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RESEARCH ARTICLE

INFLUENCE OF TIDES TO THE CAVE WATER QUALITY: A CASE STUDY ON ZANZIBAR ISLAND, TANZANIA

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ABSTRACT

This study was carried out to determine the influence of tides to the quality of cave water in Zanzibar Island, part of Tanzania. It was to establish the effect of tidal change on the cave water quality using pH, temperature, EC, TDS, and nutrients (NO_3-N, NH_3-N, PO_4^{3-}) in the water as indicators. Overall results indicated that, the cave water quality changes with tides regardless of the fluctuation of the investigated parameters. Moreover, most of the tested parameters were not in range compared to those proposed by World Health Organization (WHO). This confirms that the quality of the cave water has been influenced by low and high tides due to high intrusion of the sea water entered in the caves.

INTRODUCTION

The quality of water of the specific caves depends on number of variables. Water Quality refers to the physical, chemical, and biological characteristics of water in relation to the existence of life and especially the activities of man. All natural water contains substances derived from the environment, both natural and man-made (Lamb 1985). The amounts of these constituents in the water determine its quality. Consequently, sampling of water and measuring the concentrations of various constituents can qualify the quality of that water. Information about water quality is vital in determining the adequacy of the water for various purposes (Machiwa, 2002). Pollutants disseminated into the environment from both natural and anthropogenic sources move from one medium to another: air to water-or land to water and from one water body to another through a variety of routes and cross-linkages. For example, soil pollution by leacheate from solid waste dumping sites can affect the quality of groundwater and surface water either directly or after a delay in time. In some cases, pollutants emitted in one country can end up in another country through global transport mechanisms (UNDTCD. 1991). The fate of a pollutant discharged to aquatic environment depends on its own characteristics, such as its solubility, biodegradability, potential for biological accumulation along the food chain. The prevailing environmental conditions like ambient temperature within a given time frame and the action of physical and other mechanisms that tend to remove it from an ecosystem also influence pollutant dynamics (Stumm and Morgan 1981). This study aimed to find out the influence of tides to the quality of cave water in Zanzibar Island, Tanzania.

Study area

This study was conducted in Zanzibar Island, Tanzania located in the Indian Ocean at Longitude 39° east and Latitude of 6° south of the equator (Else 1998). The study was on six different sites, two from each region of Zanzibar Island. The Chomvindogo, and Chomvikubwa, are situated at Dimani, Urban – West region of Zanzibar. The MizawaMiza and Kilindi from Kizimkazi, are caves from the Southern region of Zanzibar. The Choweni and Makutani are caves at Fukuchani, from the Northern region of Zanzibar.

METHODS

Water samples were taken from the six caves. Each cave was sampled twice in a day according to the sea tides. The first day of sampling was Sunday 14th December, 2008 during Lowest of the Low tidal (LL) at 11:10 AM when the tide frequency

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was 0.09 m and during Highest of the High tidal (HH) at 5:15 PM when the tide frequency was 3.46 m. The second sampling day was Monday 22nd December, 2008 at 6:47 AM and 12:28 PM when the tides frequencies were 1.38 m and 2.56 m for Highest of the Low tidal (HL) and Lowest of the High tidal (LH) respectively. The samples after collected were filtered through 0.45µm cellulose-acetate filter membrane to remove total suspended particles and then preserved by freezing at -4 ^{0}C (Clesceri *et al.,* 1998). The temperature, Electrical conductivity, Total dissolved solid and pH of the water samples were measured *insitu*by using pH/Conductivity/TDS/^{o}C/^{o}F Meter. Ammonium-N was measured spectrophotometrically using Nesslers reagent while Phosphate-P and nitrate- N were measured using Phosver-3 and nitra Ver-5 respectively. Nutrients analysis methods described are the same as those presented in Nutrient analysis in tropical marine waters (UNESCO, 1993). Chloride was analyzed by titration against 0.05M $AgNO_3$ by using potassium chromate as indicator (Clesceri *et al.,* 1998). Analysis of Chlorides and nutrients were done at Ardhi University laboratory situated at Mwenge, Dar es Salaam Tanzania.

RESULTS AND DISCUSSION

pH

pH represents the effective concentration (activity) of hydrogen ions (H^+) in water. In this study, the pH values showed that the water samples were neutral to slightly alkaline (Table 1). It ranges from 7.02±0.08 at Chomvikubwa during lowest of the low tide (LL) to approximately 8.0 at Kilindi during lowest of the high tide (LH). Chomvindogo and Chomvikubwa give clear trend that pH was greater during HH than LH and HL was greater than LL but for the rest of the caves there were no clear trend. Therefore, the influences of tides to pH values in these caves were very low. The pH values were in the range proposed by WHO (Table 2)

