Effect of Rainfall Variability on pH and Electrical Conductivity of Springs and Groundwater in Zanzibar Urban West Region

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ABSTRACT-- ***This study reports on an analysis conducted to determine the effect of rainfall on pH and electrical conductivity (EC) of Zanzibar groundwater sources. In June 2012, thirty water samples were collected from spring and underground water sources for fecal coli (FC) and total coli (TC), alkalinity, phosphate (PO_4-P) and ammoniacal nitrogen (NH_4-N) analysis. The Palintest photometer procedures were used to determine the levels of alkalinity, PO_4-P, and NH_4-N, while FC and TC were analyzed following the standard methods for the examining water and wastewater, method 909A. In August and October 2012, Horiba multiparameter meter was used to measure EC and pH levels in water samples. The levels of PO_4-P, NH_4-N, and alkalinity in water samples were in the range of 0.08-5.15 mg L^{-1}, 0.03-6.71 mg L^{-1} and 47- 430 (as mg L^{-1} $CaCO_3$) respectively. During dry period, the lowest and the highest EC levels were 181.02 µS cm^{-1} and 6180 µS cm^{-1} respectively, while 167.36 µS cm^{-1} and 7985.03 µS cm^{-1} were the respective lowest and highest EC levels measured during wet period. The variation of pH levels during dry and rainy period were in the range of 6.31- 8.30, and 7.13 - 8.44, respectively. During dry and wet period, 40% and 17% of the samples respectively had EC level beyond the guideline recommended by World Health Organization (WHO). 33% of the water samples were free from FC and TC contamination. FC and TC contaminated 43% and 67% of the water sources respectively. The presence of FC, TC and elevated levels of EC in some of water samples warns for the groundwater quality thus rendering them unsafe for human consumption.***

Keywords-- Zanzibar, rainfall, Electrical conductivity, pH.

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1. INTRODUCTION

The two principal natural sources of water are; groundwater (such as borehole water and well water) and surface water (such as fresh water lakes, rivers, streams, etc.) [1], [2]. The quality of drinking water is an environmental determinant of health. The management on the quality of drinking water has been an important factor in order to prevent and control the waterborne diseases for over one and a half centuries. Diarrhea and cholera have been estimated to cause an annual incidence of 4.6 billion episodes, which cause 2.2 million deaths every year [3]. The lack of adequate clean and safe water along with insufficient sanitary infrastructures leave millions exposed to high-level of health risks, which intensify the harshness on their daily life [4]. The United Nation had estimated that 1.7 billion people do not have adequate supply of portable drinking water [5].

Groundwater and water from two spring sources (Mtoni and Bububu) serves a considerable number of Zanzibar populations in central and stone town areas. Rainwater is another source of water used in Zanzibar. However, due to the shortage and an unpredictable public water supply, some individuals or communities decide to dig their own wells in an effort to overcome the problem. The recharge of these wells mainly depends on the amount of falling precipitation. Presently, Zanzibar experiences rainfall scarcity, which also varies unpredictably (Table 1 & Fig.1). This in turns can cause deterioration of groundwater quality. Moreover, groundwater resources are being over-exploited as a result saline water can find its way into the underground water aquifers, a phenomenon known salt intrusion.

In most coastal aquifers, saline water may intrude into underground freshwater aquifers naturally. This process is favored by the hydraulic connection that exists between groundwater and seawater systems. However, an excessive use of groundwater is one amongst the primary cause of saltwater intrusion. This phenomenon can lead to contamination of drinking water sources as well as other consequences [6], [7]. Under extreme weather conditions, such as hurricanes and storm surges, the impact of salt intrusion is expected to shift towards an exacerbated level [8].

Among the consequences of groundwater over extraction are land subsidence, lowered groundwater table, salt intrusion, and deterioration of groundwater quality. Pressure on aquifers is highest during dry season; this is because the demand of water is at its higher level while aquifers recharge rate is lowest [9]. The electrical conductivity (EC) of natural water decreases with the increasing groundwater recharge. EC is a function of total anions and cations present in water [10].

The pH of rainwater normally ranges from 5 to 6. Under the natural conditions and in non-polluted areas the pH is 5.6. The pH of rainwater is contributed by the presence of atmospheric carbon dioxide gas, however, anthropogenically produced air pollutants, which include carbon dioxide itself, nitrogen oxides, and sulphur dioxide play significant role in lowering down the pH of rainwater. The acidity of rainwater has an effect on the composition of soil hard water minerals. Usually rainwater tends to increase the pH of hard water minerals. Bicarbonate ion (HCO_3^-) in limestone deposits react with water to produce OH^- ion according to the chemical reaction shown in equation 1, thus, the resulting pH of water in these areas can go up to 8.5. On the other hand, acid rain might also cause acidification to the soil that has scarcity of bases [11].

$$HCO_3^- (aq) + H_2O (l) \rightarrow H_2CO_3 (l) + OH^- (aq) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Acidity and alkalinity as applied to natural water are the base and acid neutralizing capacities (ANC) of water. Weak acids and bases normally exist in most of natural waters. Waters with low alkalinity levels (low acid buffering capacities) are more susceptible to changes in pH (Table 2) [12].

