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Influences of limestone stone quarries on groundwater quality

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ABSTRACT

Rapid population growth and increasing demand for the modern settlement has led to the increase of environmental pollution. Limestone quarry is one among the activities that affect environment and ecosystem in Pemba Island-Zanzibar. Quarrying activities brought an inevitable destruction to the environments ranging from excavation, soil and land degradation, loose of biodiversity and water pollution. This study reports the impact of limestone quarries on groundwater quality based on analyses of various physico-chemical parameters of groundwater. Ground water samples were collected during the wet and dry season of 2016 from nine different wells in vicinity of limestone quarries. One groundwater sample, which was located about 5 kilometers from limestone quarries, was collected as a control. The result shows that the groundwater have an elevated level of pH, total dissolved solid, Electrical Conductivity, total alkalinity, as compared to control sample. Also the concentration level of Ca^{2+}, Mg^{2+} and Na^{+} slightly increases in all samples from dry season to wet season. This is probably due to the mixing of surface pollution and dissolution of limestone rocks. The study revealed that the nitrate and potassium concentrations are very high in the well nearest the limestone quarries. It is likely due to percolation of fertilizer from agricultural runoff stagnated nearby limestone quarries. This study shows that a conceptual physico-chemical interpretation of the results from water samples provides information of groundwater contamination, which is mainly derived from agricultural runoff and stagnated nearby limestone quarries. This study recommends that the quarrying activities should be minimal towards the subsurface level in order to reduce the possibility of aquifer contamination.

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INTRODUCTION

The process of getting useful stone from a quarry is known as quarrying. The methods and equipment used in quarry depend on the purpose for which the stone is extracted. Rapid growth of construction activity to meet the modern-day requirements of increasing population and housing development needs of the society, has immensely boosted the demand for building, thus stimulating stone quarrying operations (Lad and Samant, 2014). In the developing countries where poverty levels are higher, small scale informal quarrying has become a significant source of livelihood due to little potential of the formal sector to create jobs (Ibrahim, 2007). In Pemba Island-Zanzibar majority of poor people depend on quarry operations as the only alternative form of livelihood (Ibrahim, 2007). Six main areas of quarries are now

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present in Zanzibar. However, rock quarrying and stone crushing is now a global phenomenon and has been the cause of concern everywhere in the world, including the advanced countries (Lameed and Ayodele, 2010). Quarrying negatively affects the environment in a variety of ways from exploration and blasting, transport and disposal of waste rocks. The major environmental effects are destruction of vegetation, disruption of animal habitats, diversion and blockage of natural drainage systems, soil erosion and river siltation, noise and vibration and dust pollution (Maponga and Munyanduri, 2001). The Revolutionary Government of Zanzibar has made several interventions in protecting the environment through different policies such as the Environmental Policy of 2013, the Education Policy of 2006 and the Water Policy of 2004. Furthermore, the Government of Zanzibar formulated the Strategy for Growth and Reduction of Poverty (GoZ, 2004) to stem out environmental problems (GoZ, 2010). Yet, most environmental problems, including those arising from quarry operations have been difficult to solve (Backsdale, 2013). Good drinking water quality is essential for the well-being of all people. Unfortunately, in many countries around the world, including Tanzania, some drinking water supplies have become contaminated, which has impacted on the health and economic status of most people. Potable water has become a scarce commodity due to over exploitation and pollution. Scarcity and misuse of potable water pose a serious and growing threat to sustainable development and protection of the environment. Human health and welfare, food security, industrial development and ecosystems are all at risk, unless water and land resources are managed more effectively in the present decade and beyond than they have been in the past, (ICWE, 1992). Problem of this nature have been increasing in scope, frequency, and severity because the demand for water continue to grow while supply of renewable water remain fixed. While it is agreed that water is one of the most important resources with great implications for African development, the freshwater situation in Africa is unfortunately not encouraging. Presently, it is estimated that more than 300 million people in Africa live in a water-scarce environment (WHO and UNICEF, 2012). In many countries, requirements for domestic freshwater use, sanitation, industry and agriculture cannot be met (WHO, 2004). The situation is getting worse because of population growth, rapid urbanization, increasing agriculture and industrial activities, mining and lack of adequate capacity to manage freshwater resources. Several researches have been conducted on groundwater quality. However, study on limestone rock quarrying and its influence on water quality has not been conducted in Zanzibar. Therefore, the study analyzes the influence of limestone quarrying on groundwater quality at the vicinity limestone quarrying. This study has been carried out in Kangagani and Uwandani pemba, Zanzibar Tanzania in 2016.