Temperature

Temperature of water is a very important factor for aquatic life. It controls the rate of metabolic and reproductive activities, and determines which fish species can survive (Hem, 1985). Temperature also affects the concentration of dissolved oxygen and can influence the activity of bacteria and toxic chemicals in water. It is affected by riparian vegetation, or trees and plants growing along the banks of a river or creek that provide shade to the cave and preventing the sun from heating up the water. If the sun shines directly on water, the water can warm up very quickly, and to very high temperatures (Hem, 1985). In this study temperature varies between 27.2±0.41 at MizawaMiza and 30.6±0.65^{o}C at Chomvindogo (Table 1). These values are seemed to be very high due to the fact that in Zanzibar, December (the sampling month) was hot season and therefore the cave water somehow affected to the heat of the sun. Again there were not clear relation on tides and temperature value obtained.

Electrical Conductivity (EC) and Total Dissolved Solids (TDS)

Electrical conductivity refers to the ability of water to conduct electrical current. It is a quality of water that reflects the amount of ionized matter presents (Flanagan 1990). The conductivity of the samples ranged from 869±8.68 to 1068 ±7.78µScm^{-1} at Chomvindogo, 882±10.3 to 886 ±10.3µScm^{-1} at Chomvikubwa, 1030±10.5 to 1115 ±9.50µScm^{-1} at MizawaMiza, 8020±10.3 to 11170 ±25.0µScm^{-1} at Kilindi, 7680±2.12 to 12640±11.0µScm^{-1} at Choweni and 7950±25.1 to 12050±12.0µScm^{-1} at Makutani. Total dissolved solids are the sum of the concentration of all dissolved solid species in the water. Deeper water contains more dissolved solids because the water has more retention time in the ground and therefore more times to dissolve rock minerals. In this study the trend was 435±4.65 mgL^{-1} to 534±3.54 mgL^{-1} at Chomvindogo, 433±5.06 to 443±4.71 mgL^{-1} at Chomvikubwa, 515±4.74 mgL^{-1} to 558±5.26 mgL^{-1} at MizawaMiza, 4010±4.78 to 5580±5.44 mgL^{-1} at Kilindi, 3840±3.54 mgL^{-1} to 6320±5.49 mgL^{-1} at Choweni and 3970±5.28 mgL^{-1} to 6030±0.71 mgL^{-1} at Makutani. These values show clear difference between conductivity and TDS of these caves. The small values are at Chomvindogo, Chomvikubwa and MizawaMiza while large values were observed at Kilindi, Choweni and Makutani caves. The trend showed that the caves contained large EC and TDS during HH>LH and LL>HL except for Chomvikubwa which opposed the trend. The observed similar trend between EC and TDS suggests that they are closely related. The amount of TDS is directly proportional to the conductivity of water (Fig.1)

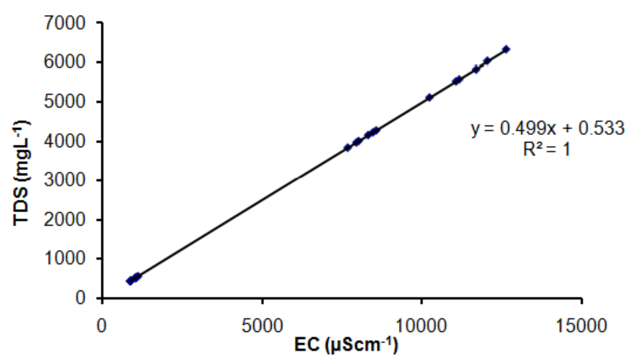

Figure 1: Relation between Total dissolved solids and Electrical conductivity of the cave water showing inverse relation between them.

Local high TDS value is also due to anhydrite lenses and to shallow sea water intrusion around the coast, due to 4 to 5 meter tide (UN, 1987). For drinking water a maximum 1000ppm was specified (Montgomery, 2000). WHO (Table 2) also recommended 1000mgL^{-1}. Therefore water from Kilindi, Choweni and Makutani are not good for drinking purpose. The smallest values of conductivity, 866±10.7µScm^{-1} and TDS 433±5.06mgL^{-1}, were recorded at Chomvikubwa during highest of the low tide (HL) and the highest values of conductivity and TDS were 12640±11.0µScm^{-1} and 6320±5.49 mgL^{-1} respectively which were recorded at Choweni during highest of the high tidal (HH) (Table 1)

Mass balance of water

Water balance in the cave might be affected by number of processes including rain event, level of water table, tidal changes as well as water consumption. Most of water table in Zanzibar Island is affected by sea water intrusion of different

