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Full Length Research Paper

Quality assessment of drinking water in Temeke District (part II): Characterization of chemical parameters

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This paper presents a study on drinking water quality in Temeke District (Dar es Salaam), which involved analyses of chemical parameters of drinking water samples from different drinking water sources. The drinking water sources examined included tap water, river water and well water (deep and shallow wells). Water quality studied includes pH, chloride, nitrate and total hardness levels. The concentrations of total hardness in mg $CaCO_3$/L and chloride were obtained by titration method while the nitrate concentration levels were determined by spectrophotometer. Tap water was found to be of high quality than other sources in terms of chemical characteristics. The study revealed that the chemical parameters of water sources did not meet the permissible World Health Organization (WHO) and Tanzania Bureau of Standards (TBS) levels. Examining exceedence above the WHO standards, it was revealed that most of the samples contained chloride levels above allowable WHO limits. It was recommended that drinking water sources for domestic use should be protected from pollution sources.

Key words: Drinking water quality, pH, chloride, nitrates, total hardness, exceedence.

INTRODUCTION

Temeke District is comprised of 73 wards and 302 Urban sub-wards (Nourse, 2003). In this district alone, many residents drink water of dubious quality from several of the shallow and deep wells maintained by local resident water officials. Also, during the rainy and dry season potable water scarcity becomes a major issue leaving many residents to seek other alternative drinking water resources. During these times of adversity many residents succumb to various diseases such as malaria, gastroenteritis, and cholera.

In this study, the quality of drinking water sources (ground and surface wells) in Temeke District were analyzed through testing of the chemical parameters. In addition, a visual assessment of the water infrastructure was also conducted to determine the condition of the wells that the residents use as the water resource. This assessment was aimed at providing a preliminary view on the current state of water quality in the Temeke Districts in hopes of stimulating future health studies while providing engineering and sanitation remediation to the area (CDC, 2005; Abbaszadegan et al., 2003). This paper is a continuation of Part 1, which focused on characterization of physical parameters (Napacho and Manyele, 2008). In that paper, the following parameters were presented based on the same samples: conductivity, turbidity, total suspended solids (TSS), and total dissolved solids (TDS).

LITERATURE REVIEW

Drinking water quality is a relative term that relates the composition of water with effects of natural processes and human activities. Deterioration of drinking water quality arises from introduction of chemical compounds into the water supply system through leaks and cross connection. Rainfall is one of the factors affecting water quality as it can wash dissolved nutrients into the watershed and increase organic carbon level, and can also depress alkalinity levels and stimulate corrosion. However, during dry season, the absence of rain can result in proportionally high levels of dissolved minerals or nutrients in a particular

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water source. A quality standard sets the acceptability levels of concentration for pollutants in water to be used for various purposes, e.g., drinking, irrigation, aquaculture, etc.

Pollution is a major problem in urban areas of Tanzania. Improper management of waste especially treatment and disposal of solid and liquid wastes are the major contributors to urban area pollution. The combined results of these problems lead to drinking water contamination, which is detrimental to human health. Over 2 billion people of the world's population have suffered from diseases related to drinking polluted waters. More than 250 million new cases of waterborne diseases are reported each year, resulting in more than 10 million deaths and nearly 75% of these waterborne disease cases occur in tropical areas (McFeters, 1990).The relationship between water quality and health problems are complicated and include both negative and positive effects (Tebbut, 1983). The Bonn International Conference on Freshwater in 2001 revealed that half of the people in Africa suffer from water-related diseases.

In Dar es Salaam, the leakage in the transmission or distribution system contributes to the infiltration of sediments and contaminants into piped water. This problem becomes severe when sewage and piped water systems interfere with each other. The chemicals used for water treatment can also be a source of contamination of drinking water (Lohani, 1982). Distance traveled, age of pipes and extent of internal deposition in mains and conduits are the key factors contributing towards drinking water contamination.

The ground water quality, on the other hand, is relatively uniform throughout an aquifer. Changes in quality occur slowly due to the fact that it is not exposed to the air and is not as subject to direct pollution and contamination from runoff as surface water. Due to natural filtering action of the aquifer, the ground water is relatively free from microbes than surface water. In most cases contamination results either from improper well construction or poor waste disposal facilities (American Water Works Association, 1971). The urbanization process threatens the ground water quality. The urban population in Tanzania does not match with provision of basic infrastructure like water supply, sanitation and waste management.

The quality of surface water (rivers and streams) is dynamic and can change within the catchments area. Small streams may carry clear water for most part of the year (American Water Works Association, 1971). During the rainy seasons, however, the water may carry moderate amounts of dirt organic debris and suspended materials. As rivers move close to inhabited areas, water quality can deteriorate further, although, rivers have the tendency of natural self–purification.

Chemical parameters of drinking water quality give an indication of water acceptability for human consumption, which can be domestic use, agricultural use and industrial use (Chatwell et al., 1989). The chemical parameters must be taken into consideration in the assessment of water quality, such as source protection, treatment efficiency and reliability and protection of the distribution network (WHO, 1996).

In most natural waters, pH is controlled by the carbon dioxide-carbonate-bicarbonate equilibrium system. An increased carbon dioxide concentration will lower the pH, whereas a decrease will cause it to rise. The pH value of water may also be affected by domestic sewage (generally neutral or slightly alkaline), industrial wastes (may be strongly acidic or alkaline depending on the type of industry), etc. Municipal and industrial wastewater discharges may influence the pH values of rivers and wells (Bhattacharya, 1988). The WHO and TBS permissible level for pH in drinking water is 6.8 - 8.5 (TBS, 1997; WHO, 1996).

The parameters of concern in this study were total hardness, chloride and nitrates levels in the drinking water. Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring considerably more soap to produce lather. The hardness or softness of water varies from place to place and reflects the nature of the geological properties of the area, with which water have been in contact. In general, surface waters are softer than ground waters, although, this is not always the case (Mato, 2002). The WHO and TBS permissible level for total hardness is 500 mgL^{-1} as $CaCO_3$. Water hardness can be classified as soft, moderate soft, slightly soft, slightly hard, moderate hard and excessively hard (Mato, 2002). Water hardness can be classified as soft, moderate soft, slightly soft, slightly hard, moderate hard and excessively hard. Table 1 clarifies more about water hardness classification (Gray, 1994; Mato, 2002).

The presence of chloride in drinking water sources can be attributed to the dissolution of salt deposits (National Academy of Sciences, 1977), effluents from chemical industries (Little, 1971), oil well operations (Pettyjohn, 1971), sewage (Pettyjohn, 1972), irrigation drainage (Bond and Straub, 1973), refuse leachates (Schneider, 1970), sea spray and seawater intrusion in coastal areas like Temeke (NRCC, 1977). Each of these sources may result in local contamination of surface water and groundwater. The chloride ion is highly mobile and is eventually transported into closed basins or to the oceans (NRCC, 1977).

Chloride is widely distributed in nature as salts of sodium chloride (NaCl), potassium chloride (KCl) and calcium chloride ($CaCl_2$). Chlorides are leached from various rocks into soil and water by weathering. The chloride ions are highly mobile and are easily transported to closed basin and oceans (Gray, 1994). Chloride in surface and ground water originates from both natural and anthropogenic sources such as the use of inorganic fertilizers, landfill, septic tank effluents, animal feed, industrial effluents, just to mention a few. Chloride levels

Table 1. Classifications used for water hardness.