Alkalinity and acidity signify buffering capacity of water systems, and for domestic use the maximum acceptable alkalinity is 100 mg L^{-1} [13]. Alkalinity can help to normalize metal contents in natural waters. Toxic metals such as lead, cadmium, and barium, can be precipitated out of the solution by CO_3^{2-}, and HCO_3^- ions present in aquatic systems [14]. For example, cadmium can form insoluble salt when reacting with CO_3^{2-} ion (equation 2).

$$Cd^{2+} (aq) + CO_3^{2-} (aq) \leftrightarrow CdCO_3 (s) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Therefore, cadmium through precipitation reaction can be effectively removed to a safe level in an insoluble form (equation 2).

Factors such as synthetic detergents containing builders, and the application of fertilizers increase the phosphate levels in the environment. Prior to the use of phosphate detergents, most of the inorganic phosphorus generated to most of the wastewaters came from human wastes. The daily release of inorganic phosphorus from urine per person was 1.5 g [15]. The presence of high phosphate level in the drinking water sources can promote the formation of algal blooms, which can enhance the production of toxins producing bacteria. Furthermore, human waste appears to be the potential source of groundwater contamination due to the release nitrogen containing species such as ammoniacal nitrogen, which under the presence of specific microbes can be converted to nitrate (NO_3^-) via nitrite (NO_2^-) both of which can cause adverse health effects.

Zanzibar being among the less developed countries faces a problem of inadequate supply of portable drinking water, a problem which accounts for the occurrence of dysentery and cholera every year (Table 3 & 4). Moreover, the incidences of cholera outbreak that claim lives of people are also very common during rainy period. During this period, the water table is increased and therefore the groundwater infiltration happens very quickly [16].

Although groundwater represents an important source of drinking water, its quality is currently threatened by a factors such as water and soil chemistry, geological variation (such as soil type), and anthropogenic activities, which include onsite leaky septic tanks, pit latrines, and all activities conducted around the water sources. All these factors can influence the transportation, distribution, and fate of the chemicals and other contaminants in the groundwater aquifers [17].

The effects of climate change, such as global warming, rise in sea level, and extreme weather conditions have raised serious concern in many countries. In this regard, the present study highlights the effect of the rainfall variability on pH and EC levels of groundwater sources in urban-west region of Zanzibar Island. The levels of FC, TC, PO_4-P, NH_4-N, and alkalinity were also investigated.

2. MATERIALS AND METHODS

2.1 Study area

In this study, thirty water samples from different areas of Zanzibar were collected. Global positioning system (GPS) was used to allocate the sampling positions (Figure 2).

2.2 Collection of water samples

The water samples from twenty-eight underground water sources and two springs water sources were collected in pre-cleaned polyethylene bottles. In June 2012, water samples from thirty locations were collected for the analysis of biochemical parameters (FC, TC, PO_4-P, NH_4-N, and alkalinity). EC and pH measurements for all water samples were carried out insitu in two different phases. The first one was done during wet period (August 2012), and the second one during dry season (October 2012). Water samples were collected from spring water (SW), public bore wells (PBW), private bore wells (BWP), open hand dug wells (OHDW), and closed hand dug wells (CHDW).

2.3 General experimental procedures

Parameters measured in this study were, PO_4-P, NH_4-N, alkalinity, FC, TC, electrical conductivity (EC) and pH. Analysis for the levels of PO_4-P, NH_4-N, and alkalinity was carried out using procedures outlined in Palintest Photometer Method (Palintest 5000, Camlab, UK). FC and TC were analyzed in the laboratory following the standard methods for the examining water and wastewater, method 909A [18]. EC and pH were measured in situ using Horiba multiparameter meter.

3. RESULT AND DISCUSSION

The level of FC and TC, each ranged from 0-TNTC (too numerous to count), where as for statistical purposes values of 500 and 200 were assigned to represent (as TNTC) the levels of TC and FC respectively (Fig. 3 & 4). Table 5 shows the proportions of bacterial contamination for all sources of the analyzed water samples. FC and TC contamination in SW samples were 50% and 100% respectively (Table 5). For the PBW, the contamination by FC and TC were 20% and 40% respectively. FC and TC contamination in water samples collected from the CHDW were 38% and 63% respectively. Bacteriological contaminations due to FC and TC in water samples collected from OHDW sources were 75% and 87.5% respectively. Both SW sources were contaminated with TC; however, only Bububu spring was FC free. Water samples from BWP showed equal levels (29%) of FC and TC contamination.. The trends of FC and TC contaminations (Table 5) are:

FC contamination: OHDW > SW > CHDW > BWP > PBW.

TC contamination: SW > OHDW > CHDW > BWP > PBW.