Table 1: Table of results

SITE	DATE	TIDE	NO_3^--N (mgL^{-1})	P-PO_4^{3-} (mgL^{-1})	N-NH_4^+ (mgL^{-1})	Temp (ºC)	pH	TDS (mgL^{-1})	EC (μScm^{-1})
CN	14/12/08	HH	0.80± 0.07	0.38 ± 0.04	0.50 ± 0.04	28.4 ± 0.66	7.49 ± 0.62	534 ± 3.54	1068 ± 7.78
CN	14/12/08	LL	0.70± 0.04	0.21 ± 0.03	0.30 ± 0.01	28.8 ± 0.41	7.06 ± 2.05	512 ± 6.02	1025 ± 13.1
CN	22/12/08	LH	1.00± 0.48	0.33 ± 0.04	0.67 ± 0.11	27.3 ± 0.83	7.40 ± 0.43	514 ± 5.45	1028 ± 10.9
CN	22/12/08	HL	0.80± 0.04	0.13 ± 0.03	0.42 ± 0.06	30.6 ± 0.65	7.88 ± 1.05	435 ± 4.65	869 ± 8.68
CK	14/12/08	HH	1.00± 0.06	0.10 ± 0.04	0.21 ± 0.06	29.0 ± 0.35	7.23 ± 0.42	441 ± 5.32	882 ± 10.3
CK	14/12/08	LL	0.80± 0.06	0.13 ± 0.03	0.44 ± 0.04	29.1 ± 0.58	7.02 ± 0.08	434 ± 5.01	867 ± 9.25
CK	22/12/08	LH	0.50± 0.03	0.08 ± 0.03	0.27 ± 0.03	27.2 ± 0.41	7.07 ± 0.34	443 ± 4.71	886 ± 10.3
CK	22/12/08	HL	0.60± 0.04	0.21 ± 0.06	0.31 ± 0.06	29.7 ± 0.49	7.18 ± 0.04	433 ± 5.06	866 ± 10.7
MM	14/12/08	HH	1.50± 0.07	0.40 ± 0.04	0.75 ± 0.03	30.2 ± 1.09	7.59 ± 0.21	558 ± 5.26	1115 ± 9.50
MM	14/12/08	LL	0.70± 0.04	0.44 ± 0.04	0.24 ± 0.06	28.9 ± 0.40	7.95 ± 0.47	529 ± 5.39	1058 ± 10.8
MM	22/12/08	LH	1.20± 0.14	0.62 ± 0.04	0.82 ± 0.08	29.3 ± 1.07	7.09 ± 0.03	519 ± 4.64	1037 ± 9.27
MM	22/12/08	HL	1.30± 0.04	0.71 ± 0.04	0.61 ± 0.11	29.4 ± 0.98	7.24 ± 0.24	515 ± 4.74	1030 ± 10.5
KL	14/12/08	HH	0.70± 0.06	0.16 ± 0.03	0.37 ± 0.06	29.7 ± 0.47	7.63 ± 0.08	5580 ± 5.44	11170 ± 25.0
KL	14/12/08	LL	0.80± 0.11	0.18 ± 0.01	0.36 ± 0.03	28.5 ± 0.54	7.40 ± 0.16	5120 ± 4.78	10240 ± 10.3
KL	22/12/08	LH	0.70± 0.01	0.10 ± 0.04	0.39 ± 0.03	29.6 ± 0.52	7.97 ± 0.63	4280 ± 7.07	8570 ± 28.3
KL	22/12/08	HL	0.90± 0.28	0.24 ± 0.07	0.67 ± 0.01	30.2 ± 0.93	7.48 ± 0.06	4010 ± 4.78	8020 ± 10.3
CW	14/12/08	HH	0.80± 0.06	0.58 ± 0.04	0.50 ± 0.07	28.7 ± 0.78	7.29 ± 0.68	6320 ± 5.49	12640 ± 11.0
CW	14/12/08	LL	0.80± 0.01	0.67 ± 0.03	0.60 ± 0.03	28.2 ± 0.88	7.27 ± 0.24	5530 ± 6.36	11070 ± 27.6
CW	22/12/08	LH	0.60± 0.03	0.95 ± 0.04	0.23 ± 0.06	29.2 ± 0.38	7.10 ± 0.68	4160 ± 1.41	8320 ± 2.12
CW	22/12/08	HL	1.12± 0.04	0.83 ± 0.04	0.84 ± 0.06	29.5 ± 1.13	7.14 ± 0.07	3840 ± 3.54	7680 ± 5.66
MK	14/12/08	HH	0.80± 0.04	0.12 ± 0.03	0.72 ± 0.04	29.1 ± 1.06	7.43 ± 0.68	6030 ± 0.71	12050 ± 12.0
MK	14/12/08	LL	0.58± 0.04	0.32 ± 0.04	0.39 ± 0.04	28.3 ± 0.51	7.45 ± 0.60	5830 ± 4.95	11700 ± 48.1
MK	22/12/08	LH	0.72± 0.04	0.39 ± 0.03	0.22 ± 0.04	29.4 ± 0.35	7.66 ± 0.15	4230 ± 4.79	8470 ± 24.4
MK	22/12/08	HL	1.30± 0.08	0.10 ± 0.04	1.20 ± 0.30	29.3 ± 1.40	7.30 ± 0.24	3970 ± 5.28	7950 ± 25.1

