The microbiological quality of wells and borehole waters in Dar es Salaam Region.

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Abstract: *The present study was carried out to examine the microbiological quality of 45 randomly selected wells and boreholes in Dar es Salaam City. Total coliform and fecal coliforms were used as indicator microorganisms. Coliform count was done by using a three tube assay of Most Probable Number (MPN) technique in which both Presumptive coliform test and Confirmation test were carried out. Questionnaire and observational methods were used to collect information on the possible sources of contamination and the construction and maintenance of well/ boreholes. The results generally indicate poor water quality with an overall mean values of 424 and 379 cfu/100 ml for total caliform and feacal caliform (for Temeke Municipality), 5 and 8 cfu/100ml for total and feacal califorms respectively (for Ilala Municipality) and 175 and 113 cfu/100 ml for total and feacal califorms respectively (for Kinondoni Municipal). Toilets, septic tanks and poor construction and maintenance of wells and boreholes were identified as the possible potential sources of contamination of the well and borehole waters. The majority of the wells and boreholes were within 10 to 20m from toilets and septic tanks while the WHO guideline recommends 30m away from latrine and 17m from septic tanks. On the other hand, most of them were not protected and lacked concrete floor around the dug well. Records on the depth of boreholes and wells showed that the majority of the water sources had a depth of over 50m and very few had depth of <20m and between 20-30m.*

Keywords: Boreholes, well, total coliform, feacal coliform

INTRODUCTION

Water is essential for the well being of mankind and for sustainable development. It is necessary for human survival. However a substantial fraction of a population is denied access to potable water and sufficient water to maintain basic hygiene. The effects of drinking water which is contaminated results in thousands of deaths every day, mostly among children under five years in developing countries (WHO, 2004). Diseases due to consumption of contaminated water, and poor hygienic practices are the leading causes of death among children worldwide (WHO, 2003). Thus lack of safe drinking water supply, basic sanitation and hygienic practices are associated with high morbidity and mortality from excreta related diseases. Diarrhea remains a major killer in children and it is estimated that 80% of all illnesses in developing countries is related to water and sanitation; and that 15% of all children deaths under the age of 5 years in developing countries result from diarrhea (WHO/UNICEF, 2000; WHO, 2004). Globally, 1.1 billion people rely on unsafe drinking water sources from lakes, rivers and open wells. The majority of these are in Asia (20%) and Sub-Saharan Africa (42%). Furthermore, 2.4 billion people lack adequate sanitation worldwide (WHO, 2000; WHO/UNICEF-JMP, 2004).

The underground water supplies are usually considered safe provided they are located, constructed and operated according to the guideline for drinking water (WHO 1971, WHO 1993, National Regulation Act No.42 of 1974). Boreholes are a low-cost technology option for domestic water supply in developing countries and when properly constructed and maintained, provide consistent supplies of safe and wholesome water with low microbial load and little need for treatment provided the collection, transportation, storage and decantation of water are free from subsequent contamination (Jabu and Grimason, 2005)

Borehole and wells are among the main water sources found in various places in Dar es Salaam City. Wells refer to shallow underground water sources dug by hand though some may be quite deep and they are often lined with bricks where as boreholes refer to narrow holes drilled into the ground that tap into ground water. However most of these sources are dug or drilled locally without following hygienic standards and / or consulting relevant regulatory bodies. Lack of basic sanitation and poor hygienic practices in the supply of water for drinking and other domestic uses have been associated with high morbidity and mortality; diarrhea and cholera being the reported killer diseases (WHO 2000, 2004) and these have been a persistent problem in Dar es Salaam. On the other hand, the city has been witnessing an increase in the number of industries over the years and the human population has grown tremendously. By 2011 the population was 3,194,903 (Dar es Salaam Regional and Districts Projections, 2006). According to Mato (2002) though the city has had three master plans (prepared in 1948, 1968 and 1979) there is yet less compliance reflected by huge divergence between master plan and actual urban growth and development. The non compliance is demonstrated by the emergence of unplanned residential areas or squatter areas. There are more than 40 unplanned residential areas in Dar es Salaam, accommodating about 70% of the city population. The current status of the quality of water supply is limited or not known especially for borehole and well waters. Poor habitant's infrastructure, improper disposal of wastes and sewages are some of the unhygienic practices associated with increased population in the city. Therefore the overall objective of the study was to examine the microbiological quality of well and borehole waters in Dar es Salaam and specifically to determine the overall microbiological quality of water sources, to determine the level of contamination of total coli form and faecal coliform in well and borehole waters and to identify the potential sources of microbial contamination of well and borehole waters.