MATERIALS AND METHODS

Selection of study area

The study area, Uwandani and Kangagani was selected because the quarrying area is found nearest to the settlements, and the villagers depend on surface and groundwater sources for drinking and domestic purposes.

Location and access

The study was carried out at Uwandani and Kangagani quarries which were administratively in Chake-chake District in South Region Pemba, Zanzibar. Zanzibar is a part of the United Republic of Tanzania. It consists of two major sister islands Unguja and Pemba which are situated in the Indian Ocean, approximately 35km off the mainland of Tanzania at 70 and 90 at 60 South of the Equator and about at 390 E. The Island of Pemba lies about 40 km North East of Unguja Island with a surface area of 988 km^2 (Kombo and Kanyama, 2015). The demand for aggregates in the islands of Unguja and Pemba has increased dramatically over the recent years due to increased construction activities and the need for modern settlements. Uwandani and Kangagani were endowed with informal quarrying operations which affect the environment negatively (Backsdale, 2013). This study was specifically conducted in eight villages of Uwandani and Kangagani, namely, Uwandani Makaani, Kwareni, Makaani chuoni, Uwandani kanisani, Mandani, Magereza, Shukwa and Nyange . These villages are located near the quarrying sites of Uwandani, and kangagani (Fig. 1).

Sample ccollection and tested parameters

Samples were collected from 9 boreholes.4 stations found nearest to each quarry site, 1 station found

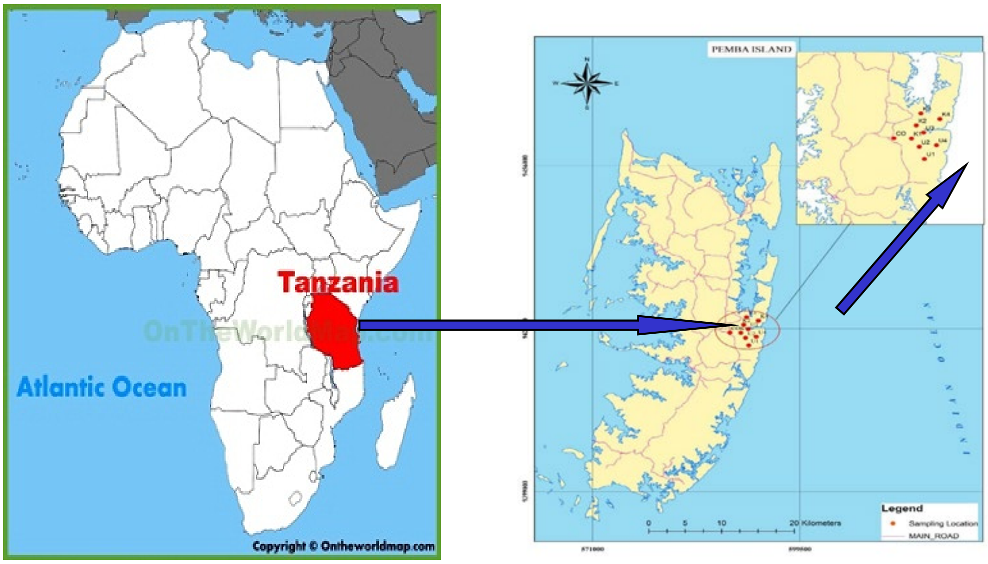

Fig. 1: The geographic location of the study area in Uwandani and Kangagani quarry Pemba-Island Zanzibar, Tanzania