Classification A		Classification B	
Concentration mgL^{-1}	Degree of hardness	Concentration mgL^{-1}	Degree of hardness
0 - 50	Soft	0-75	Soft
50 - 100	Moderate soft	75-150	Moderately hard
100 - 150	Slightly hard	150-300	Hard
150 - 250	Moderately hard	300+	Very hard
250 - 350	Hard		
350+	Excessively hard		

in unpolluted waters are often below 10 mgL^{-1} (Department of National Health and Welfare, 1978). The chloride concentrations in excess of about 250 mgL^{-1} can give rise to detectable taste in water, depending on associated cations. Chlorides are found in water as mineral solvents. It is said that huge ingestion of chlorides may results in several health effects including tooth decay. Water quality standards for human consumption have been set at ten milligrams of nitrate-nitrogen per liter of water (10 mgL^{-1} NO_3-N). This level of nitrate-nitrogen is equivalent to 45 mgL^{-1} of nitrate (NO_3)[1]. When reading laboratory reports of water quality, be sure to note whether reported values are for nitrate-nitrogen or nitrate. Note that one mgL^{-1} equals one ppm (part per million). Most reported cases of blue baby syndrome due to contaminated water have occurred when infant formula was prepared using water with greater than 40 mgL^{-1} as NO_3-N.

Nitrate (NO_3^-) is a stable form of combined nitrogen for oxygenated systems although, chemically unreactive. Its reduction to nitrite in the cavity wall of stomach and reaction with amines to form nitrosamine may cause health concern (Holden, 1970). Nitrate is toxic because it can be converted to nitrite ion (NO_2^-) in the stomach causing a serious illness and sometimes death in infants less than six months of age. It combines with haemoglobin giving a complete methanoglobin, in which the association constant is larger than oxyhaemoglobin thus depriving the tissue of oxygen. The symptom for acute disease is blueness of the skin. Nitrate concentration in surface water is normally low (0 - 18 mgL^{-1}), especially in areas without intensive agriculture (Gray, 1994). In surface water, nitrification and denitrification may also occur, depending on the temperature and pH (WHO, 1996). The natural nitrate concentration in ground water under aerobic condition is 10 mgL^{-1} and depends strongly on soil type and the geological conditions (Gray, 1994). Under anaerobic conditions, nitrate may be denitrified or degraded almost completely. The toxicity of nitrate to humans is thought to be solely the consequence of its reduction to nitrite. Nitrate has been implicated in methaemoglobinaemia and also a number of currently inconclusive health outcomes. These include proposed effects such as cancer (through the bacterial production of *N*-nitroso compounds), hypertension, increased infant mortality, central nervous system birth defects, diabetes, spontaneous abortions, respiratory tract infections, and changes to the immune system (CDC, 1996; Gupta et al., 2000). Signs of methemoglobinemia appear at 10% MetHb or more symptoms include an unusual bluish gray or brownish gray skin color, irritability, and excessive crying in children with moderate MetHb levels and drowsiness and lethargy at higher levels (Brunning-Fann and Kaneene, 1993).

Nitrate is a naturally occurring compound and is an important component of vegetables because of its potential to accumulate. It is formed naturally in living and decaying plants and animals, including humans (Lundberg et al*.,* 2008; Camargo and Alonso, 2006). Nitrate is also used in agriculture as a fertilizer to replace the traditional use of livestock manure and in food processing as an approved food additive. Nitrate *per se* is relatively nontoxic, but its metabolites, nitrite, nitric oxide and N-nitroso compounds, its conversion to nitrite plays an important antimicrobial role in the stomach, whereas other nitrate metabolites also have important physiological /pharmacological roles (Lundberg et al., 2004, 2008; Bryan et al., 2005).

Additionally nitrate biotransformation is complex and involves nitrate reduction, nitrite formation, nitrite reoxidation to nitrate, and resulting methaemoglobin in a dynamic equilibrium (Lundberg et al., 2004, 2008). Nitrogen radicals are also effective against tumour cells (Ying and Hofesth, 2007). Nitrate in the form of nitric oxide may play a role in host defence, (Lundberg et al., 2008). All nitrogen species, including may lead to increased concentrations of nitrate in the plasma (Schopfer et al., 2003, Lundberg et al., 2004 and 2008, Cui et al., 2006).
Several epidemiological investigations over the last 50 years have demonstrated a relation between risk for cardiovascular disease and drinking water hardness or its content of magnesium and calcium. Exposure to extreme pH value results in irritation to the eyes, skin and mucous membrane. Eye irritation and exacerbation of skin disorders have been associated with pH greater than 11.

[1]http://www.healthgoods.com/Education/Healthy_Home_Information/Water_Quality/nitrate_drinking_water.htm

Figure 1. Map of Dar es Salaam region showing sampling points in Temeke District.

Additions to that, a solution of pH 10 – 12.5 have been reported to cause hair fibers to swell, pH below 12.5 damage epithelium (WHO, 1986).

METHODOLOGY

Purpose, study area and scope

The research was conducted in Temeke District. The sampling sites were selected in a scientific manner so as to come up with results, which reflect the entire spectrum of the water quality profile in Temeke District. Figure 1 shows the location of sampling sites on the map.

This paper describes and explains the physical drinking water quality parameters of water sampled from tap (piped), river/stream water, shallow and deep wells used for domestic purposes (drinking) in Temeke District. The results are based on samples collected from 7 tap (piped) water sites, 8 river sources, 17 shallow wells and 40 deep wells in 10 wards selected randomly. The selection of sampling areas was based on the status of outbreak of cholera and other water borne diseases. Table 2 shows the sampling sites by names of location and type of source. The main purpose of studying drinking water quality was to assess its quality in terms of chemical characteristics. The parameters analyzed include: pH, chloride, nitrate and total hardness. The results were then compared with the drinking water quality standards from TBS and WHO. Finally, an

Table 2. Identification of sampling sites.

Sampling site R = River, T – Tap water, D = Deep well (≥ 5 m deep), S = Shallow well (< 5 m deep)	
R_{1-} Kizinga River –Darajani	D_{19-} Nzasa- Kisima Cha Kwa Mzee Kasara
R_{20-} Mzinga-Kilingure A/Nzasa A	D_{4-} Mbagala Kwa Nyoka B
R_{21-} Mzinga-Kilingure B/ Nzasa A	D_{7-} Toangoma Msikiti Wa Kichangani
R_{3-} Mbagala/Kwa Nyoka A	S_{2-} Mbagala Kwa Mangaya
R_{44-}Tandika RelinI/kwaNyambwela	S_{12-}Toangoma Magengeni
R_{45-} Tandika-Kilimahewa Kwa Mzee Yasini	S_{13-} Mtoni Mtongani
R_{8-} Mto Mzinga-Kongowe	S_{15-}Charambenzasa A Kitambulio
R_{9-} Mto Mkikokozi- Kongowe	S_{16-}Charambenzasaa Kwa Madeni
T_{33-} Tambukareli-Zahanati	S_{5-} Mbagala Kwa Kipati
T_{43-} Tandika Magorofani/Bombani	S_{6-} Toangoma Kongowe
T_{47-} Tandika Chihota/Kilimahewa	S_{22-} Mbagala Kuu Kibonde Maji
T_{50-} Chihota Kwa Mgunda	S_{26-} Mbagala Kuu Kwanumbwa
T_{54-} Keko Gerezani-Getini	S_{27-} Mbagala Kuu-Kibonde Maji Msikitini
T_{55-} Keko Magurumbasi-Furniture	S_{32-} Azimio-Mtongani
T_{56-} Keko Machungwa	S_{40-} Mtoni Kwa Kabuma-Masudi Mpemba
D_{23-} Mbagala Kuu –Zakhemu Dispensary	S_{52-} Keko-Ttc Kwa Mzee Nassor
D_{24-} Mbagala Kuu – Mabomba Sita	S_{53-} Keko Mwanga
D_{25-} Mbagala Kuu -Kibonde Maji A	S_{57-} Keko Gerezani Kwa Mzee Ismail
D_{28-} Mbagala Kuu Kwa Mzee Mwangia	S_{60-} Minazi Mikinda Kwa Mzee Bayana
D_{29-} Kijichi	S_{61-} Kigamboni Kanisani
D_{30-} Kichemchem-Msikiti Wa Kwa Babi	S_{62-} Ferry-Midizini
D_{31-} Azimio-Kisima Cha Msikiti Mweupe	S_{63-} Kigamboni Shuleni
D_{34-} Tandika Azimio-Kwa Mzee Shabani	S_{65-} Kigamboni- Mtua Moyo-Shuleni
D_{35-} Azimio Kusini-Masjid Riyadhwak	S_{66-} Kigamboni- Magenge Ya Juu
D_{36-} Azimio Kusini-Tandika Sokoni	S_{67-} Kiungani
D_{37-} Azimio-Mtongani Zizini	S_{68-} Kigamboni - Mji Mwema
D_{38-} Mtoni Kwa Kabuma	S_{69-}Charambe Maji Matitu Mpang'ombe A
D_{39-} Mtoni Kwa Aziz Ali-Sokoni	S_{70-} Charambe Machinjio Kwa Mshamu
D_{41-} Tandika-Mango	S_{49-} Buza
D_{42-} Tandika- Maguruwe Kwa Shoga	S_{46-} Makangarawe-Yombo Dovya/ Bondeni
D_{10-} Toangoma Yasemwayo	S_{51-} Makangarawe
D_{11-} Zahanati-Toangoma	S_{58-} Keko Magurumbasi
D_{14-} Mtoni Mwembe Madafu	S_{59-} Kigamboni-Minazi Mikinda/ Ferry
D_{17-} Nzasa- Kisima Cha Kwa Kiparai A	S_{64-} Kigamboni-Kwa Mzee Abdallah
D_{18-} Nzasa- Kisima Cha Kwa Kiparai B	S_{48-} Yombo-Kilimani