MATERIAL AND METHODS

Location, area and administration

The City is located between latitudes 6.36 degrees and 7.0 degrees to the south of Equator and longitudes 39.0 and 33.33 to the east of Greenwich. It is bounded by the Indian Ocean on the east and by the Coast Region on the other sides (Dar Es Salaam City Profile, DCP, 2004). The total surface area of Dar es Salaam City is 1,800 km2, comprising of 1,393 km2 of land mass with eight offshore islands, which is about 0.19% of the entire Tanzania Mainland's area (DCP, 2004). The city is divided into three administrative municipalities; Kinondoni, Ilala, and Temeke which are divided into 73 wards. In terms of population it grew from a population of 76,000 in 1950 to a population of 3.31 million in 2008. With a current estimated growth rate of 4.3% per year, the city contains 26% of the country's urban population though this percentage was expected to nearly double by 2010 (Penrose et al., 2010). The Municipals (Districts) are divided into Divisions, which are in turn divided into Wards. Wards are divided into villages in the case of rural areas and Streets in the case of urban areas. At times the villages are divided into hamlets which are the smallest units (DCP, 2004).

Sample size and Sampling technique

The sampling was done in the dry season between June and August to ascertain the microbiological quality of water the period during which the contamination is at the lowest. A total of 45 randomly selected water sources (fifteen from each municipality), of which 15 were boreholes and 30 wells as summarized in Table 1. Wells refer to shallow underground water sources dug by hand though some may be quite deep and they are often lined with bricks where as boreholes refer to narrow holes drilled into the ground that tap into ground water.

Table 1: Water sources (boreholes and wells) sampled from Temeke, Ilala and Kinondoni Municipalities

Temeke		**Ilala**		**Kinondoni**	
Ward	**Water sources**	**Ward**	**Water sources**	**Ward**	**Water sources**
Tandika	3	Gerezani	3	Saranda	4
Mbagala	3	Ilala	3	Ndungumbi	2
Charambe	3	Buguruni	3	Goba	4
Toangoma	3	Vingunguti	3	Kibamba	1
Azimio	3	Jangwani	3	Makuburi	1
				Mburahati	1
				Tandale	1
				Bunju	1
Total	**15**	**Total**	**15**	**Total**	**15**

Collection and transportation of samples

The underground water sources were either open wells or wells with hand pumps or boreholes with taps. Samples were collected according to the standard procedure of FAO (1992). Cotton wool soaked in 70% (v/v) ethanol was used to sterilize the nozzle of borehole pipes from which water sample were collected. For water sources equipped with taps water was allowed to run for two minutes before 25 ml screw capped sterile glass bottles were carefully uncapped, filled with the water and then recapped. In case of water sources without taps, water was drawn by using sterile container tied with a rope followed by pouring water into the sampling bottle and then recapped. Water samples were then transported to the Chief Government Chemist Laboratory in an iced container for bacteriological analysis within two hours of collection.

Determination of microbiological quality

The microbiological quality was determined based on the detection of total coliforms and faecal coliforms.

Enumeration of Total coliform and feacal coliform count

Coliform counts were done by using a three tube assay of Most Probable Number (MPN) technique. Presumptive coliform test was performed using MacConkey broth (Oxoid). The first set of three set of 5 tubes had sterile 10ml double strength broth and the second and third sets had 5ml single strength broth respectively.