approximately 5 kilometer far from the quarries and will be control (Co), at Uwandani the station were named as U-1, U-2, U-3, and U-4, where K-1, K-2, K-3, and K-4 were the well found at Kangagani. All stations now are used as a source of water for domestic purposes including drinking. The water samples were collected two times, dry season (January-February) and rainy seasons (March- April) of 2016. Samples for analysis were collected in 1Litre sterile plastic bottles; these bottles were previously soaked in 5% HNO3 over-night and thoroughly washed with distilled water. A group of physical and chemical parameters were tested in groundwater samples. The Physical parameters include temperature, pH and electrical conductivity (EC). The chemical parameters include: Nitrite (NO_3), Ammonia (NH_4), Chloride (Cl), Sulfate (SO_4), Iron (Fe), and bicarbonates. Some cation like calcium, magnesium and iron were tested in Zanzibar water authority laboratory following the standard methods (American Public Health Association, 2005). All other chemical analysis was done at Ardhi university laboratories where bottles were sealed and transported to laboratory in the same day of collection. The water samples parameters were checked for its accuracy by using charge balance error. Generally water samples solution has to be electrically neutral. This means that the concentration of anions has to be balanced by (i.e. equal to) that of the cations. In doing so the following formula was used. It was found that charge discrepancy between cations and anions were less than ±5%, except for one groundwater U-4 which had 12% anions deficiency, the negative value indicate that anions are higher than cations. Table 1 shows the charge balance error for groundwater samples.

RESULTS AND DISCUSSION

The average mean values of pH in the dry and wet season are 7.4 and 7.6 respectively. All values were within the 2004 W.H.O standard of 6.5-8.5 for drinking water guideline value. The general basicity of the water samples might be due to the dissolution of limestone rocks (Essumang *et al*., 2011). However, this alkaline nature of water may be due to limestone mining. Since, mother rock of the area is calcium bicarbonate which dissolves in water generates alkalinity. In all station increasing of pH is direct proportion to the HCO_3^-, this may be caused by ion of carbonate rocks which in water form carbonic acid that dissociate to H^+ and HCO_3^- ions. The acidity generated enhances the weathering of the calcite and dolomite in the aquifer basement, resulting increased concentration of pH and HCO_3. The physical parameters of the sample-ID is shown in Table 2.

Temperatures ranged between 30.1 -30.8°C and 29.9°C -30.7°C for dry season and wet season respectively. All values were above the W.H.O

Table 1: Charge balance error for groundwater samples

Sample	Na^+ (meq/L)	K^+ (meq/L)	Mg^{2+} (meq/)	Ca^{2+} (meq/L)	Sum cation	Cl^- (meq/L)	NO_3^- (meq/L)	SO_4^- (meq/L)	HCO_3- (meq/L)	Sum anions	Diff. Ions	Sum Cation	EB (%)
control-d	2.001	0.084	0.015	2.632	4.732	0.366	0.510	0.001	2.961	3.838	0.894	8.570	10.43
U1-d	8.045	0.453	0.169	1.721	10.39	3.122	0.024	0.003	8.975	12.12	-1.736	22.51	-7.711
U2-d	4.000	1.662	0.342	2.200	8.210	2.894	0.062	0.043	6.201	9.200	-0.988	17.41	-5.674
U3-d	3.935	0.183	0.631	4.269	9.018	2.87	2.536	0.002	4.904	10.31	-1.294	19.33	-6.694
U4-d	9.431	0.103	0.885	7.902	18.32	3.017	5.364	0.017	11.62	20.01	-1.698	38.34	-4.429
K1-d	8.212	0.150	1.075	3.821	13.25	8.631	0.003	0.056	6.100	14.79	-1.532	28.04	-5.462
K2-d	5.460	0.100	0.432	6.235	12.22	1.801	3.681	0.001	8.321	13.80	-1.577	26.03	-6.058
K3-d	4.641	0.120	0.247	4.642	9.650	2.035	1.032	0.061	7.510	10.63	-0.988	20.28	-4.869
K4-d	12.80	0.015	0.841	9.148	22.80	14.32	1.346	0.003	6.942	22.61	0.194	45.41	0.422
control-w	2.316	0.105	0.251	2.963	5.635	0.680	0.004	0.000	3.901	4.585	1.050	10.22	10.27
U1-w	8.925	0.923	0.092	3.506	13.44	3.601	0.901	0.083	10.16	14.74	-1.299	28.19	-4.607
U2-w	5.862	1.962	0.160	4.176	12.16	4.325	1.232	0.030	8.320	13.90	-1.747	26.06	-6.701
U3-w	5.508	0.200	1.024	6.971	13.70	6.891	0.901	0.000	8.103	15.89	-2.192	29.59	-7.405
U4-w	9.974	0.134	1.247	12.84	24.19	3.261	1.767	0.015	13.69	18.73	5.463	42.93	12.72
K1-w	11.73	0.601	2.002	8.054	22.38	10.32	4.926	0.158	8.825	24.23	-1.850	46.62	-3.967
K2-w	5.873	0.331	0.343	9.421	15.96	2.960	0.001	0.000	11.30	14.26	1.702	30.23	5.629
K3-w	4.901	0.290	0.641	9.882	15.71	2.735	0.092	0.055	13.32	16.20	-0.494	31.92	-1.547
K4-w	12.90	0.102	3.532	14.09	30.63	14.82	2.461	0.032	14.10	31.41	-0.781	62.04	-1.258