With respect to TC contamination, water samples from spring sources (Mtoni and Bububu) showed the highest degree of TC contamination. These water sources are not well protected, the presence of houses at their vicinities make them so vulnerable to various contaminants. Mtoni spring is highly surrounded by residential houses (septic tanks), and some farm animals having their habitat very close to this water source. Furthermore, wastewater channel from Mtoni kidatu traverses alongside the Mtoni spring. All these are the possible causes for the presence of pathogens in the water sources.

OHDW are the most susceptible to microbial contaminations (Fig.3 & 4), which is caused by all types of cleaning activities taking place near water collecting points. Nevertheless, bore wells contained the least level of FC contamination; these water sources are the best of all other sources with respect to FC contamination (Fig.3). Normally bore wells are deeper compared to hand dug wells, and this might allow enough time for microbes to be filtered off before reaching the ground water aquifers. Moreover, bore wells are well constructed, thus the surface seepage of contaminants becomes rather difficult in bore wells as compared to other water sources. On the other hand, the OHDW contained the highest level of FC and TC contamination. The nature of OHDW and the onsite human activities are the main cause of elevated degree of bacteriological contamination in these water sources.

The level of ammoniacal nitrogen (NH_4-N) fluctuated between 0.03 to 6.71 mg L^{-1} (Table 6), the lowest NH_4^+-N level was noted from sampling sites 3 and 4 (Kwarara), and the highest NH_4-N level was from sampling sites 10 (Sogea) and 30 (K/hewa Juu) (Fig.5). Effluents from the surrounding pit latrines and leaky septic tanks are the probable cause for the elevated concentration of NH_4-N in these two water sources.

Only two water sources (SW and PBW) had the NH_4^+-N levels which were within WHO recommended limit, whereby, 17% of all water samples contained NH_4^+-N level beyond WHO guideline for drinking water (Table 5 & 6).

The level of PO_4-P in all water samples were in the range of 0.08 -5.15 mg L^{-1} (Table 6 & Fig. 6).The lowest recorded concentration of PO_4-P was from sampling site 29 (K/hewa chini), the sampling site 17 (Mkunazini) has the highest concentration of PO_4-P. The sampling site 17 is located inside the residential house and this increases the possibility of groundwater contamination.

The alkalinity level in the water sample ranged from 47 to 430 as $CaCO_3$ mg L^{-1} (Table 6). The highest alkalinity level was recorded from sampling point 5 (Mtoni spring) (Table 6 & Fig. 7). This value is comparable to 395 as $CaCO_3$ mg L^{-1} recorded from sampling site 7 (Bububu spring). Although the two springs have different origins, their alkalinity levels were comparably similar. Mtoni spring is coral in nature, while Bububu spring is a sandy one.

As a remarkable note, in general, the alkalinity levels recorded from Kwarara areas (sites 1-4) were relatively lower as compared to the alkalinity levels measured from other water sampling sites (Table 6). The levels of total hardness from Kwarara areas were also found to be relatively lower as compared to other studied sampling points [19].

The alkalinity levels in all water sources (expect CHDW and OHDW) were greater than sixty (i.e. > 60 mg L^{-1}), therefore these water sources fell on the 'low category' of the alkalinity-risk ranking scale (Table 2 & 8), which indicates that majority of the analysed water sources have adequate levels of alkalinity to maintain stable pH in most circumstances [20]. While 87.5% from each of CHDW and OHDW water sources had alkalinity level greater than sixty (>60 mg L^{-1}), the remaining proportions (12.5% each) fell on the 'moderate category' of the ranking scale.

The pH and EC levels recorded from water samples collected during dry period (August 2012) were 6.31- 8.30, and 181.02 - 6180 µS cm^{-1} respectively (Table 10). The lowest pH level (6.31) was recorded from sampling site 10 (Sogea), while the highest pH level (8.30) was measured from site 5 (Mtoni). For the case of EC, the lowest recorded EC level was from sampling site 3 (Kwarara), and the highest EC 6180 µS cm^{-1} recorded from site 16 (Chukwani). 20% of the water samples from PBW had pH level below the WHO (6.5-8-5) range, and 37.5% of the water samples from CHDW showed pH level below WHO range (Table 10).

The pH levels from other water sources (OHDW, SW, and BWP) were within the range of the WHO guideline for drinking water. EC level from all water sources (except SW) were well above WHO limit (1000 µS cm^{-1}). The proportions of the elevated EC level (> 1000 µS cm^{-1}) were 20%, 38%, 50%, and 57% for PBW, OHDW, BWP, and CHDW sources respectively (Table 5).

As an important remark, higher EC level (7985.03 µS cm^{-1}) was recorded during wet period at site 16 (Chukwani) as compared to 6180 µS cm^{-1}, which was measured during dry period. There are two possible reasons for this exceptional observation. First, because the water source is very close to the sea (Fig. 2), there is a great possibility of salt intrusion. Second, the water source is located at the coral rage land, therefore even if it rains heavily, the precipitation cannot seep into the coral rage to recharge groundwater aquifers, and hence the possibility to dilute the dissolved ions in the groundwater aquifers is hindered.