insight of the effect of such parameters on human health was presented.

Figure 2 shows a frequency distribution of drinking water sources used in this study. Most of the samples were collected from deep wells (which forms most of the water sources) and shallow wells.

Sampling procedure

One of the basic requirements of a water quality analysis was to develop and adopt a sound sampling technique. It involved transferring a pre-selected small volume of water from the original collection point to another location for analysis without causing any change in its properties. Great care was taken during sampling to prevent contamination of the sample being collected. The sample containers were rinsed with the water from the collection station. River, well and tap water samples were collected and stored in suitable bottles to permit accurate analysis. The sample details were adequately described and the sample bottles were properly labeled to avoid errors. The selected physical parameters were tested immediately to avoid further microbial and chemical activities in the sample.

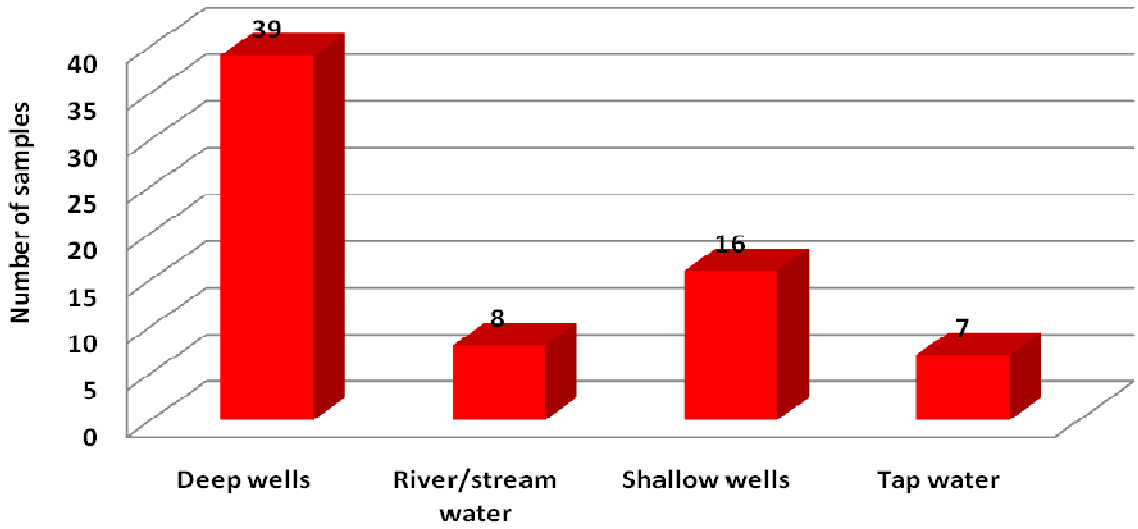

Figure 2. Frequency chart for the different drinking water siourdces used in this study.

Sample analyses

The analyses of water samples were conducted using standard methods including classical laboratory methods (HACH, 1997). Ministry of Water Laboratory and Government Chemist Laboratory Agency (GCLA) were used for physical analysis.

Drinking water pH levels

The measurement of pH was done by using a portable pH meter on site. The meter was calibrated with standard buffer solutions of pH 4 and 7, making adjustments for temperature and asymmetry potential required by the instrument. The electrode was removed from the buffer and rinsed with the sample and after adjustment, the pH was recorded. The electrode was rinsed with distilled water between successive measurements.

Total hardness of the drinking water

Total hardness was obtained by titrating a sample solution with a 0.01 N of ethylenediaminetetraacetic acid (EDTA) solution by using Eriochrome black T indicator, until the color changes from purple to pure blue. Approximate 50 ml of water sample was accurately transferred into a 250 ml conical flask, and then 2 ml of buffer solution were added, stirred and mixed with Eriochrome black T. Indicator was added and mixed well until dissolved. After that the mixture was titrated with 0.01 N, EDTA solution until the color change from purple to pure blue.

Chloride concentration

Several analytical techniques may be used for chloride in water, including titration (e.g., potentiometric titration with silver nitrate), colorimetry (e.g., thiocyanate colorimetry), chloride ion selective electrode and ion chromatography (30). Limits of detection range from 50 µg/L for colorimetry to 5 mgL^{-1} for titration. Mercuric nitrate method was used due to the fact that the end point in this method is easier to detect. In this study, the chloride value was obtained by titrating 2.256 N mercuric nitrate with diphenyl/carbazone indicator; the end point was obtained by the color change from yellow to light pink. Approximately 100 ml of sample was filled to a graduated cylinder to the 100 ml mark. The sample was poured into a clean 250 ml Erlenmeyer flask. The contents of one diphenyl carbazone pillow will be added and mixed. The sample was titrated until color change from yellow to light pink. Then the concentration of chloride in mgL^{-1} will be obtained.

Nitrate concentration

Nitrate values were determined by using Cadmium reduction method by using nitrate powder pillows to prepare a solution. A spectrophotometer will be used. The stored program number, for high range nitrate- nitrogen will be entered. The wavelength dial will be rotated until the range of 500 nm. Approximate 25 ml of water sample was filled into a sample cell and an indicator is added. The sample color will change from colorless to yellow. Then the mixture was allowed to settle for 5 min. The blank was placed into the cell holder. Zero buttons was pressed. The same procedure was used for each sample.

RESULTS AND DISCUSSION

Presentation of the overall data

Table 3 presents the data in tabular form to form the reference for the data analysis and presentation. The major parameters include pH, chloride ion concentration, nitrate concentration and hardness values, arranged by drinking water source, with reference also to Table 2. The variations for each parameter are studied in details in the subsequent section using graphical presentation (histograms and bar charts).

The pH level in drinking water

The pH levels for drinking water from different selected

Table 3. Overall results for chemical parameters.

