polluted and highly contaminated abandoned quarry pits.

4. CONCLUSION AND RECOMMENDATIONS

Study findings include increased levels of the physicochemical parameters in the hand dug wells which are therefore a grave danger to consumers, and show that the near surface water table and rock over-breaking due to uncontrolled blasting **are** enhancing pond water and groundwater interaction, and the resultant groundwater pollution in the study areas. This buttresses the fact that their presence in the hand dug wells of the study areas could be finger printed to contaminations from the abandoned quarry ponds in the study areas.

According to UNEP [21], water quality is influenced by many factors. It is dynamic in nature and cannot be defined or measured only by one parameter. It is variable in both time and space and requires routine monitoring to detect spatial patterns and changes overtime. Quarry Company can exploit quarries as long as the rock or the economic deposit remains intact. Eventually, they go out of production and become abandoned. Quarries that are no longer in operation pose dangers to man and all animals in the vicinity, and other nearby communities during their production and operation processes. Many quarries naturally fill with water after abandonment and become lakes. Others are made into dump sites and this happens very frequently resulting to untreated wastewater pollutes the underground aquifers.

It is difficult to reach operators of most abandoned quarry pits in the lower Benue Trough after they left the site Absence or lack of enforcement of relevant mining laws has led to quarry operators abandoning quarry pits without giving concern to environmental safety. Abandoned isolated pits are now within close proximity to residential areas due to increasing population and development.

Therefore, the quarry operators must reclaim the pits before departing or provide for the reclamation. Where government agency issuing quarry license fail to enforce this; land owners or the host community must not fail. As a matter of urgency, the company should act to contain the expanding groundwater plume and further remediate contaminated aquifers. According to EPA [22] water supplier system must continue to monitor the parameter levels. If contaminant levels are found to be consistently above the MCL, government must take necessary steps to reduce the amount so that it is consistently below that level.

The following treatment methods have been approved by U. S. EPA, WHO and EU will be controlled by Effluent Limitation Regulations, Basic Standards and Best Management Practice (BMPs).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Appendix 1.Table 2. Correlation matrix (r) between the physiochemical parameters

P^H	Cond	TDS	$CaCO_3$	TSS	Salin	Turb	Nitrat	Sulph	Sodiu	
Cond	**-0232**									
TDS	**0.281**	**0.526**								
$CaCO_3$	**-0967**	**0.290**	-0.058							
TSS	-0.153	0.456	0.768	0.386						
Salin	0.892	0.135	0.460	-0.862	-0.129					
Turb	0.327	0.640	0.964**	-0.123	0.766	0.505				
Nitrat	0.458	0.422	0.862	-0.247	0.787	0.471	0.930**			
Sulph	0.161	0.318	0.874	0.089	0.942**	0.149	0.852	0.902		
Sodiu	-0.239	0.742	0.826	0.425	0.796	0.029	0.789	0.601	0.727	
Temp	-0.355	0.915	0.155	0.315	0.141	0.000	0.307	0.093	-0.054	0.440

*** *Correlation is significant at P<0.01 level (2 tailed). Temp = temperature, TDS= Total Dissolve Solid, TSS= Total Suspended Solids, $CaCO_3$= Calcium Carbonate, Conduct = Conductivity*

Appendix 2. Regression models between TSS and sulfate

Model summary[b]

Model	R	R^2	Adjusted R^2	Std. error of the estimate	Change statistics				
					R^2 change	F change	df1	df2	Sig. F change
1	.942[a]	.888	.860	16.87265	.888	31.653	1	4	.005

a. Predictors: (Constant), TSS; b. Dependent Variable: Sulfate

ANOVA[a]

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	9011.255	1	9011.255	31.653	.005[b]
	Residual	1138.745	4	284.686		
	Total	10150.000	5			

a. Dependent Variable: Sulfate; b. Predictors: (Constant), TSS

Coefficients[a]

Model		Unstandardized coefficients		Standardized coefficients	t	Sig. F
		B	Std. error	Beta		
1	(Constant)	129.373	16.706		7.744	.001
	TSS	.163	.029	.942	5.626	.005

a. Dependent Variable: Sulfate

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