Another remarkable observation on EC level was noted from water well located at sampling site 3 (Kwarara). There was water scarcity problem at Kwarara (site 3), which had forced the community to dig their well further deep in an effort to overcome it, but unexpectedly, high EC level of 832 µS cm^{-1} was recorded from this water site during wet period as compared to 181.02 µS cm^{-1} measured during dry period (Table 10). It is very likely that saline water zone might have replaced the fresh water zone of the groundwater aquifer at sampling site 3, which is the probable reason for an elevated EC level measured during wet period rather than dry period. This effect can be taken as an indicator of overexploitation of groundwater resources.

The pH and EC levels recorded from water samples collected during wet period (October 2012) ranged between 7.13 - 8.44, and 183.99 - 7985.03 µS cm^{-1} respectively. Water sample from site 29 (K/hewa chini) showed the lowest pH value of 7.13, while site 8 (K/kikombe) showed the highest pH level of 8.44. The lowest EC (167.36 µS cm^{-1}) was recorded from site 7 (Bububu), and highest EC (7985.03 µS cm^{-1}) from sampling point 16 (Chukwani). Only two water sources, OHDW and BWP showed elevated EC levels, which is presented by 13% and 43% respectively (Table 5 & Fig. 8). Generally, the pH levels measured during wet period were relatively higher than pH levels measured during dry period (Fig.9).

Strong correlation (r^2 = 0.88) was observed between EC (wet period) and EC (dry period) indicating the level of EC in water sources varied linearly with respect to the weather variability and rainfall in particular (Fig. 10).The data analysis of this study shows that the variability in rainfall has effects on the pH and EC levels. Higher pH levels were observed during wet period (rainy season) as compared to the dry period, which could be explained by chemical reaction as shown in equation 1. Contrary to this observation, generally, EC levels were relatively lower during wet period as compared to dry season. The cause of observed low EC levels in groundwater sources during rainy period could be a dilution effect on the amount of total dissolved solids that occurs during efficient recharge of groundwater aquifers.

4. CONCLUSION

Generally, the quality of the analyzed water samples ranged from good, bad to worse. In this regard, there is vital demand for taking the precautionary water-management approach. It is also very important to avoid over exploitation of groundwater resources because once they become intruded by saline water it can take decades or even centuries for the fresh groundwater aquifers to restore their original conditions. Apparently, with less amount of rainfall, which prevails in Zanzibar, the EC levels tend to rise whereby pH levels tend to decrease. More importantly, most of the water sources have ample alkalinity level to resist low pH circumstances. As noted from site 3 (Kwarara), it seems that there is already an alarming sign of salt intrusion due to over extraction of groundwater, which has an additional pressure on freshwater resources in Zanzibar Island. Other areas such as Chukwani, Mkunazini, Malindi, Michenzani, Sogea, and Kwarara had elevated levels of EC, which could be taken as an important index of salt intrusion.

Therefore, the present study shows the urgent need for the government of Zanzibar to allocate new and well-protected underground fresh water zones. This effort should go simultaneously with an establishment of stringent rules to secure its drinking water resources. The government also needs to establish drinking water plants to guarantee the safety of the water for the consuming population. Furthermore, unnecessary over-extraction of groundwater resources should be avoided to insure their sustainability for the present and the future generation

5. ACKNOWLEDGEMENT

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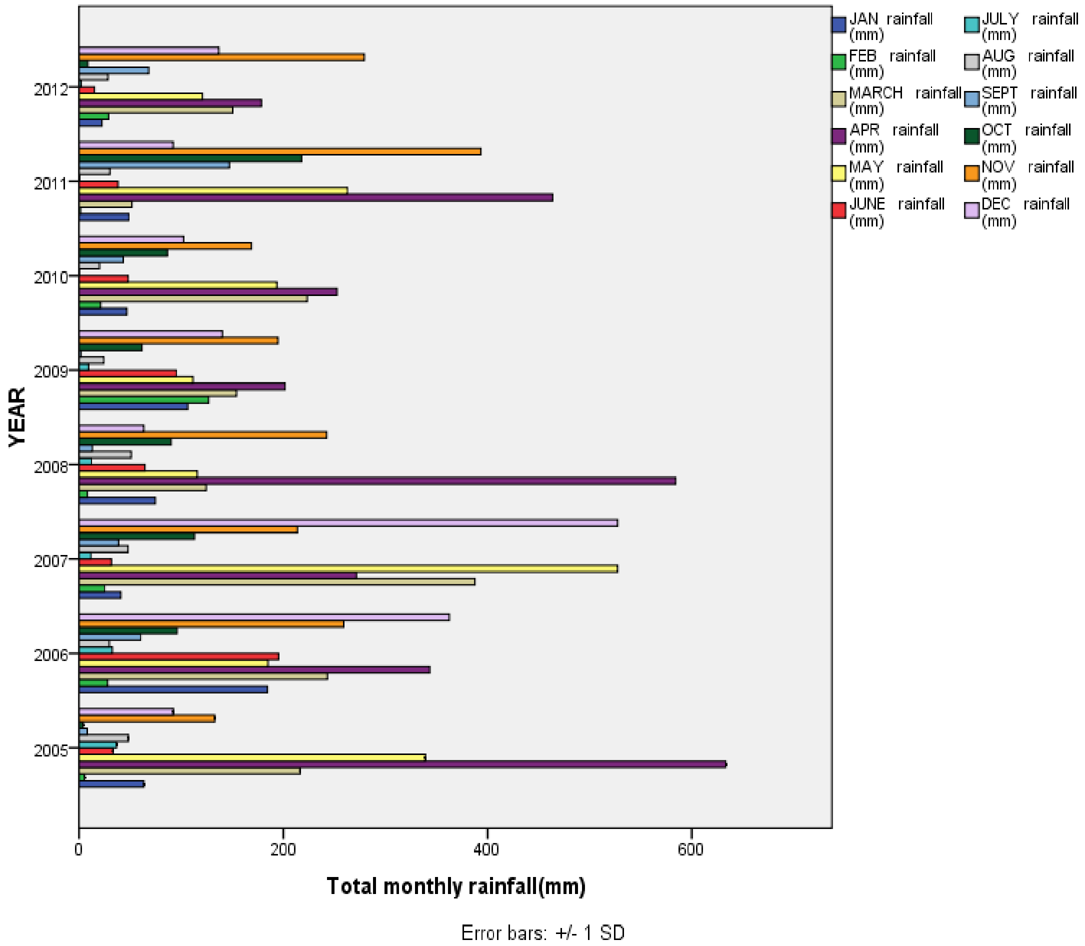