Source Identification	Type of drinking water source	pH	Chloride Cl^-, (mgL^{-1})	Total hardness (mgL^{-1})	Nitrate NO_3^- (mgL^{-1})
D4	Deep well	7.6	156	60	2.23
D18	Deep well	7.7	880	80	24.58
D25	Deep well	7.7	1140	600	16.35
D7	Deep well	8	140	30	19.55
D10	Deep well	7.5	164	50	0
D14	Deep well	7.5	192	100	28.88
D38	Deep well	7.7	700	210	2.53
D39	Deep well	7.3	640	160	0.97
D40	Deep well	7.2	700	210	6.65
D17	Deep well	8	2020	670	1.75
D19	Deep well	6.9	1340	20	0.47
D69	Deep well	8.2	620	60	2.9
D70	Deep well	7.9	760	200	15.5
D23	Deep well	7.4	600	320	1.65
D24	Deep well	7.2	640	220	28.24
D28	Deep well	7.4	660	190	0.16
D29	Deep well	8.2	1380	710	0
D30	Deep well	7.9	2060	1210	42.87
D31	Deep well	7.4	740	90	12.56
D34	Deep well	7.6	800	330	0.07
D35	Deep well	6.9	760	430	3.76
D36	Deep well	7.5	940	410	22.13
D37	Deep well	7.2	580	140	0.02
D41	Deep well	7.9	680	330	8.67
D42	Deep well	7.5	720	310	18.75
D48	Deep well	7.1	720	180	9.06
D49	Deep well	7.9	820	360	3.02
D51	Deep well	6.7	480	210	8.47
D52	Deep well	6.7	598	250	19.54
D53	Deep well	7.8	782	100	0
D57	Deep well	6.9	680	400	0.7
D58	Deep well	7.1	860	460	3.4
D62	Deep well	8.2	420	470	5.12
D63	Deep well	6.2	400	290	1.78
D64	Deep well	7.5	600	220	0.48
D65	Deep well	7.8	640	170	0.02
D66	Deep well	6.9	660	200	10.5
D67	Deep well	7.6	700	420	2.5
D11	Deep well	7.4	520	230	0.16
R3	River water	8.6	240	160	9.26
R_1	River water	8.4	440	280	4.59
R8	River water	7.8	168	50	2.25
R9	River water	8.2	196	80	0.14
R20	River water	7.8	920	80	0.9
R21	River water	7.6	740	80	2
S46	Shallow well	8.3	600	300	32.18
R44	Stream water	8	760	400	3.25
R45	Stream water	7.8	900	710	6.25
S2	Shallow well	7.6	300	60	52.73
S5	Shallow well	8.2	348	440	90.28

Table 3. Continued.

S6	Shallow well	8.2	244	230	41.17
S12	Shallow well	7.7	112	30	0.17
S13	Shallow well	7.2	128	40	0.07
S15	Shallow well	7.2	228	120	33.52
S16	Shallow well	7.6	244	100	19.18
S22	Shallow well	7.6	740	120	22.15
S26	Shallow well	7.5	860	190	35.4
S27	Shallow well	7.2	600	710	15.62
S32	Shallow well	7.8	1280	430	80.1
S59	Shallow well	7.4	2240	420	52.82
S60	Shallow well	7.7	640	500	16.75
S61	Shallow well	6.8	580	300	40.3
S68	Shallow well	8.2	520	540	20.94
R44	Stream water	8	760	400	0.14
R45	Stream water	7.8	900	710	0
T33	Tap water	7.2	760	90	3.02
T43	Tap water	7.3	680	250	2.5
T47	Tap water	7.4	960	90	1.02
T50	Tap water	6.9	760	150	0
T54	Tap water	7.3	460	70	0.17
T55	Tap water	7.5	400	80	2.23
T56	Tap water	7.2	360	70	24.58

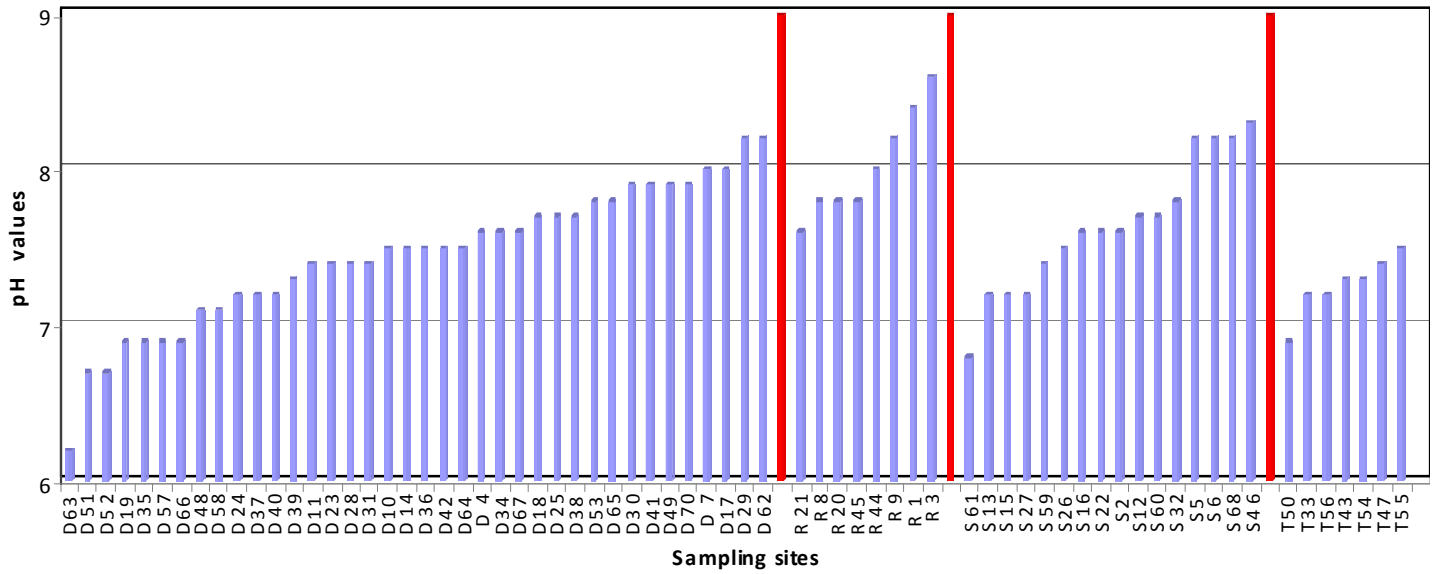

Figure 3. pH values for different water sources in Temeke District.

water sources showed little variation, as shown in Figure 3. The variation in pH was due to nitrates, chloride, carbon dioxide and or dissolved minerals that normally affect the pH. The acceptable range of pH for drinking water quality as per TBS and WHO standards is 6.5 - 8.5. The noticeable effects above the maximum contaminant level for pH is that, low pH leads to bitter metallic taste and corrosion, high pH leads to slippery feel and soda taste[2]. The statistical results for different water sources for pH were standard deviation, 0.46 mean, 7.54 and median 7.55. The highest frequency was shown at pH 7.2. Hence this shows that most of drinking water sources had the pH