guideline of 22°C - 29°C for drinking water. Water temperature could be affected by the weather, types of the wells and altitudinal variation of the sites (Fritz, 2001). The higher temperature in dry season was also reported by Kadam *et* al. (2007) that higher transparence occurred, during dry season due to absence of rain, runoff and flood water as well as gradual settling of suspended particles. The value of E.C varied from 118 ms/cm - 487 ms/cm in dry season and 187ms/cm - 784ms/cm in wet season with an average value of 252ms/cm in dry and 464.88ms/cm in wet season. The water samples at control, K-2 and K-4 show relatively low E.C, whereas high EC value in K-3, K-1 and U-4 for both the seasons. All values recorded for the dry and wet season were below the W.H.O recommended value of 300 µS/cm for drinking water. High electrical conductivity of the water could be directly attributed to the concentration of dissolved salts or minerals in the water. Groundwater is susceptible to high mineral salt concentration which comes from the dissolution of minerals in the soil as a result of quarrying activities which disturb mineralized rocks and could release absorbed ions into the water to increase the ionic content, and subsequently the conductivity of the water (Prowse, 1987). Electrical conductivity (EC) gives a measure of the ability of water to conduct an electric current; the greater the content of ions in the water, the more current the water can carry (Dharmappa *et al*., 2000). Total Dissolved Solids may be considered as salinity indicator for classification of groundwater. TDS in groundwater is due to the presence of Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Chloride and Sulphate ions. In the study area TDS value ranged from 21mg/L– 177mg/L in dry season and 86mg/L– 301mg/L in wet season with an average of 169.55mg/L. Whereas maximum concentration was found in U-2 and K-1, the higher TDS is probably due to the additions of more organic and inorganic ions from the contaminated water discarded in these water bodies by the limestone quarry. As prescribed limit of TDS for drinking water is 500 mg/L, all the water samples have TDS concentration well below the prescribed limit by WHO.

Table 2: The physical parameters of the sample-ID

Sample-ID	pH		Temp. (°C)		TDS (ppm)		E.C (µS/cm)		Turbidity (NTU)	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Control	7.10	7.00	30.4	30.0	21.0	86.0	118	187	0.30	0.96
U-1	7.07	7.20	30.8	30.2	98.0	164	141	288	4.50	9.50
U-2	7.37	7.70	30.1	30.7	151	301	308	534	6.00	8.40
U-3	7.64	7.30	30.2	30.0	124	190	174	308	1.90	4.82
U-4	7.70	7.40	30.1	30.1	170	243	281	494	1.30	2.13
K-1	7.52	7.60	30.5	30.3	177	263	243	553	3.40	4.80
K-2	7.50	7.74	30.4	30.9	176	237	487	687	2.80	6.70
K-3	7.56	7.50	30.5	30.0	136	217	325	784	0.100	0.69
K-4	7.70	8.01	30.4	30.0	102	204	191	349	4.80	6.66