Figure 1: Rainfall pattern in Zanzibar Island over the last eight years (2005-2012).

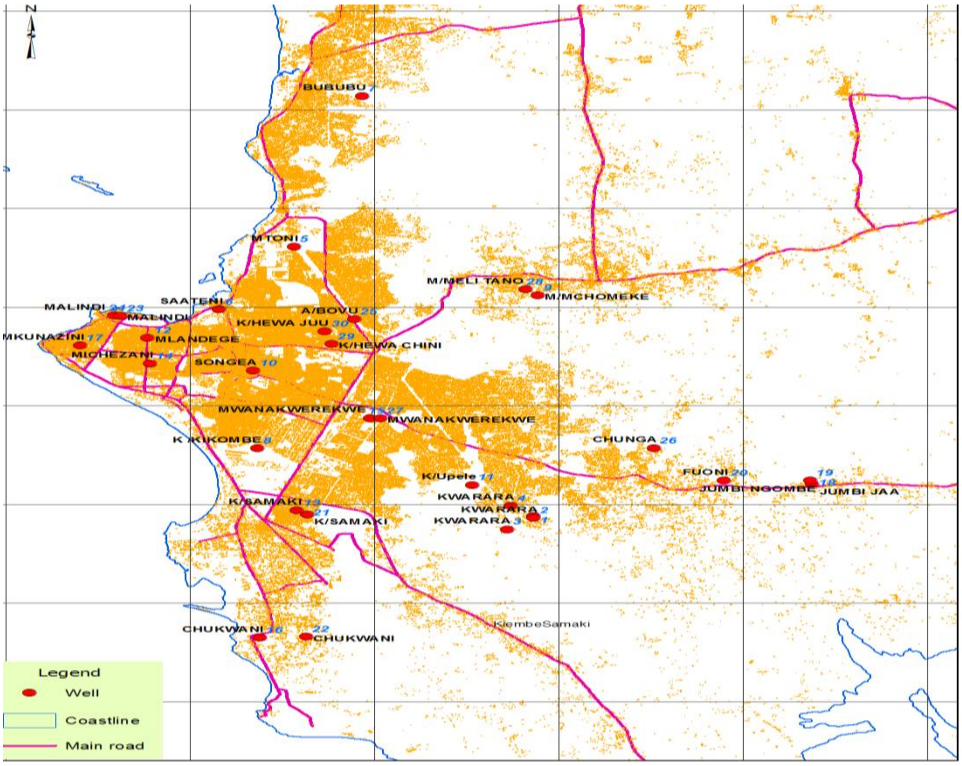

Figure 2: Locations of water sampling sites in Zanzibar Island.