[2] http:// www.epa.gov/ safewater/index.htm

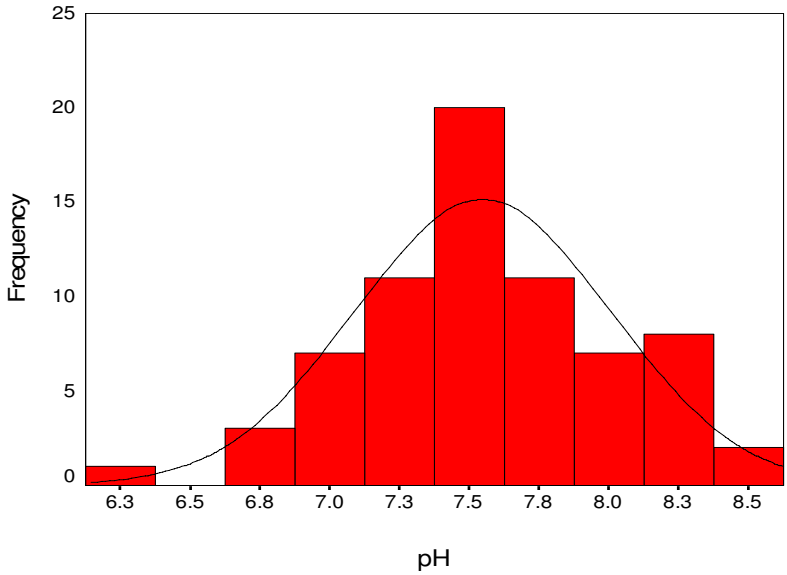

Figure 4. Histogram of pH levels for different water sources in Temeke District chloride levels.

of 7.2. The mean was less than median, hence the negative/left skewness. The left skewness was caused by few values to become extremely small compared to others. This was the deep well found at Kigamboni Shuleni. The environmental characteristic of that area such as geological location is the cause of having low pH level that is water to be acidic and also presence of dissolved minerals can attribute the lowering of pH in this well.

The pH values of deep wells ranged from 6.2 to 8.2. The pH values of water sample drawn from a well situated at Kigamboni Shuleni was 6.2, lower pH values may be attributed by larger quantities of dissolved minerals and also in well water there is a continuous abstraction of water that reduces the concentration of dissolved minerals in the water and thus the effect of the pH of the water. Water with a low pH can be acidic, soft and corrosive. This water can leach metals from pipes and fixtures, such as copper, iron, lead, manganese and zinc. It can also cause damage to metal pipes and aesthetic problems, such as a metallic or sour taste, laundry staining or blue-green stains in sinks and drains. Water that contains elevated levels of toxic metals could also show a low pH level.

The pH of tap water ranged from 6.9 to 7.5. On the basis of pH values, tap water can be regarded as suitable for drinking, as the values obtained met the permissible levels as recommended by WHO and TBS. The comparison between the tap water and the well water shows that the former is superior due to the fact that, for wells, the presence of algae additionally may cause dramatic swings in pH. The pH values for shallow wells ranged between 6.7 and 8.3. As water moves through the soil and rocks it dissolves small amounts of minerals and hold them in solution. Calcium and magnesium are the two most common minerals that can cause alkalinity in water and the degree may increase as calcium and magnesium ion increases. This causes water to be hard and leads to aesthetic problems and bitter taste.

The pH values obtained in water sampled from the river streams vary from one location to another. The pH values of the river water studied ranged between 7.6 and 8.6; this is due to the fact that most of the open water bodies are exposed to various pollutants that can influence the variation of pH. The District and industrial discharges have great influence on pH values of river and stream water. The higher pH value (8.6) was observed in water sampled from Kwa Nyoka A in Mbagala ward. The high pH value can be attributed by different activities done near the river such as washing clothes and cars, also due to the fact that the quality of river can change within the catchment areas as the streams and rivers move through inhabited areas, water quality can deteriorate further (Gray, 1996). Drinking water with a pH level above 8.5 could indicate that the water is hard. Hardness can cause aesthetic problems, such as an alkali taste to the water that makes coffee taste bitter; build-up of scale on pipes and fixtures than can lead to lower water pressure; build-up of deposits on dishes, utensils and laundry basins; difficulty in getting soap and detergent to foam; and lowered efficiency of electric water heaters. Comparison of the pH values of the samples with drinking water standards it was noted that most of water samples examined from different localities met the accepted pH range as recommended by WHO and TBS (6.5 - 8.5). Statistical analysis of the pH levels in the water samples shows a symmetric histogram about the pH = 7.5, as shown in Figure 4.

The levels of chloride for tap water from different selected localities are shown in Figure 5. These levels are

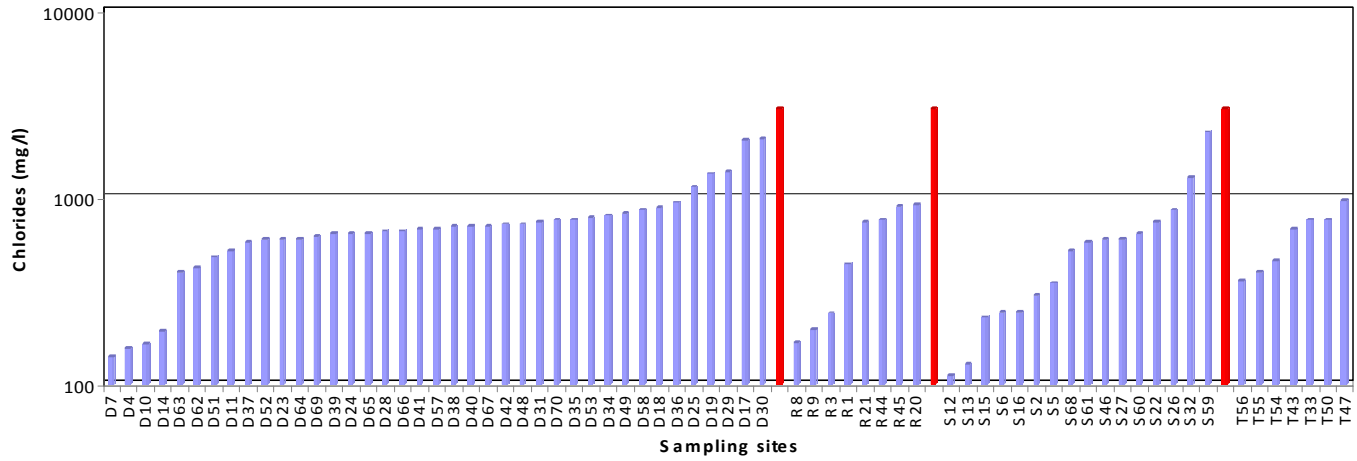

Figure 5. Chloride values for various water sources in Temeke District.

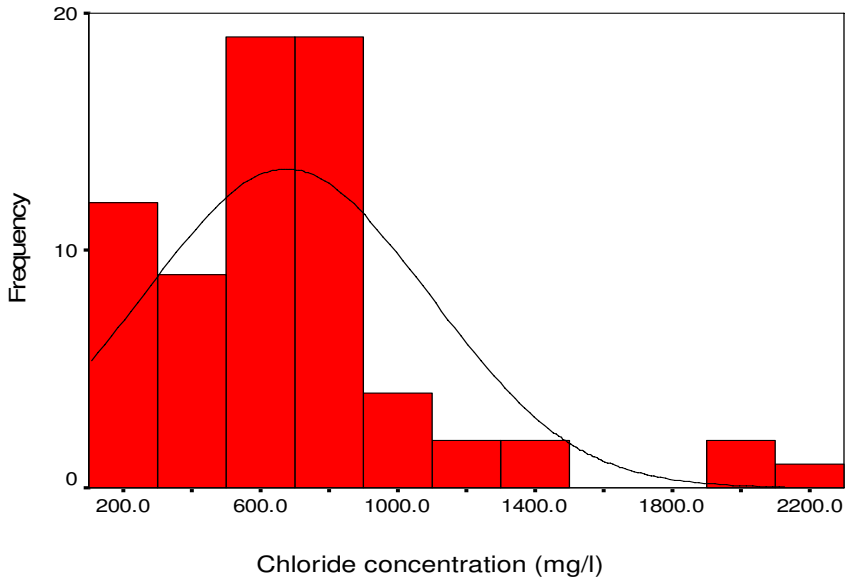

Figure 6. Histogram of chloride concentration levels for different water sources in Temeke District.

not supposed to exceed WHO standards (200 mgL^{-1}) and TBS (800 mgL^{-1}). All water samples examined seem to exceed that of WHO. The result of water sample brought from Tandika Chihota–Kilimahewa (960 mgL^{-1}) seems to exceed those of both WHO and TBS standards. The higher chloride levels may be due to natural mineral deposits and environmental pollution of those areas.