All tubes were equipped with Durham tubes before addition of media and sterilization. The three sets of 5 tubes received 10ml, 1ml and 0.1ml quantity of water samples respectively using sterile pipettes. The tubes were then incubated at 37oC for 24 - 48 hrs for estimation of total coliforms and at 44.5oC for 24 – 48 hrs for feacal coliforms estimation and examined for acid and gas production. Acid was determined by color change of broth from reddish purple to yellow (using Kovacs reagent) and gas production was checked for entrapped gas in the Durham tubes. The results were expressed as the most probable number per 100ml (MPN /100ml)

Confirmation test
Confirmation test was carried out by transferring a loopful of culture from a positive tube from the presumptive test into a tube of Brilliant Green Lactose Bile (BGLB) broth Oxoid) with Durham tubes. The BGLB tubes were incubated at 37oC for 24 – 48h to detect total coliforms and were examined for gas production.
Loopful of culture from a positive tube from presumptive test was inoculated to the tubes of 5mls tryptone broth and incubated at 44.5oC for 24-48hr. Confirmation of faecal coliform was done by indole production where by 0.2 - 0.3 mls of kovacs'reagent was added to the tryptone tube, an appearance of a distinct red colour in the upper layer was an indication of a positive test.

Sources of microbial contamination
The possible sources of microbial contamination were identified based on the parameters affecting microbiological quality of ground water sources. The information was gathered by using questionnaires and also by physical observation.

Questionnaire
Data on the distance of wells and boreholes from pit latrines and septic tanks and other related information such as the general management of these water sources were collected using structured questionnaire. The questionnaire was successfully administered to forty five randomly selected owners of wells and boreholes.

Observation
Physical observation was used to confirm some of the responses from respondents including those related to distances from pit latrines and septic tanks and protection of water sources.

RESULTS

Microbiological quality of water from 5 boreholes and 10 wells in Temeke Municipality
The results of feacal and total coliforms of water samples tested from 5 boreholes and 10 wells during dry season in Temeke Municipality are presented in Table 2. The water sources were either privately, communally or government owned. Out of the five randomly selected

wards with a total of 15 wells and boreholes from which water samples were collected only five water sources (33.3%) were free from total caliform contamination and eight sources (53.3%) were free from feacal caliform contamination. The MPN index for both total and feacal coliform ranged from 0-1800cfu/ 100ml. The overall mean value for total coliform contamination was in the range of 16-1200cfu/100 ml and from 0-1200cfu/100 ml for the feacal coliform. The overall mean values were 424 and 379 cfu/100 ml for total coliform and feacal coliform respectively which reflects poor quality based on WHO guidelines which recommends zero MPN index/100ml.

Table 2: Total coliform and feacal coliform counts incidences in 5 borehole and 10 well waters in Temeke Municipality

S/N	Ward	water sources	Positive sources (T/coliform)	Total caliform Cfu/100ml		Positive sources (F/coliform)	Feacal coliform cfu/100ml	
				Mean	Range		Mean	Range
1	Tandika	3	3	137	13-350	2	7	0-14
2	Mbagala	3	1	16	0-49	0	0	0
3	Charambe	3	2	1200	0-1800	2	1200	0-1800
4	Toangoma	3	2	160	0-240	1	80	0-240
5	Azimio	3	2	607	21-1800	2	607	23-1800
	Total/Overall mean/range	15	10	424	0-1800	7	379	0-1800

Microbiological quality of water from 4 boreholes and 11 wells in Ilala Municipality

Fifteen water sources (4 boreholes and 11wells) were sampled in Ilala Municipality. The water sources with positive contaminations of total coliform and feacal coliform were 6 (40%) in either case (Table 3). On the other hand the total coliform and feacal coliform counts ranged from 0-28 cfu/100ml with mean counts ranging from 0-28 cfu/ 100ml. The overall mean counts were 5 and 8 cfu/100ml for total and feacal coliforms respectively. Out of the five selected wards only two wards, Ilala and Vingunguti had water sources which were free from both total and feacal coliforms contamination. The highest incidence of contamination was recorded in Jangwani ward.