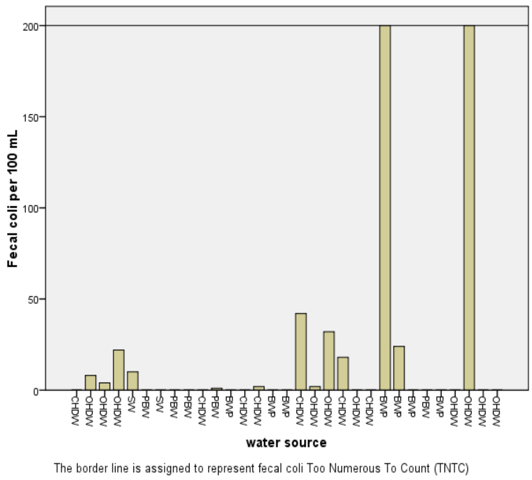

Figure 3: Level of *Fecal coli* in 30 water samples

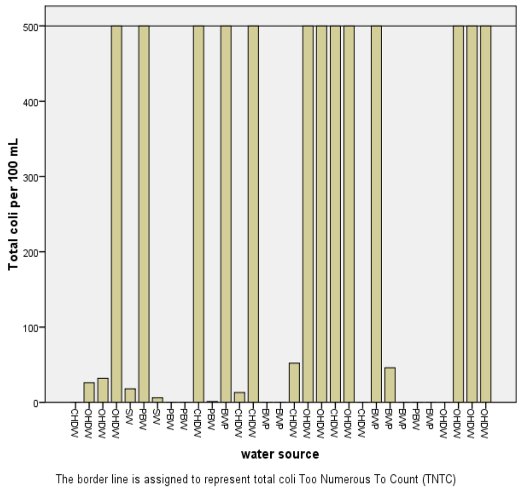

Figure 4: Level of *Total coli* in 30 water samples

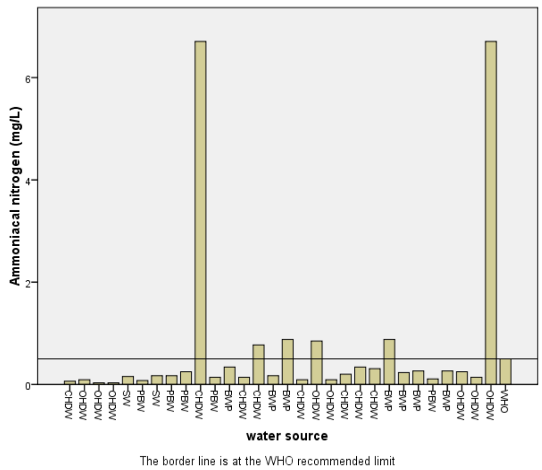

Figure 5: Level of NH_4^+-N in water samples

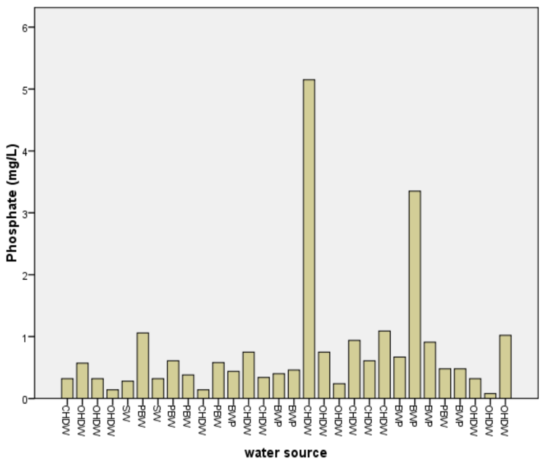

Figure 6: Level of PO_4-P in water samples

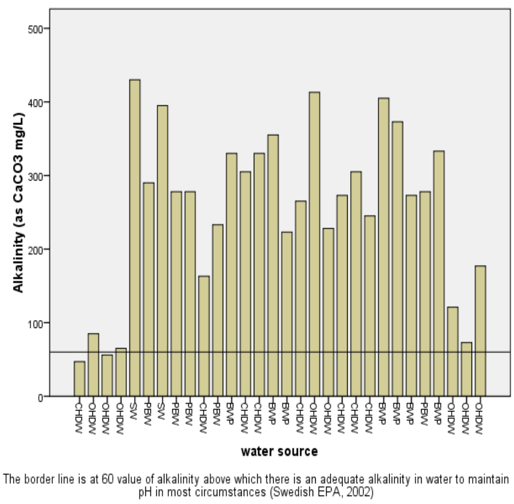

Figure 7: Level of alkalinity in water samples

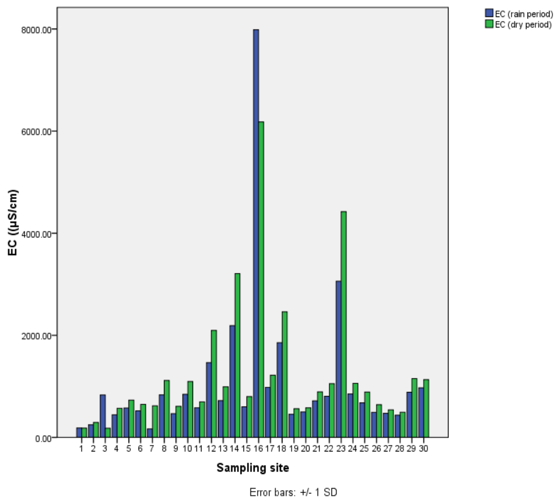

Figure 8: EC levels during dry and rainy period

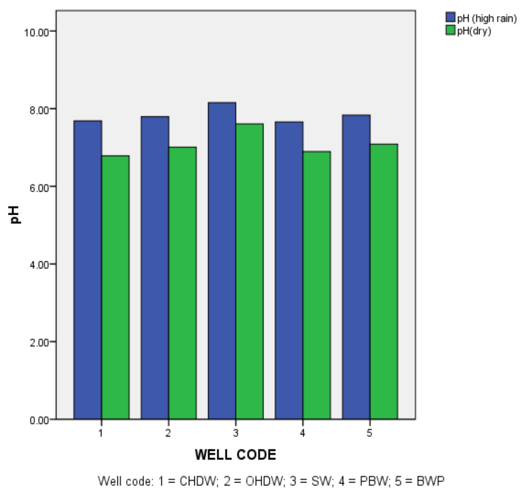

Figure 9: pH levels during dry and wet period

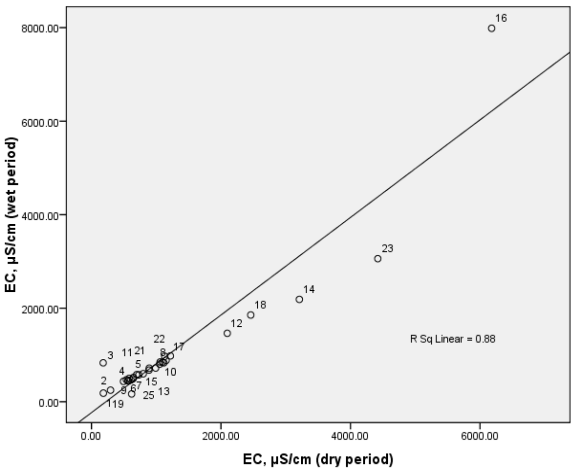

Figure 10: EC (wet period)- EC (dry period) correlation

Table 1: Total rainfall pattern (in mm) in Zanzibar for eight years (2005-2012), [21].

YEAR	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
JANUARY	63.6	184.6	41	74.8	106.2	46.6	48.8	22.3
FEBRUARY	5.4	28.1	25.2	8.2	126.9	21.1	1.7	29
MARCH	216.6	243.3	387.6	124.5	154.1	223.3	51.9	150.5
APRIL	633.1	343.2	271.5	584	201.7	252.7	463.4	178.4
MAY	339.1	185	527.4	115.7	111.8	193.8	262.8	121
JUNE	33.2	195.5	31.6	64.6	95.4	48.1	38.3	15.2
JULY	37	32.5	11.7	12.3	9.3	0.3	0.7	2.3
AUGUST	48.5	29.8	47.9	51.2	24.2	20	30.2	28.5
SEPTEMBER	8	60.4	38.9	13.2	2.1	43.4	147.4	68.1
OCTOBER	4.1	96.2	113.1	90.2	61.8	86.6	218	8.6
NOVEMBER	133.1	259.1	213.7	242.6	194.9	169.1	393.2	279.4
DECEMBER	92.4	362.6	527.4	63.6	140.2	102.4	92.1	137