KEY: CN-CHOMVI NDOGO, CK-CHOMVI KUBWA, MM-MIZA WA MIZA, KL-KILINDI, CW-CHOWENI, MK-MAKUTANI

Table 2: Water quality standards for drinking purpose according to WHO (2004) used to compare with the findings obtained in this study

Name of constituent	Maximum level according to WHO (2004)
Hardness ($CaCO_3$)	200 mgL^{-1}
pH	6.5 – 8.5
EC	1000 μScm^{-1}
TDS	1000 mgL^{-1}
NO_3^-–N	10 mgL^{-1}
P-PO_4^{3-}	0.1 mgL^{-1}
N-NH_4^+	0.05 mgL^{-1}
Sulphate	0.1 mgL^{-1}
Sodium	175 mgL^{-1}
Calcium	100 mgL^{-1}
Magnesium	50 mgL^{-1}
Chloride	250 mgL^{-1}

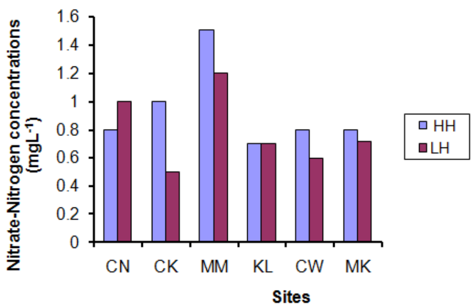

Figure 2: Spatial variation of nitrate during the Highest and Lowest of High tides

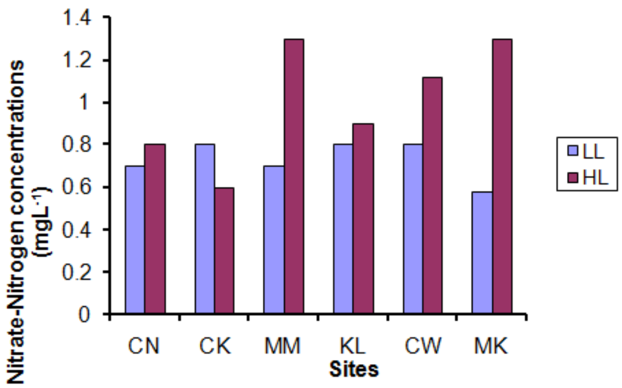

Figure 3: Spatial variation of nitrate during Lowest and Highest of the Low tides

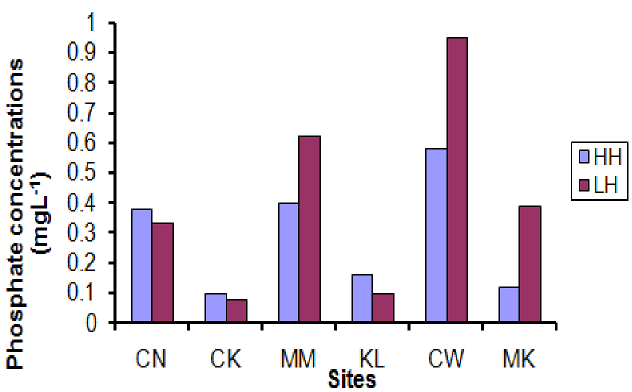

Figure 4: Spatial variation of phosphate during the Highest and Lowest of the High tides

degree. The level of sea water contribution was evaluated using Cl^- concentration assuming that it is conservative and obeys simple dilution formula. The higher the Chloride concentration means the higher the sea water contribution. The quantity of mass of water contributed by sea was calculated by the formula $M_1V_1=M_2V_2$; whereby M_1 represents concentration of chloride (mgL^{-1}) during highest of the high tide (HH) and highest of the low tide (HL) respectively; M_2 is the concentration of chloride (mgL^{-1}) during lowest of the high tide (LH) and lowest of the low tide (LL) respectively; V_1 is the volume during highest of the high tide (HH) and highest of the low tide (HL) respectively; and V_2 is the volume used during lowest of the high tide (LH) and lowest of the low tide (LL) respectively. Then $\%V_2$ was calculated by taking $(V_2 - 1)*100$ and the results are summarized in table 3 below:-

Table 3: Summary of calculations for mass balance of water using chloride concentrations in mgL^{-1} of different sites