Table 3: Pearson correlation coefficients for 10 variables of water samples in dry season

	TDS	pH	Temp	K^+	Na^+	Ca^{2+}	Mg^{2+}	Fe^+	NO_3^-	Cl^-	HCO_3^-	Salinity
TDS	1											
pH	-0.011	1										
Temp	-0.289	0.157	1									
K^+	0.147	-0.305	-0.319	1								
Na^+	0.257	0.834**	0.164	-0.284	1							
Ca^{2+}	0.292	0.669*	-0.308	-0.509	0.670*	1						
Mg^{2+}	0.603	0.453	-0.297	-0.252	0.668*	0.602	1					
Fe^+	0.024	-0.289	-0.363	-0.243	0.100	0.215	0.283	1				
NO_3^-	0.080	0.280	0.132	0.881**	0.112	0.519	-0.109	-0.340	1			
Cl^-	0.096	0.839**	0.107	-0.189	0.818**	0.542	0.670*	-0.160	0.632	1		
HCO_3^-	0.576	0.255	0.008	-0.077	0.565	0.444	0.302	0.267	0.090	0.032	1	
Salinity	0.306	0.778*	0.216	-0.432	0.840**	0.757*	0.593	-0.125	0.573	0.803**	0.369	1

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

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

Chemical analysis of groundwater

The average values of the chemical parameters of the water samples for each station were presented in Tables 2, 5 and 6. According to Pallant (2011), a correlation coefficient can be described as: small correlation - 0.10 ≤ r ≤ 0.29, medium correlation -0.30 ≤ r ≤ 0.49 and large correlation 0.50≤ r ≤ 1.0.The positive and the negative point to the direction of the relationship, where the positive indicates an increase in one variable associated with an increase in the other, whilst the negative correlation means an increase in one variable related to a decrease in the other.

Impact of limestone quarries on ground water quality

Among the cation Calcium concentration slightly increases in all sampling stations, excluding control station, from dry season to rainy seasons. The level of calcium is seen to be high at all stations nearest the quarry site, K-4 show the highest value 282.4638mg/L. The value of Ca^{2+} varied from 2.74 mg/L – 183.32 mg/L in dry season. During the wet season the value range from 9.37 mg/L – 282.40mg/L with an average mean 94.80mg/L and 160.12 mg/L respectively. Variation of calcium from dry to wet season may be attributed by weathering of limestone rocks by rain water. Magnesium concentration was reported to be lesser than the calcium values in all cases. Mg^{2+} concentration varied from 0.18 mg/L – 13.06 mg/L in dry season and 3.05 mg/L – 42.93 mg/L in wet season with an average mean of 6.26 mg/L and 12.54 mg/L respectively. Since the area is covered with thick limestone, this variation is likely due to dissolution of the rocks. Both sodium and potassium concentration gradually increases from dry to wet season in all sample station. The level of Na^+ is higher than that of K^+. In dry season the level of Na^+ vary from 6.00 mg/L – 194.25 mg/L while that of K^+ vary from 0.58 mg/L - 64.98 mg/L . Na^+ in wet season varies from 23.24 mg/L – 236.64 mg/L and K^+ varies from 4.10 mg/L – 76.71 mg/L. the level of potassium is slightly increases in those wells nearest to the quarries, reason may be due to percolation of surface pollution downward to aquifer. Iron (Fe) occurs naturally from rocks and is found in many surface and groundwater sources at levels ranging 0.3 to 50 mg/L (WHO, 2004). The highest concentration was recorded in the wet season at U-4 0.94 mg/L, the average concentration is 0.052 mg/L and 0.146 mg/L in dry and wet season respectively. No significant difference was observed between the dry and wet seasons. Iron, generally does not look problematic in the area. The WHO (1993) limit its concentration in potable water to 300 µg/L because of the aesthetic effect it produces (Kortatsi, 2004). However, an upper limit of 1000 µg/L should suffice for most purposes (WHO, 2004). The study area comprises limestone rocks. The groundwater within the area observed with high elevation of Ca^{2+} and Mg^{2+} of HCO_3^- type. Results for chemical parameters of both dry and wet season are shown in Tables 5 and 6. The mean and standard deviation showed in Tables 7 and 8. The level of HCO_3^- in wet season is higher compared to dry season. This show the interaction of CO_2 with water produces (H_2CO_3) which give the solution its ability to attack and dissolve minerals. The reaction is represented as Eq. 1.