Table 3: Total coliform and feacal coliform counts in 4 borehole and 11 well waters in Ilala Municipality

S/N	Ward	water sources	Positive sources (T/coliform)	Total caliform Cfu/100ml		Positive sources (F/coliform)	Feacal coliform cfu/100ml	
				Mean	Range		Mean	Range
1	Gerezani	3	1	4	0-11	1	4	0-11
2	Ilala	3	0	0	0	0	0	0
3	Buguruni	3	2	9	0-17	2	6	0-17
4	Vingunguti	3	0	0	0	0	0	0
5	Jangwani	3	3	14	0-28	3	14	0-28
	Total/Overall mean/range	15	6	5	0-28	6	8	0-28

Microbiological quality of water from boreholes and wells in Kinondoni Municipality

A similar number of wells and boreholes (a total of 15) was sampled from Kinondoni municipality like in the other two municipalities of the city. The water sources with positive contamination of total coliform and fecal coliform were 10 (66.7%) and 5 (33.3%) respectively. Out of 8 wards, only two wards of Kibamba and Tandale had water sources free of both total and feacal coliforms contamination. The highest incidences of contamination were recorded in Saranda and Goba wards where three out of four water sources were contaminated with either or both total and faecal coliforms. The counts for total coliform and feacal coliform contamination were in the range of 0-1800cfu/100ml with an overall average count of 175 and 113 cfu/100 ml respectively (Table 4).

Table 4: Total coliform and feacal coliform counts incidences in six borehole and nine well waters in eight wards in Kinondoni Municipality

S/N	Ward	water sources	Positive sources (T/coliform)	Total caliform Cfu/100ml		Positive sources (F/coliform)	Feacal coliform cfu/100ml	
				Mean	Range		Mean	Range
1	Saranda	4	3	901	0-1800	2	451	0-1800
2	Ndungumbi	2	1	12	0-23	0	0	0
3	Goba	4	3	455	0-1800	3	453	0-1800
4	Kibamba	1	0	0	0	0	0	0
5	Makuburi	1	1	14	0-14	0	0	0
6	Mburahati	1	1	8	0-8	0	0	0
7	Tandale	1	0	0	0	0	0	0
8	Bunju	1	1	11	0-11	0	0	0
	Total/Overall mean/range	15	10	175	0-1800	5	113	0-1800

Table 5: comparative incidences of total coliform and feacal coliform counts in 15 boreholes and 30 wells in the three municipalities of the city

SN	Municipality	water sources	Positive sources (T/coliform)	Total coliform Cfu/100ml		Positive sources (F/coliform)	Feacal coliform cfu/100ml	
				Mean	Range		Mean	Range
1	Temeke	10 wells	7	581	0-1800	5	541	0-1800
		5 Boreholes	3	62	0-240	2	7	0-21
2	Ilala	11 wells	4	5	0-28	3	4	0-28
		4 Boreholes	2	9	0-17	2	7	0-17
3	Kinondoni	9 wells	6	603	0-1800	4	401	0-1800
		6 Boreholes	4	9	0-23	1	1	0-8

Results in Table 5 show the contamination levels of water sampled from 15 boreholes and 30 wells from the three municipalities of Dar es Salaam city. The results generally show that the contamination levels were higher in wells compared to boreholes in both total coliform contamination and fecal coliform contamination. With the exception of Ilala municipality the mean contamination level in wells were almost 9 and 77 times higher in total coliform count and feacal coliform count respectively. The higher contamination level could be due to the poorer management of the wells as compared to the boreholes.

Protection of boreholes and wells

The protection of water sources was considered by looking at some of the factors that can affect the quality of water i.e. the potential sources of microbiological contamination which included protection of water sources, distance from latrines/toilets and sewage system (septic tanks), depth of boreholes and wells and handling of water collection buckets. While all the boreholes were fully enclosed (protected) about 9 wells were used unprotected (5 from Temeke and 4 from Kinondoni). All the unprotected wells were also lacking concrete floor around them. For the unprotected wells small tied buckets were used by community members in water collection. The handling of the water collection buckets was similarly poor; they were kept on ground after water collection. Soil is one of the potential sources of microbial contamination. With regard to the depth of boreholes and wells and the distances from sewage system (septic tanks) and from toilets results are summarized in Figures 1-3 and Tables 6 & 7. Figure 1 shows that the majority of water sources are located within < 10 m and between 10 to 20 m. The municipality with the highest number of wells and boreholes located closest to the toilets within < 10 m is Kinondoni, followed by Temeke and lastly Ilala. A similar trend was observed for the distances from the septic tanks (Figure 2). On the other hand Table 6 summarises the distances of water source from septic tanks and toilets for each of the three municipalities based on the category of the water source (that is, boreholes and wells).