SITE (HIGH TIDES)	M_1(HH)	M_2(LH)	$V_2 = M_1V_1/M_2$	$\%V_2$
CHOMVI NDOGO	127.79	115.44	1.1070	10.70
CHOMVI KUBWA	119.56	115.33	1.0367	3.67
MIZA WA MIZA	157.81	151.55	1.0413	4.13
KILINDI	1008.09	958.92	1.0513	5.13
CHOWENI	1131.54	1067.17	1.0603	6.03
MAKUTANI	1008.65	1000.48	1.0082	0.82
SITE (LOW TIDES)	M_1(HL)	M_2(LL)	$V_2 = M_1V_1/M_2$	$\%V_2$
CHOMVI NDOGO	121.86	116.22	1.0485	4.85
CHOMVI KUBWA	114.66	114.62	1.0003	0.03
MIZA WA MIZA	153.50	153.66	0.9990	-0.10
KILINDI	1004.11	972.74	1.0323	3.23
CHOWENI	1085.91	1082.45	1.0032	0.32
MAKUTANI	1003.77	987.07	1.0169	1.69

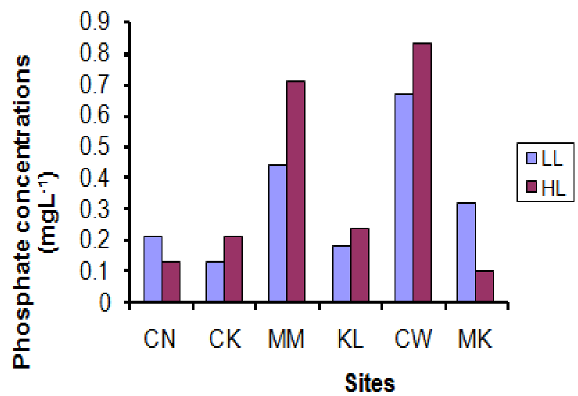

Figure 5: Spatial variation of phosphate during the Lowest and Highest of the Low tides

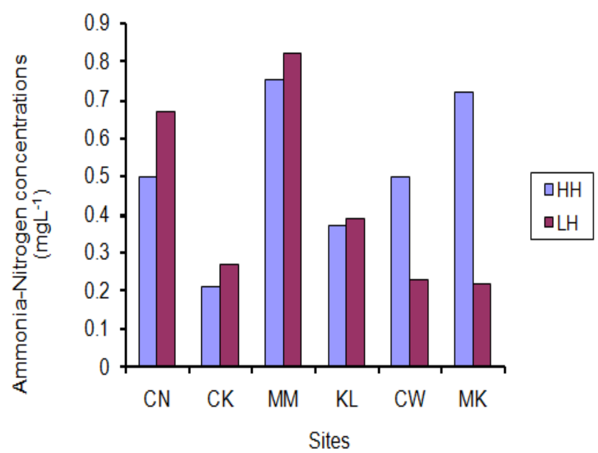

Figure 6: Spatial variation of Ammonia during the Highest and Lowest of the High tides

From table 3, the change in percentage of V_2 between highest of the high tidal (HH) and lowest of the high tidal (LH) ranges between 0.82 to 10.70 where the minimum value was at Makutani and the maximum value was from Chomvindogo. During highest and lowest of low tidal (HL and LL) the percentage change of V_2 ranges between negative -0.1 to 4.85. The minimum value was from MizawaMiza cave and the

Table 4: Variation of nutrients (mgL^{-1}) with different tides (HH, LL, LH and HL) from sampling sites

SITE	NO_3^--N HH	NO_3^-N LL	NO_3^-N LH	NO_3^-N HL	P-PO_4^{3-} HH	P-PO_4^{3-} LL	P-PO_4^{3-} LH	P-PO_4^{3-} HL	N-NH_4^+ HH	N-NH_4^+ LL	N-NH_4^+ LH	N-NH_4^+ HL
DIM1	0.8	0.7	1	0.8	0.38	0.21	0.33	0.13	0.5	0.3	0.67	0.42
DIM2	1	0.8	0.5	0.6	0.1	0.13	0.08	0.21	0.21	0.44	0.27	0.31
KIZ1	1.5	0.7	1.2	1.3	0.4	0.44	0.62	0.71	0.75	0.24	0.82	0.61
KIZ2	0.7	0.8	0.7	0.9	0.16	0.18	0.1	0.24	0.37	0.36	0.39	0.67
FUK1	0.8	0.8	0.6	1.12	0.58	0.67	0.95	0.83	0.5	0.6	0.23	0.84
FUK2	0.8	0.58	0.72	1.3	0.12	0.32	0.39	0.1	0.72	0.39	0.22	1.2

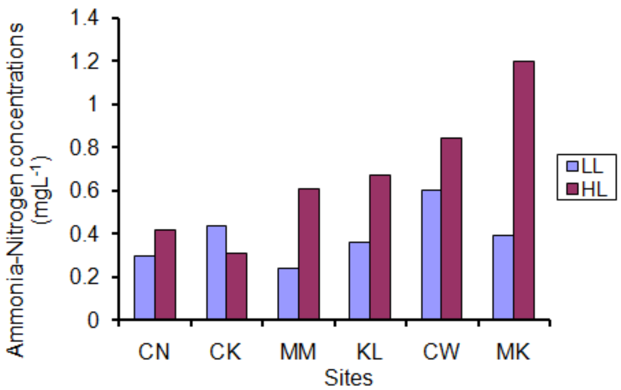

Figure 7: Spatial variation of Ammonia during the Lowest and Highest of the Low tides