Annual rainfall	**1614.1**	**2020.3**	**2237**	**1444.9**	**1228.6**	**1207.4**	**1748.5**	**1040.3**

Table 2: Ranking Scale for Alkalinity (as $CaCO_3$ mg L^{-1}**)** Risk-Response,[24].

Risk ranking	Alkalinity	pH range	Description
Low	> 60	> 6	Ample to maintain most circumstances
Moderate	30-60	5.5-7.5	Unlikely to maintain a stable pH in areas with significant acid leaching
High	10-30	5-6	Implausible to keep a stable pH in acid sulfate soil areas
Very high	< 10	< 5	May be unsuitable for use due to high metal and arsenic level

Table 3: Dysentery cases; children (5 years and above) in Urban and West district (2008-2010), [23].

Patients	Urban	West	Total (female & male) , Urban	Total (female & male) West)
Female , 2008	1180	950		
Male , 2008	1094	922	**2274**	**1872**
Female , 2009	1074	326		
Male , 2009	782	442	**1856**	**768**
Female , 2010	2684	414		
Male, 2010	2732	414	**5416**	**828**

Table 4: Cholera scenarios in Zanzibar in different years, [22].

YEAR	PLACE	VICTIMS	DEATH
1978	Unguja	411	51
1997	Unguja & Pemba	672	156
2006	Unguja & Pemba	1211	66
2009/2010	Unguja	1605	11

Table 5: FC, TC, and EC contamination in groundwater sources

Water source	PBW	CHDW	OHDW	BWP	SW
% *Fecal coli* contamination	20	38	75	29	50
% *Total coli* contamination	40	63	87.5	43	100
Dry period: % EC Contamination (EC$\geq$ 1000 µS/cm)	20	57	38	50	0
Rainy period: % EC Contamination (EC$\geq$ 1000 µS/cm)	0	0	13	43	0

Table 6: Levels of NH_4-N, PO_4-P in mg L^{-1}, alkalinity (as $CaCO_3$ mg L^{-1}) FC and TC for 30 water sources