The chloride levels in drinking water should not exceed acceptable value of 200 mgL^{-1} according to WHO standards and TBS allowable value of 800 mgL^{-1}. According to Figure 5, most of water samples drawn from shallow wells were seen to exceed WHO acceptable level, except Toangoma Magengeni (112 mgL^{-1}) and Mtoni-Mtongani (128 mgL^{-1}) which were within both WHO and TBS standards. Water samples drawn from Kigamboni-Ferry (2240 mgL^{-1}), Azimio-Mtongani (1280 mgL^{-1}) and Kibonde maji kwa Numbwa (860 mgL^{-1}) were seen to exceeded those of WHO and TBS maximum allowable and recommended values. High chloride concentration values in these areas can be attributed to natural mineral deposits and sea water, either by intrusion, e.g., in Kigamboni or by air borne spray from agriculture or irrigation discharges or from sewage and industrial effluents. The chloride levels of deep wells ranged from 140 to 2060 mgL^{-1}. Only 16% of all water samples examined for deep wells met both WHO and TBS standards. Most of water samples drawn from selected localities were seen to exceed the WHO acceptable values.

Figure 6 show that the chloride levels for river water

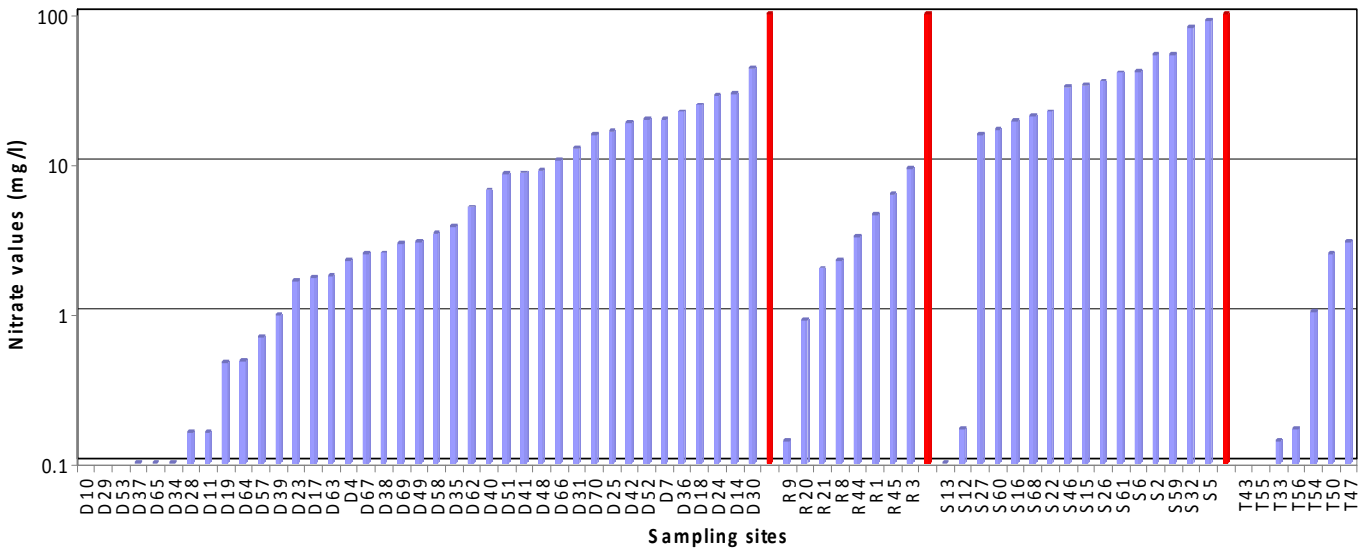

Figure 7. Nitrate values (mgL^{-1}) from various water sources in Temeke District.

were exceeding the acceptable drinking water quality standards. Most of water samples drawn from selected localities were observed to exceed the WHO (200 mgL^{-1}) and TBS (800 mgL^{-1}) acceptable levels. Higher levels of chloride for those areas may be due to the fact that river water is difficult to know the source of pollution and it is dynamic that is can change as it passes different catchments areas.

The statistical results for different water sources for chloride were standard deviation 415.15 mgL^{-1}, mean 675.7 mgL^{-1} and median 650 mgL^{-1}. The highest frequency was shown at 760 mgL^{-1}. The mean was greater than median, hence the positive/right skewness. The right skewness was caused by few values to become extremely large compared to others. The highest chloride levels were observed at a deep well at Nzasa A- kwa Kiparai (2020 mgL^{-1}) and at Kigamboni – Minazi Mikinda, near ferry (2240 mgL^{-1}). The higher chloride levels can be attributed to the environmental condition of the well, it is situated near the ocean, and therefore, ions such as chloride, may enter into the well through intrusion of sea water to the land. For the deep well at Nzasa A- Kwa Kiparai, the higher chloride levels can be attributed to geological condition and soil characteristics of that area.

Nitrate concentration

High-nitrate drinking water is most often associated with shallow wells with depths <15 m in regions with permeable soils (Fan et al., 1987). It is exactly the situation of Temeke District as most of the wells sampled and analyzed are privately owned and religion institution wells, whereby poorly regulated and unsanitary waters were observed. The factors responsible for elevated nitrate contents in well-water sources include geography, geology, groundwater hydrology, and the addition of nitrates naturally and from surface contaminated by nitrogenous fertilizers or by organic waste of human or animal origin (Shearer et al., 1972). Although, water derived from privately owned wells may be the most common source of high-nitrate drinking water, municipal drinking water supplies may also be contaminated.

The nitrate levels of water for different selected localities are shown in Figure 7. All river and tap water samples examined were observed to meet TBS (100 mgL^{-1}) drinking water standards. Nitrate in drinking water is associated with an increased risk for bladder cancer. Most of drinking water samples from deep and shallow wells were observed to exceed the WHO acceptable level (30 mgL^{-1}). Their presence in high concentration in well water is troublesome because the human body naturally converts nitrate molecules into nitrite, it is not common to find very high levels of nitrate unless the aquifer or the well itself has been compromised directly by surface water.

The toxicity of nitrate to humans is thought to be solely the consequence of its reduction to nitrite. Nitrate has been implicated in methaemoglobinaemia and also a number of currently inconclusive health outcomes. These include proposed effects such as cancer (via the bacterial production of *N*-nitroso compounds), hypertension, increased infant mortality, central nervous system birth defects, diabetes, spontaneous abortions, respiratory tract infections, and changes to the immune system (CDC, 1996; Gupta et al., 2000). The nitrate levels of deep wells ranged from 0 to 28.8 mgL^{-1} while for the river water studied ranged from 0 to 9.2 mgL^{-1}. All water samples drawn from selected deep wells from studied areas are within the WHO and TBS acceptable limits. The low level