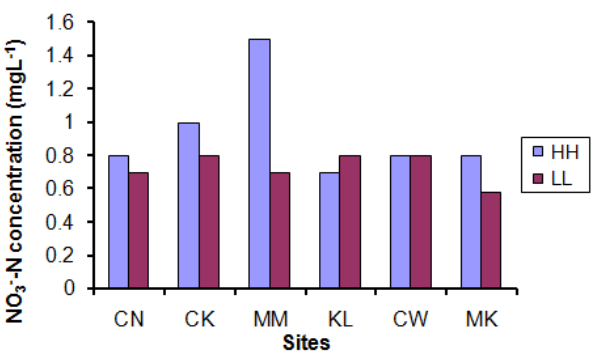

Figure 8: Effects of Highest of the High and Lowest of the Low tides to Nitrate

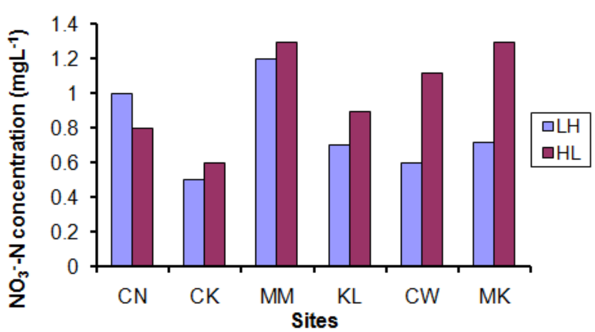

Figure 9: Effects of Lowest of the High and Highest of the Low tides to Nitrate

maximum value was again from Chomvindogo cave. Statistical the V_2% show clear differences between the tidal effects to the water mass of these caves. In this regards during high tides the tidal change has greater influence to the water mass while during low tides, the tidal change has low influence to the water mass from these caves. By considering the Chloride concentrations of each cave it can be seen that Kilindi, Choweni and Makutani have got higher values compared with those proposed by WHO (Table 2), and therefore have higher sea water contribution compared to the rest of the caves hence the water from these caves is not good for drinking purpose.

NUTRIENTS

Nitrate-Nitrogen (NO_3^--N)

Nitrate is highly soluble in water and is stable over a wide range of environmental conditions. It is easily transported in streams and groundwater. Nitrates feed plankton (microscopic plants and animals that live in water), aquatic plants, and algae, which are then eaten by fish. Excessive concentrations of nitrate and/or nitrite can be harmful to humans and wildlife. Nitrate is of most concern for humans. Nitrate is broken down in our intestines to become nitrite. Nitrite reacts with hemoglobin in human blood to produce methemoglobinemia, which limits the ability of red blood cells to carry oxygen. This condition is called methemoglobinemia or "blue baby" syndrome (because the nose and tips of ears can appear blue from lack of oxygen). It is especially serious for infants, because they lack the enzyme necessary to correct this condition. They are also transformed into cancer-causing nitrosamines in the human gut (Cunningham and Saigo, 1997). Wells and caves contaminated by sewage or agricultural runoff are a major concern in some areas, because of the possibility of water high in nitrite/nitrates and the subsequent increased risk of blue baby disease. High nitrate and nitrite levels can also cause methemoglobinemia in livestock and other animals.

Nitrates are groundwater contaminants of particular concern due to its widespread in aquifers and potential health and environmental impacts. Nitrates are found naturally in the soil and animal wastes and anthropogenically as byproducts of agriculture and human wastes (Masetti et al., 2007). Major anthropogenic nitrate sources are fertilizers, feedlots, dairy and poultry farming, sewage system and septic tank drainages (Madison and Burnett, 1985). Other sources include nitrogen fixing bacteria and leachate from landfills. Organic nitrogen and urea in the manure are converted to ammonia and, ultimately, to nitrate in the soil. Nitrate that is not used by plants washes from farmlands and residential and commercial lawns into storm drains and nearby streams, or seeps into groundwater. In this study concentration of nitrate-nitrogen ranges from 0.5±0.03 to 1.5±0.07 mgL^{-1} (Table 1), which may be results of contaminants leached to the soil and final to the cave water particularly during rainy season. During HH tidal (Fig. 2), the concentration of nitrate reached a maximum of 1.5 mgL^{-1} at MizawaMiza cave (MM), and the rest of the caves have an average of approximately 0.8 mgL^{-1}. At LH tide (Fig. 2) the maximum concentration of 1.0mgL^{-1} was again obtained at MizawaMiza cave (MM) and the minimum concentration of approximately 0.5 mgL^{-1} at Chomvikubwa (CK). The rest of the cave showed average concentration of approximately 0.7mgL^{-1}. The nitrate concentration during LL tide (Fig. 3) was observed to be in average of 0.7 mgL^{-1} for all caves, while at HL tide (Fig. 3), again the MizawaMiza cave has maximum concentration together with Choweni (CW) and Makutani (MK), while the rest of caves followed a similar trend of an average of approximately 0.8 mgL^{-1}. The values agreed with those reported by WHO for drinking water (Table 2)