A similar trend was observed in either cases in which most of the water sources, both boreholes and wells were within <10 to 20 m from septic tanks and boreholes.

On the other hand records on the depth of boreholes and wells (Figure 3) show that the majority of the water sources in all the municipalities had a depth of over 50m and very few had the depth of <20m and between 20-30m. None of the boreholes in both Kinondoni and Temeke Municipalities have < 20 m depth where as the reverse is true for wells in the two Municipalities.

The age of the wells and boreholes (Table 7) on the other hand show that Kinondoni municipality has the largest number of water sources aged between < 2 to < 5 years (73.3%) followed by Temeke (46.7%) and lastly Ilala (40%).

Table 6: Distances of boreholes and wells from septic tanks and toilets for each of the three municipalities

Distances (m)	Kinondoni				Ilala				Temeke			
	Boreholes		Wells		Borehole		Wells		Boreholes		Wells	
	Septic	Toilet	Septic	Toilet	Septic	Toilet	Septic	Toilet	Septic	Toilet	Septic	Toilet
<10	2	3	3	3	0	0	0	0	0	0	2	2
10-20	0	0	3	4	2	2	8	8	5	5	6	6
21-30	1	0	0	0	1	1	2	2	0	0	1	1
>30	3	3	3	2	1	1	1	1	0	0	1	1
Total	6	6	9	9	4	4	11	11	5	5	10	10