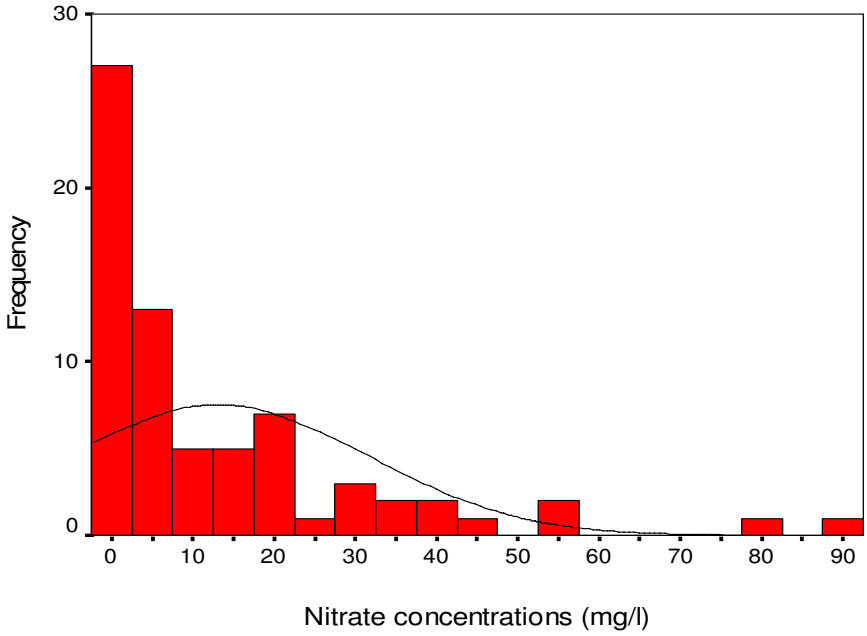

Figure 8. Histogram showing the frequency of nitrate concentration levels in mgL^{-1} for different water sources in Temeke District.

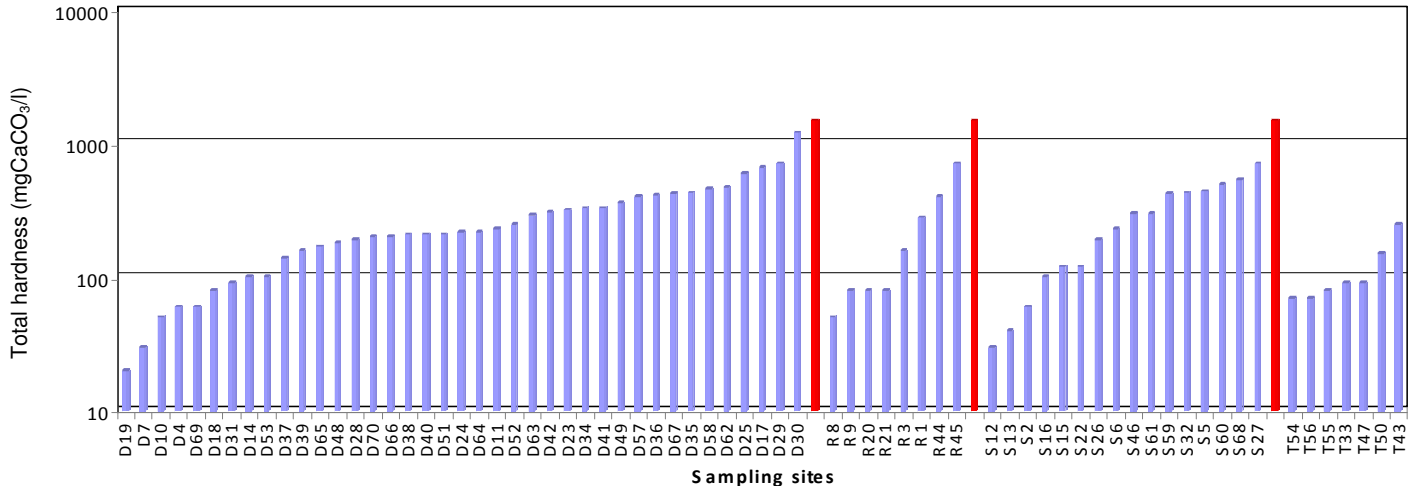

Figure 9. Total hardness levels from various water sources in Temeke District.

of nitrate can be caused by low intensive agricultural activities done in those areas.

The statistical analysis of different water sources for nitrate indicated a standard deviation of 18.55 mgL^{-1}, mean 13 mgL^{-1} and median 3.58 mgL^{-1}. The mean was greater than median, hence the positive/right skewness, as shown in Figure 8. High frequency was shown at 0 mgL^{-1}, indicating that most of water samples in Temeke have low nitrate level (nil). The right skewness was caused by few values being extremely large compared to others. The higher nitrate levels of 90.28 and 80.1 mgL^{-1} were observed for water sampled from shallow wells found at Mbagala kwa Kipati and Azimio–Mtongani, respectively. The higher nitrate levels were attributed to the natural levels of nitrate in groundwater, soil type and geology (WHO, 1996).

Total hardness

The total hardness values of the shallow wells studied ranged between 30 and 710 mgL^{-1}. Higher total hardness levels were observed in fewer sampling sites (Figure 9). According to water hardness classification, most of

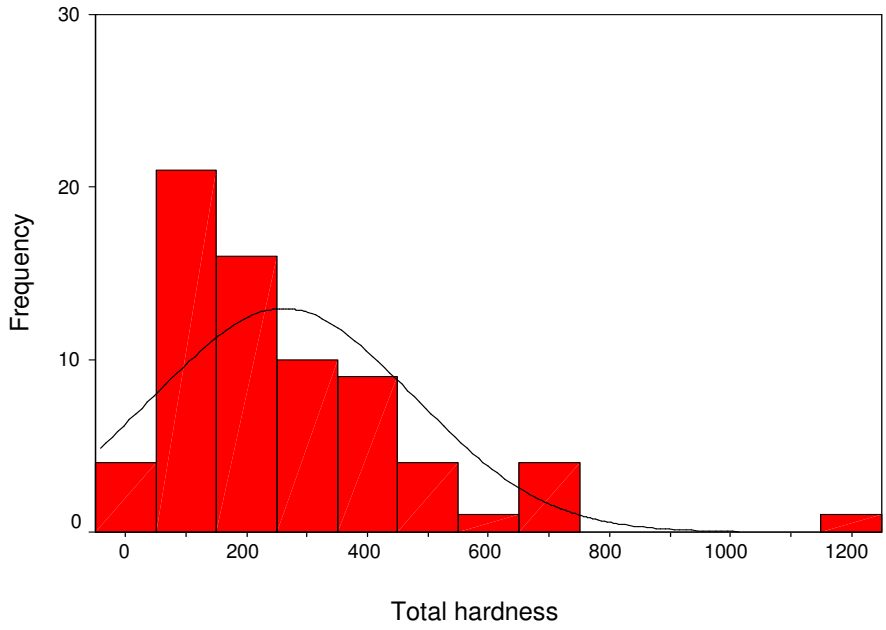

Figure 10. Histogram of total hardness levels in mgL^{-1} from water samples from different water sources in Temeke District.

samples fall to slightly and very hard classification. The water samples results drawn from Kibonde Maji-Kwa Numbwa (710 mgL^{-1}) and Mji Mwema (540 mgL^{-1}) deviates from WHO and TBS standards respectively.

Water hardness in Temeke District ranged significantly among sampling points. Water samples collected in taps and river/stream are soft to moderately hard; while samples collected from wells ranged from soft to very hard. Several epidemiological investigations over the last 50 years have demonstrated a relation between risk for cardiovascular disease and drinking water hardness or its content of magnesium and calcium[3]. The total hardness levels are not supposed to exceed 500 mgL^{-1} according to WHO standards and 600 mgL^{-1} TBS standards. Figure 9 shows that the hardness of water from different sampling sites ranged from 70 to 250 mgL^{-1}. Hence all water samples drawn from selected localities were observed to meet that of WHO and TBS maximum allowable and recommended values. According to water hardness classification A (Table 1), most of water samples are moderate soft. According to classification B, most of results are moderate hard except water sampled from Tandika – Magorofani which are hard (250 mgL^{-1}).