P-Phosphate ($P\text{-}PO_4^{3-}$)

Phosphate occurs naturally from the rocks as calcium phosphate, from the plants, microorganism, animal wastes, and agricultural fertilizers such as super phosphates $Ca(H_2PO_4)_2$. Sea birds also deposit guano (faeces) used as a phosphate fertilizers). Other sources are sewage discharges, seawater, run off and detergents. The concentration of phosphates in the samples ranges from 0.10±0.04 to 0.95±0.04 mgL^{-1} (Table1). A higher concentration (0.95mgL^{-1}) was found at Choweni cave at LH. According to WHO standards all sites showed high values of phosphates (Table 2). This was attributed to the detergents since people use water for washing activities or agricultural activities practiced nearby the cave where the farmers mainly use fertilizers. Both figures 4 and 5 show high content of Phosphate at Choweni cave (CW) followed by MizawaMiza cave (MM) and Chomvindogo cave (CN) with respect to all tidal time. The maximum and minimum concentration was during LH tidal (Fig. 4) with approximately 0.95 mgL^{-1}at Choweni (CW) cave and 0.08 mgL^{-1}at Chomvikubwa (CK). These trends suggested that there was high use of detergents and decomposition of organic matter at Choweni (CW) cave compared to the rest of the caves.

Ammonium-N ($N\text{-}NH_4^+$)

Ammonia is found in water in two forms - the ammonium ion (NH_4^+), and dissolved, unionized (no electrical charge) ammonia gas (NH_3). Total ammonia is the sum of ammonium and unionized ammonia. The dominant form depends on the pH and temperature of the water. The reaction between the two forms is shown by this equation:

$$NH_3 + H_2O \rightleftarrows NH_4^+ + OH^-$$

The form of ammonia changes easily when pH changes. As pH increases, H^+ concentration decreases, and OH^- concentrations increase. This makes the equation above move left, increasing the amount of aqueous NH_3. When the pH is below 8.75, NH_4^+ predominates. At pH 9.24, about half of aqueous NH_3 is transformed to NH_4^+. Above pH 9.75, NH_3 predominates (Hem, 1985). Unionized ammonia (NH_3) is much more toxic to aquatic organisms than the ammonium ion (NH_4^+). Toxic concentrations of ammonia in humans may cause loss of equilibrium, convulsions, coma, and death. Ammonia concentrations can affect hatching and growth rates of fish; changes in tissues of gills, liver, and kidneys may occur during structural development.

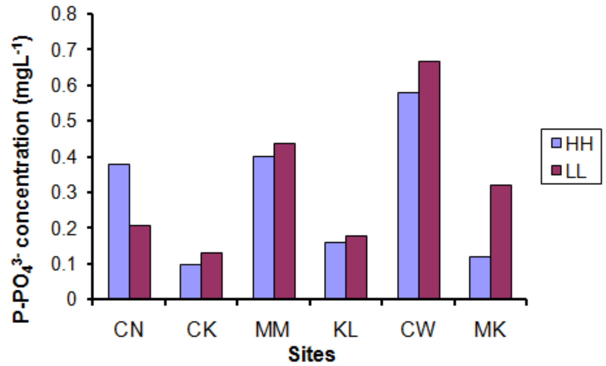

Figure 10: Effects of Highest of the High and Lowest of the Low tides to Phosphate

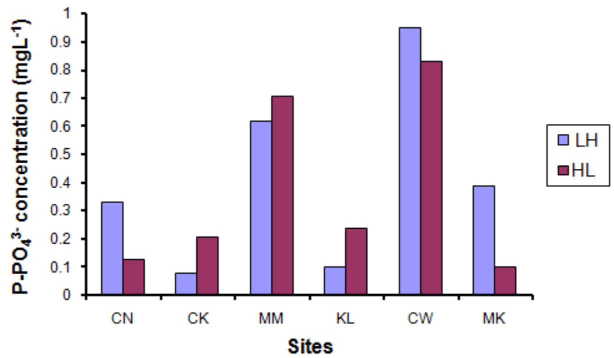

Figure 111: Effects of Lowest of the High and Highest of the Low tides to Phosphate