$$CO_2\,(g) + H_2O\,(aq) \quad \rightarrow H_2CO_3(aq) \tag{1}$$

Table 4: Pearson correlation coefficients for 10 variables of water samples in wet season

	TDS	Temp	pH	Na^+	Ca^{2+}	Fe^+	Mg^{2+}	K^+	Cl^-	NO_3^-	HCO_3^-	Salinity
TDS	1											
Temp	0.565	1										
pH	0.677*	0.397	1									
Na^+	0.390	-0.099	0.554	1								
Ca^{2+}	0.344	-0.165	0.639	0.590	1							
Fe^+	0.219	-0.200	-0.102	0.310	0.481	1						
Mg^{2+}	0.149	-0.366	0.609	0.775*	0.727*	0.132	1					
K^+	0.525	0.561	0.152	-0.057	-0.518	-0.263	-0.392	1				
Cl^+	0.265	-0.191	0.666	0.783*	0.514	-0.139	0.919**	-0.112	1			
NO_3^-	-0.180	-0.136	-0.311	0.235	-0.419	-0.252	-0.180	0.787*	0.051	1		
HCO_3^-	0.440	-0.042	0.609	0.580	0.844**	0.393	0.463	-0.215	0.339	-0.053	1	
Salinity	0.170	-0.272	0.621	0.838**	0.578	0.017	0.937**	-0.196	0.908**	-0.021	0.424	1

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

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

The H_2CO_3 (aq) is consumed when CO_2 is charged ground water react with limestone rocks. Carbonic acid reacts with calcite proceeds as Eq. 2.

$$CaCO_3(s) \quad + H_2CO_3\,(aq) \rightarrow Ca_2 + (aq) + HCO_3 - (aq) \qquad (2)$$

And react with dolomite as Eq. 3.

$$CaMg(CO_3)_2(s) \quad + \quad H_2CO_3(aq) \rightarrow Ca^{2+}(aq) + Mg^{2+} + HCO^{3-}(aq) \qquad (3)$$

Calcite and dolomite dissolve rapidly in ground water charged with CO_2, equation 1 through 3 shows why Ca^{2+}, Mg^{2+} and HCO_3^- are the dominant dissolved species within the shallow ground water of the study area. Mg^{2+} show positive correlation with HCO_3^- ($r = 0.753^*$). The overall ground water of the study area show visible trend of Ca^{2+} - Mg^{2+} ratio of carbonate type year around, in no instances were either calcites or dolomite. Ground water within the area generally contain between 21 mg/L– 177 mg/L in dry season and 86 mg/L– 301mg/L in wet season with an average of 169.55 mg/L of total dissolved solid (TDS). The most abundant cation constituents are two alkaline metals Ca^{2+} and Mg^{2+} with increasing in Na^+ in some wells. This account approximately 50 percent of TDS. Bicarbonate is the most anion species and comprises 40 percent of dissolved species, and over 90 percent of total alkalinity of the groundwater within the range of pH (Drever 1988).

Impacts of anthropogenic activities on groundwater qualities

Nitrate and potassium are nutrients that are usually kept at low concentration in nature due to rapid plant uptake. They are the most ubiquitous chemical contaminant in words aquifer and level of contamination increasing (kortasi *et al.*, 2006). Nitrate concentration in groundwater samples ranged from 0.62 mg/L – 130.43 mg/l in dry season and 2.24 mg/l – 183.32 mg/l in wet season. NO_2- and NH_4^+ in dry season range from 0.024 mg/l -1.204 mg/l and 0.001 mg/l - 0.080 mg/l respectively. The higher value of nitrates observed at U-1 and K-2 which are closer to the quarries. As per (Lerner *et al.,*2003), higher concentration of NO_3^- greater than 10mg/L in the shallow groundwater indicates pollution of groundwater, and between 9-58mg/L is probably attributed to farming and agricultural practices in the area (Finley *et al.,* (1990). Since nitrate has no lithological source and hence it reveals an anthropogenic loading, in the study