The total hardness levels were observed for wells with 30 mgL^{-1} for Toangoma-Kichangani Msikitini and 20 mgL^{-1} for Nzasa kwa Mzee Kasara indicated soft water. The remaining samples fall in moderate hard and very hard classification as stipulated in Table 1. Many studies of populations in areas of naturally occurring hard and soft water have found few occurrences of cardiovascular diseases, cancer, diabetes, respiratory diseases or other health problems in hard water areas.

Figure 9 shows also that the hardness of river water ranged between 50 and 710 mgL^{-1}. Most of water samples drawn from selected localities were observed to meet the WHO and TBS maximum allowable and recommended levels. According to Table 1 of water hardness classification A, most of water samples were moderate soft and slightly hard except water sampled from Tandika-Kilimahewa Kwa Mzee Yasini (710 mgL^{-1}) and Tandika–Relini were very hard. The hardness can be caused by some activities done near the sampling point such as washing clothes and also geological condition of the area. The statistical analysis of total hardness levels shows the following: standard deviation = 215 mgL^{-1}, mean = 261 mgL^{-1} and median = 210 mgL^{-1}. The mean was greater than median, hence the positive/right skewness, as shown in Figure 10. The right skewness was caused by few values to become extremely large compared to others, in particular at Kichangani- Msikiti wa Kwa Babi where a value of 1210 mgL^{-1} was observed.

Researches and studies proved that water with low magnesium can cause increased morbidity and mortality for cardiovascular disease, higher risk of motor neuronal disease, pregnancy disorders and preeclampsia. Water with low in calcium may be associated with higher risk of fracture in children, certain neurodegenerative diseases, pre-term birth and low weight at birth. Lack of both calcium and magnesium in water can also cause some types of cancer.[4]

[3] http: // jn.nutrition.org/misc/terms.shtml

[4] http: // www.lenntech.com/ WHO's – drinking-water-standards.htm

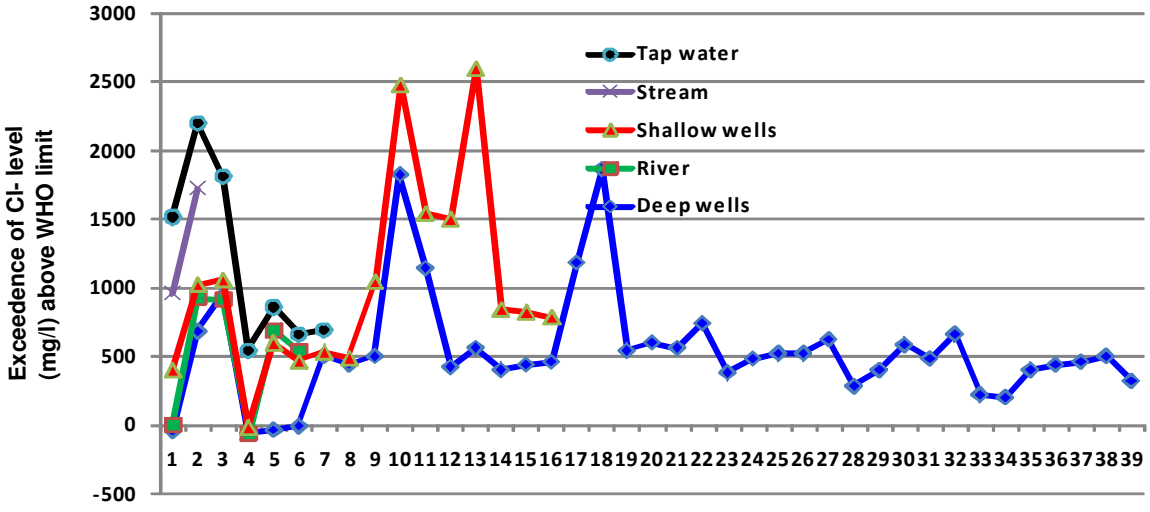

Figure 11. Exceedence values for chloride above WHO limit for water samples from Temeke District.

Direct comparison with WHO limits

Figure 11 compares the exceedences (concentration above WHO limit) for different water sources in Temeke District. Almost all the values measured were above the WHO limit, with exception of few samples. Highest exceedences were observed for shallow water, whereby values of chloride levels 2500 mgL^{-1} above the limit were observed. None of the tap, deep wells and stream water samples were permissible according to WHO chloride limit.

Treatment technologies for the chemical pollutants

Chloride

Because chloride is very soluble in water, it is not easily removed, and conventional water treatment processes are generally ineffective (WHO, 1984). A removal of 87% has been reported using a point-of-use treatment device employing granular activated carbon adsorption and reverse osmosis (Regumathan et al., 1983). Chloride concentrations in water may increase during the treatment process if chlorine is used for disinfection purposes or if aluminum or iron chloride is used for flocculation purposes (WHO, 1979).

Nitrates

Because nitrate is tasteless and odorless, water must be chemically tested to determine contamination. Before investing in treatment equipment or a new water supply, have your water tested at a reputable laboratory. If water contains greater than 10 mgL^{-1} NO_3-N, the options for reducing health risks are substitution, in-home treatment, and source elimination. Substitution of bottled water for drinking and cooking is a simple and relatively inexpensive means of reducing nitrate intake. Nitrate is easily dissolved in water, which means that it is difficult to remove. The technology for removal of nitrate from drinking water does exist. Three water treatment systems that remove nitrate are distillation, reverse osmosis, and ion exchange. Distillation boils water, then catches and condenses the steam while nitrate and other minerals remain in the boiling tank. Reverse osmosis forces water under pressure through a membrane to filter out contaminants. Ion exchange introduces another substance, normally chloride, to "trade places" with nitrate in water. [5]

Treatment of drinking water to remove nitrate is expensive. Consider not only the initial purchase price but also the cost of regular maintenance when purchasing a water treatment system. Simple household treatment procedures such as boiling, filtration, disinfection, and water softening do not remove nitrate from water. Boiling actually increases the nitrate concentration of the remaining water. Improperly installed, operated, or maintained, equipment can result in nitrate passing through the treatment process and in some cases concentrating the nitrate above the incoming levels. Bacteriological problems can also develop in improperly installed and poorly maintained systems. [6]

CONCLUSION AND RECOMMENDATIONS

The study has revealed that:

[5] http://www.healthgoods.com/Education/Healthy_Home_Information/Water_Quality/nitrate_drinking_ water.htm

[6] http://www.michigan.gov/printerFriendly/0,1687,7-135-3313_3675_3690-9161--,00.html

1. The results for comparison between the chemical parameters of water sources and WHO/TBS acceptable levels have shown that most of the chemical parameters were above the permissible levels. This shows that the water sources analyzed from this District are more polluted in terms of chemical parameters. Based on the water quality parameters analyzed in this study, tap water was found to be of high quality than others.
2. There is a significant difference for deep and shallow wells inn terms of nitrate content, most of the shallow wells shows higher nitrate content exceeding the WHO limit.
3. There is no significant difference in total hardness and chloride for shallow and river/streams water.
4. There is a significant difference in chemical parameters among water sources, i.e., tap, wells and river water, this is because these sources are found from different locations, soil type and level of pollution. This is the reason during statistical analysis, most of the parameters for difference sources skewed to the right.
5. Statistical analysis shows that the histograms of chemical parameters in the drinking water are skewed to the higher concentration levels, showing that the drinking water is heavily polluted.
6. The samples with chemical parameters passing the TBS limits failed to pass WHO limits due to the latter being more stringent than the former.
7. It is recommended that district should improve sewerage systems in the area, prohibit release of chemical wastes from industrial activities, provide the community with deep wells, and educate the community to abandon use of shallow wells as a source of drinking water.

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