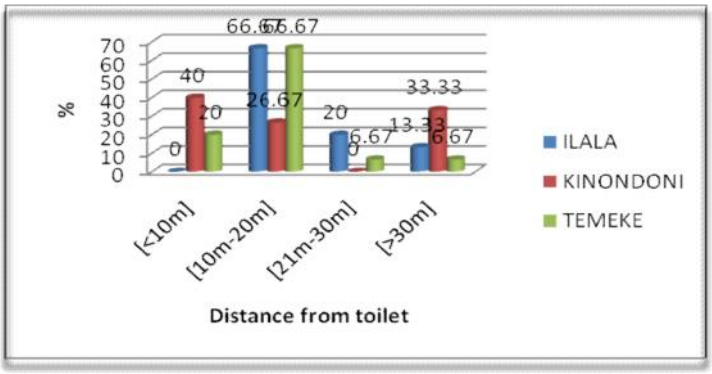

Figure 1: Distances of water sources from toilets in each municipality

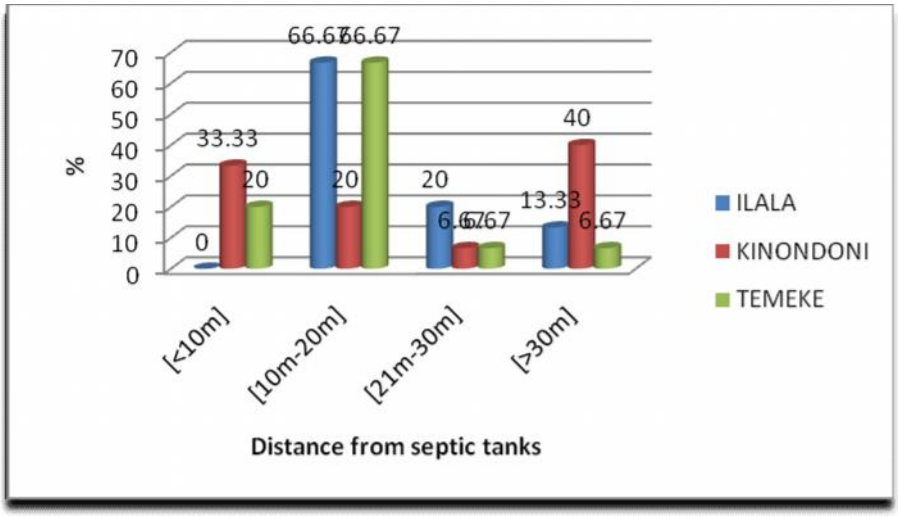

Figure 2: Distances of water sources from septic tanks in each municipality

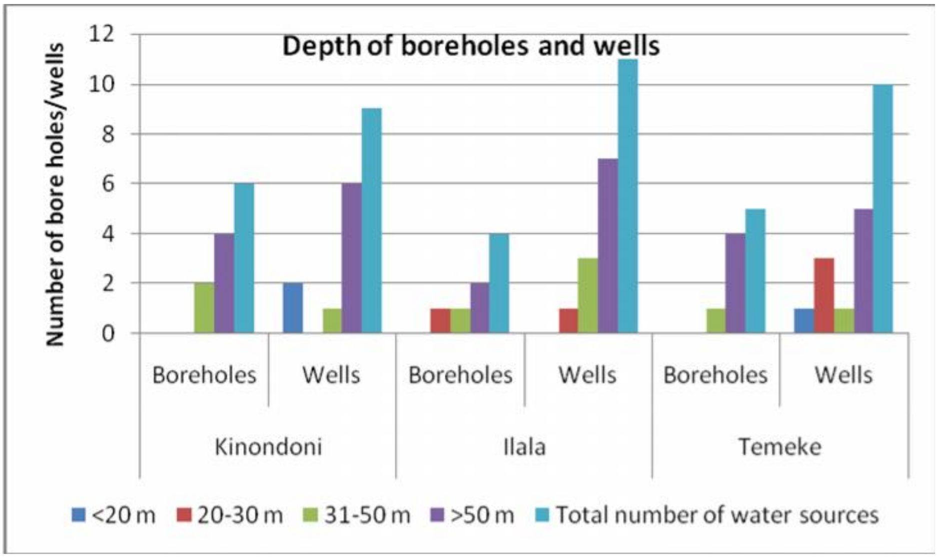

Figure 3: Depth of wells and boreholes in each municipality

Table 7: Age of wells and boreholes in each municipality

Age of water sources (years)	Number of water sources (%)			
	Ilala n = 15	Kinondoni n = 15	Temeke n= 15	Overall n= 45
< 2	3 (20)	3 (20)	1 (6.7)	7 (15.6)
2 to < 5	3 (20)	8 (53.3)	6 (40)	17 (37.8)
5 to 10	5 (33.3)	1 (6.7)	4 (26.7)	10 (22.2)
> 10	4 (26.7)	3 (20)	4 (26.7)	11 (24.4)

DISCUSSION

Water is one of the most critical problems in Dar es Salaam city not only due to inadequate supply but also due to lack of access to potable water. According to DCP (2004) 32%, 48% and 40% of the total population of Temeke, Ilala and Kinondoni municipalities respectively have no access to clean water. Though only 5% of the total population is reported to depend on wells and boreholes based on the DCP (2004) statistics, the number could even be higher than projected as one water source can be shared among several families. This implies that the poor microbiological quality of water may have a significant detrimental effect to a substantial proportion of the population. The microbiological quality of water in the three municipalities of Dar es Salaam city was examined by analyzing the total coliform and feacal coliform counts of water sampled from 45 wells and boreholes that is, fifteen from each municipal. Boreholes and wells have become the major water sources in the city due to insufficient supply of piped water. The indicator microorganisms were present in almost all water samples collected from the 45 boreholes and wells in the three municipalities (Tables 2-4).

The contamination recorded in wells and boreholes waters in Ilala municipality were relatively lower compared to that recorded in water sampled from both Temeke and Kinondoni Municipalities (Tables 2 and 4) which could be linked with the factors influencing the microbiological quality of ground water (Figures, 1-3). It was also observed 9 wells (5 from Temeke and 4 from Kinondoni) were used unprotected the situation which exposes them to contamination.