Sample	Water source	NH_4-N	PO_4-P	Alkalinity	FC per 100 mL	TC per 100 mL
1	CHDW	0.06	0.32	47	Nil	Nil
2	OHDW	0.09	0.57	85	8	26
3	OHDW	0.03	0.32	56	4	32
4	OHDW	0.03	0.14	65	22	TNTC
5	SW	0.15	0.28	430	10	18
6	PBW	0.08	1.06	290	Nil	TNTC
7	SW	0.17	0.32	395	Nil	6
8	PBW	0.17	0.61	278	Nil	Nil
9	PBW	0.25	0.38	278	Nil	Nil
10	CHDW	6.71	0.14	163	Nil	TNTC
11	PBW	0.14	0.58	233	1	1
12	CHDW	0.34	0.44	330	Nil	TNTC
13	CHDW	0.14	0.75	305	Nil	13
14	CHDW	0.77	0.34	330	2	TNTC
15	BWP	0.17	0.40	355	Nil	Nil
16	BWP	0.88	0.46	223	Nil	Nil
17	CHDW	0.09	5.15	265	42	52
18	OHDW	0.85	0.75	413	2	TNTC
19	OHDW	0.09	0.24	228	32	TNTC
20	CHDW	0.20	0.94	273	18	TNTC
21	CHDW	0.34	0.61	305	Nil	TNTC
22	CHDW	0.31	1.09	245	Nil	Nil
23	BWP	0.88	0.67	405	TNC	TNTC
24	BWP	0.23	3.35	373	24	46
25	BWP	0.26	0.91	273	Nil	Nil
26	PBW	0.11	0.48	278	Nil	Nil
27	BWP	0.26	0.48	333	Nil	Nil
28	OHDW	0.25	0.32	121	Nil	Nil
29	OHDW	0.14	0.08	73	TNC	TNTC
30	OHDW	6.71	1.02	177	Nil	TNTC

Key: TNTC = Too Numerous To Count

Private Bore Well (PBW), Closed Hand Dug Well (CHDW), Open Hand Dug Well (OHDW), Bore Well Private owned (BWP), Spring Water (SW).

Table 7: WHO Drinking Water Guidelines [25].

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Parameter	Guideline level
Fecal coli	Absent in 100 mL
Total coli	Absent in 100 mL
Electrical conductivity	1000 µS cm^{-1}
pH	6.5- 8.5
NH_4-N	0.5 mg L^{-1}
PO_4-P	NA
Alkalinity	NA

Table 8: Ranking Scale for Alkalinity Risk-Response for the thirty water samples

Risk ranking	Alkalinity (mg L^{-1})	% (CHDW)	% (OHDW)	% (SW)	% (PBW)	% (BWP)
Low	>60	87.5	87.5	100	100	100
Moderate	30-60	12.5	12.5	0	0	0
High	10-30	0	0	0	0	0
Very high	<10	0	0	0	0	0

Table 9: Proportions of pH and EC levels from WHO limit (August and October 2012)

Variable	% above WHO limit (CHDW)	% above WHO limit (OHDW)	% above WHO limit (SW)	% above WHO limit (PBW)	% above WHO limit (BWP)
pH (August)	43	0	0	20	0
pH (October)	0	0	0	0	0
EC (August)	57	38	0	20	50
EC (October)	0	13	0	0	43

Table 10: pH and EC (µS cm^{-1}) levels from the thirty water samples

Sample	Water source	pH_1 Wet period (October)	EC_1 Wet period (October)	pH_2 Dry period (August)	EC_2 Dry period (August)
1	CHDW	7.22	183.99	6.39	183.61
2	OHDW	7.81	247	6.58	294.07
3	OHDW	7.30	832	6.62	181.02
4	OHDW	7.71	444.65	7.21	570.60
5	SW	8.14	576.57	8.30	730.75
6	PBW	7.36	520.57	6.79	647.51
7	SW	8.17	167.36	6.92	620.11
8	PBW	8.44	833.09	7.31	1116.61
9	PBW	8.03	465.06	7.50	609.57
10	CHDW	7.42	844.53	6.31	1096.02
11	PBW	7.17	579.56	6.48	697.61
12	CHDW	7.49	1464.05	7.35	2096.87
13	CHDW	8.39	720.76	6.88	991.06
14	CHDW	7.49	2188.93	7.11	3210.59
15	BWP	7.49	599.52	7.30	799.75
16	BWP	7.82	7985.03	7.25	6180
17	CHDW	7.22	979.58	7.56	1219.06
18	OHDW	8.20	1855.07	6.85	2460.01
19	OHDW	8.31	452.96	6.96	562.75
20	CHDW	8.19	500	6.45	580.75
21	CHDW	7.89	716.16	6.81	892.06
22	CHDW	8.13	804.67	7.11	1053.23
23	BWP	8.25	3059.63	7.01	4421.50
24	BWP	8.41	850.08	7.17	1059.27
25	BWP	7.51	676.56	6.93	889
26	PBW	7.31	491.17	6.39	640.69
27	BWP	7.59	470.50	6.60	539.63
28	OHDW	7.79	436.07	6.80	494.08
29	OHDW	7.13	885.06	8.05	1153.31
30	OHDW	8.11	971.11	7.01	1131.77