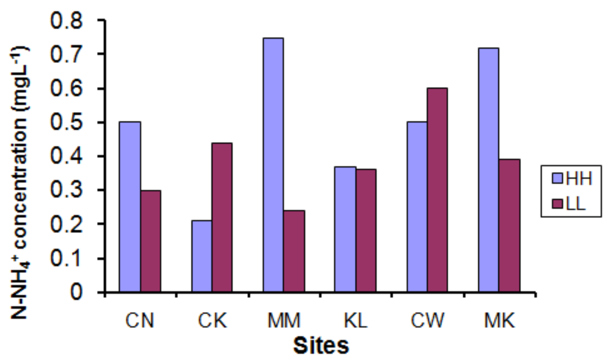

Figure 12: Effects of Highest of the High and Lowest of the Low tides to Ammonia

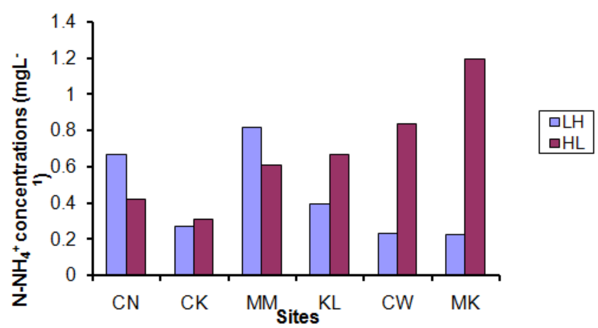

Figure 13: Effects of Lowest of the High and Highest of the Low tides to Ammonia

Figures (6 and 7) show that, ammonium concentrations were very high at MizawaMiza cave (MM), and low at Chomvikubwa (CK) during high tides (HH and LH). But during Low tides the concentration of ammonia was very high at Fukuchani caves and again Dimani caves tend to have low content of ammonia. Generally, all of the sites in this study were found with high values of ammonium ($N\text{-}NH_4^+$) compared to WHO standards (The reason for high ammonia at these caves might be due to high fertilizers used by farmers nearby to these caves as well as the infiltration of wastewater from outside the caves.

EFFECT OF TIDAL CHANGE WITH NUTRIENTS

Tidal changes affect the water mass of the cave water especially when the cave water is fed by the water table connect directly to the sea water. During high tides sea water intrusion increase similar to high extraction of water. Depending on the source of nutrient it may increase or dilute the nutrient concentration in cave water. The summary for nutrients concentrations in different tides is presented in table 4.

Effect of tidal Change with Nitrate

Nitrate concentration was very high in five caves during highest of the high tide (HH) compared to lowest of the low tide (LL), and only Kilindi (KL) cave showed opposite trend. This cave showed that during lowest of the low tide (LL) the nitrate was high than HH (Fig.8). Therefore the tides support the increased concentration of nitrate during High tides and reduced during low tide due to sea water intrusion in those five caves while the opposed trend showed by KL might be due to local source acting on that cave. Figure 9 show that, Chomvindogo cave (CN) has high concentration of nitrate during lowest of the high tide (LH). This is also opposite to rest of five caves which show high content of nitrate during highest of the low tide (HL). In general High and Low tides have shown inverse relation to one another with nitrate. These results were not expected and might be influenced by the local sources during the sampling date.

Effect of tidal change with Phosphate

Phosphate concentration appeared to be very high in five caves during LL tide, but Chomvindogo (CN) again opposing the trend because it has high phosphate during HH tide (fig.10). Choweni (CW), Makutani (MK) and Chomvindogo (CN) caves have got high phosphate during LH tides, while the rest of three caves are during HL tide as oppose the trend (fig.11)

Effect of tidal change with Ammonia

The trend of ammonia concentration were similar during sampling date with high tidal changes (Fig.12) and that with low tidal changes (Fig.13) for CN, CK, MM and CW caves. However samples collected during low tides (LL and HL) in different days show high concentration of ammonia for CK and CW. For KL and MK caves, the trend show that the high concentration of ammonia was during high tides (HH) in a day with high tidal change (Fig.12) and during low tide (HL) at the low tidal change sampling date (Fig.13). These trends might be influenced with TDS, since their averages (ammonia and TDS) for each specific cave varied proportional to one another.

Conclusions

The study of the quality of the water from Chomvindogo, Chomvikubwa, MizawaMiza, Kilindi, Makutani, and Choweni cave in Zanzibar Island shows that is affected by tidal change and generally is not good for drinking purposes with respect to physico-chemical parameters. In this regard the caves have elevated concentrations of nutrients contrary to that recommended by WHO standards. This is due to several factors such as mineral dissolution, agricultural activities, sea water intrusion, wastes, and global transportation of the dumped wastes. EC and TDS were varied proportional to one another. Chomvindogo, Chomvikubwa and MizawaMiza cave have shown low values within the ranges of the recommended values by WHO, but Kilindi, Choweni and Makutani cave the values were higher than those recommended for drinking water. This was due the high sea water intrusion entered to these caves.

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