Table 5: Chemical parameters in wet season (mg/L)

S/cod	Depth (m)	Na^+ (mg/L)	K^+ (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Fe^{2+} (mg/L)	PO^{4-} (mg/L)	NO^{3-} (mg/L)	NO^{2-} (mg/L)	NH^{4+} (mg/L)	Cl^- (mg/L)	$HCO3^-$ (mg/L)	Salinity (mg/L)
Control	65	23.24	4.100	9.370	3.050	0.016	0.001	2.240	0.002	0.000	2.100	28.09	0.610
U-1	65	25.18	36.08	70.26	1.110	0.000	2.570	155.8	0.090	0.002	27.65	619.9	2.410
U-2	60	134.76	76.71	83.68	1.94	0.002	0.930	8.370	0.008	0.000	53.32	507.6	0.910
U-3	50	126.62	7.820	139.6	12.44	0.000	0.010	19.90	0.000	0.001	4.280	494.4	1.100
U-4	60	129.30	5.230	257.3	15.15	0.347	0.460	22.44	0.044	0.127	43.60	835.4	3.020
K-1	50	269.67	23.49	161.4	24.33	0.060	4.891	14.94	0.024	0.000	69.12	538.5	4.061
K-2	50	65.02	12.94	188.7	4.160	0.000	0.010	183.3	0.000	0.000	74.93	689.8	4.501
K-3	65	112.67	11.39	198.0	7.790	0.032	1.703	85.70	0.013	0.001	96.95	813.1	2.300
K-4	55	236.64	3.980	282.4	42.93	0.011	0.993	107.6	0.143	0.000	65.36	860.4	6.823

Table 6: Chemical parameters in dry season (mg/L)

S/cod	Depth (M)	Na^+ (mg/L)	K^+ (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Fe^{2+} (mg/L)	PO^{4-} (mg/L)	NO^{3-} (mg/L)	NO^{2-} (mg/L)	NH^{4+} (mg/L)	Cl^- (mg/L)	$HCO3^-$ (mg/L)	Salinity (mg/L)
Control	65	6.000	3.280	2.740	0.180	0.030	0.031	0.620	0.170	0.000	1.290	10.68	0.100
U-1	65	14.95	17.71	34.48	2.050	0.000	0.093	121.4	0.134	0.006	10.67	547.7	0.900
U-2	60	91.96	64.98	44.24	4.150	0.002	1.333	3.840	0.063	0.003	42.59	378.4	0.400
U-3	50	40.46	7.150	85.55	7.660	0.000	0.062	10.06	0.004	0.020	1.740	299.2	0.100
U-4	60	16.81	4.020	158.3	10.75	0.054	0.527	6.820	0.915	0.000	16.93	709.1	1.200
K-1	50	88.79	5.860	76.57	13.06	0.020	1.736	9.86	0.901	0.004	35.96	372.2	4.100
63.84	507.7	25.52	3.910	124.9	5.250	0.000	0.031	130.4	1.204	0.081	-	-	0.030
K-3	65	106.6	4.690	93.02	3.000	0.000	1.891	63.99	0.019	0.001	72.14	458.2	0.900
K-4	55	194.2	0.580	183.3	10.22	0.000	0.093	83.46	0.489	0.005	57.69	423.6	6.300

area may be attributed by percolation of surface pollution from quarries and agricultural run-off into the groundwater aquifer. Ammonium and nitrite concentrations in all sampled points are low as compared to nitrate. Reason may be due its instability in nature of the two ions. Nitrate (NO_3^-) is essential to crops but harmful to humans and animals if taken in high amounts (Hardy *et al.,* 2008). Long term exposure to nitrate in drinking water may cause methamoglobinemia (blue baby syndrome) (Lerner *et al.,* 2003). Within the quarry some farms are the land that are filled with rubbish and sand after excavation, application of manure and some in-organic fertilizer may easily cause the leaching of nitrate into the groundwater aquifer through joints and band of the rocks. This confirmed by higher elevation of nitrates in wet season as compared to dry season, (Tables 5 and 6). Nitrate show strong positive correlation with potassium. (r = 0.787**) in dry season and (r = 0.881*****) in wet season. This correlation is likely because they are both present in ground water from the anthropogenic sources and since it is highly correlated in wet season, it may be due to high discharge of surface pollution and fertilizer into the aquifer by rainfall. Furthermore, since neither is correlate with any other major anion and cation, it is likely they have the same trend of increasing. Chloride concentration differs in water samples collected from different sources. All water samples investigated for chloride were within the standard limits (WHO: 250 mg/L) except K-1 and K-4. The Chloride concentration varied between 1.29 mg/L – 72.14 mg/L in dry and 2.10 mg/L – 96.95 mg/L in wet season. Chloride imparts a salty taste and sometime high concentration causes laxative effect in human beings. Chloride show strong correlation with all other marine origin elements Na^+(r = 0.818**), Ca^{2+}(r = 0.542), Mg^{2+} (r = 0.670*) and salinity (r = 0.803**). This correlation is probably due to intrusion of seawater into the groundwater system, Reasons may be due to geographical location of the wells near the Indian Ocean. The concentrations of phosphate in all samples investigated were found to be of lowest order compared to all other ions. Different samples show below detection limit (BDL) during analysis, concentration of phosphate ranged from 0.00 mg/L - 0.158 mg/L in wet season and 0.00 mg/L -0.061 mg/L in dry season. Other correlations in this study were analyzed as dissolved ions. The existing correlation among the parameters in the water samples reflects that these parameters are normally found in the studied water sources. As per (Abdul *et al.,* 2013) ions can occur with remarkable concentrations even though there is spatial variation of their water sampling sites. This shows that correlation among those parameters is not necessarily a spatially dependent factor. The Pearson correlation coefficients for 10 variables of water samples in dry and wet seasons are shown in Tables 3 and 4 which are indicated that Ca2+ and Mg2+ correlate positively with HCO3-; this core variation is likely due to weathering of limestone rocks.

CONCLUSION

The impact of quarrying activity on natural water bodies is wide and extensive. It has become a recent challenge for the industry, government and the environmentalist to prevent the water pollution due to various quarrying activity which may be direct or indirect cause for such pollution. For the cause of which, in the present work water samples from regions belonging to the quarrying belt of Uwandani and Kangagani were collected and analyzed. Analysis was done at Zanzibar water authority laboratory and Ardhi university laboratory following standard methods. Samples from nine different wells were subjected to analysis for the parameters like turbidity, conductivity, solids, iron, calcium content, pH, hardness, ammonia, nitrate, phosphate. Water sample parameters were also correlated with WHO standards for drinking water. Because of that contamination of the water body in and around the locality is highly probable. Results of physico-chemical parameters of the groundwater in the vicinity of the limestone quarries revealed that, wells that are closer to the quarries are highly contaminated. The Pearson correlation output showed that Ca^{2+} and Mg^{2+} correlate positively with HCO_3^-; this core variation is likely due to weathering of limestone rocks. Chloride show strong correlation with sodium and salinity (r = 0.783*) and (r = 0.908**) respectively. This co-variation is probably due to intrusion of seawater into the groundwater system, Reasons may be due to geographical location of the wells and over pumping of groundwater.). Nitrate show strong positive correlation with potassium (R= 0.881**). This core-variation is likely because they are both present in ground water from surface pollution accumulated in the limestone caves and nitrogenous fertilizer from agricultural land.

RECOMMENDATIONS

The recommendations provided below will facilitate a gradual eradication or minimization of infections related to quarrying at all site of quarrying activities. These are as follows:

i) Filling of impermeable clay layer thereby reducing the amount of surface pollution that results accumulated water in the limestone cave.

ii) The excavation of the rocks should be minimal towards subsurface level to reduce the possibility of reaching the ground water aquifer.

iii) Environmental regulations and laws must be enforced by government agencies, local communities and non-governmental organizations for the protection and preservation of the environment. The monitoring agencies should be equipped with the necessary logistics for effective enforcement.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

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