According to WHO guidelines, no microbial indicators are supposed to be present in any 100 ml of drinking water, however in the present study high numbers of both total and feacal coliforms were recorded. Similar findings have been reported by Samie et al.(2011). In their study they indicated that the water quality of the boreholes was poor over the study period (June to October, 2009). Indicator organisms were higher than the acceptable maximum limits prescribed by the South African Department of Water Affairs and Forestry (DWAF) and the World Health Organisation. Higher contamination of water sources have been reported in wet season compared to dry (Obiri-Danso et al. 2009). The current study was carried out in dry season, which implies that the contamination situation for these water sources could be extremely higher during rainy season. According to Potgieter et al. (2006) in dry seasons the water table becomes very low and the rate of evaporation increases and this affects the oxygen content which in turn decreases the multiplication of bacteria. Low temperatures could also reduce the amount of oxygen available and hinder the bacterial process.

Potgieter et al. (2006) in his study of microbiological quality of borehole used South African Bureau of Standards (SABS) classification which categorises water into three quality categories namely good, marginal and poor. Good means negligible risk of microbial infection; fit for human consumption (counts: total coliform - 10 cfu.100 ml-1 and faecal coliform - 0 cfu.100 ml), marginal means slight risk of microbial infection; must be treated before consumption (counts: total coliform-11-100 cfu.100 ml-1 and faecal coliform 1-10 cfu.100 ml-1 and poor means risk of infectious disease transmission; not fit for human consumption (counts: total coliform –> 100 cfu.100 ml-1and feacal coliform > 10 cfu.100 ml-1). Based on this quality evaluation criteria water from Temeke was of poor quality, that from Ilala was of marginal quality in terms of total coliform count and of poor quality in term of feacal coliform; and water from Temeke was of poor quality based on both total and feacal colifom counts.

Factors influencing microbiological quality of ground water include distance from pollution sources and construction and protection of underground water sources. Human and animal feaces are the common sources of microbiological contamination of underground water sources. To examination the effect of sanitary facilities on contamination levels the depth of boreholes and wells and the distances from Sewage system (septic tanks) and toilets were established for the water sources in each municipality. The majority of the wells and boreholes were within < 10m and between 10m to 20m from toilets and septic tanks. According to the guidelines for drinking water by WHO (1971), underground water sources (borehole and well) are supposed to be located at least 30m away from latrine and 17m from septic tanks. This reduces the chances of contamination especially from domestic pollution. The present findings suggest that toilets and septic tanks are the possible sources of microbiological contamination of these ground water sources in the city. This is supported by the lowest microbial counts recorded in Ilala municipality (Table 2) which had most of its underground water sources furthest from the septic tanks and toilets compared to other municipalities (Tables 1 and 3). In their study on borehole mirobiological quality (Potgieter et al., 2006) also found that the distance between sanitary facilities and borehole water were in most cases closer to each other. They linked the recorded high contamination with human feaces which gain access into the ground water during leaching process. They also linked the presence of water sources to sanitary facility with lack of knowledge by the community members on the principles of water protection. Adetunde and Glover (2010) reported the mean value of total viable bacterial counts of the samples to range from 1.50x104 to 5.90 x 104 cfu/mL and for total coliform bacteria from 0 to 17 MPN/100 mL and 0 to 4.07 MPN/100 mL. The highest counts were consistently found in the sample Borehole water where the borehole was located in an unsanitary environment near septic tank.

According to Mato (2002), urban residential areas without or with incomplete coverage by sewerage, seepage from on-site sanitation systems such as pit latrines and septic tanks, probably present the most widespread and serious diffuse pollution sources. The immediate concern is a risk of direct migration of pathogenic microbes to underlying aquifers and neighbouring groundwater sources. He also identified pollution arising from the indiscriminate disposal of solid wastes as another potential for of groundwater.

The presence of faecal coliforms generally indicates poor environmental sanitation (Taulo et al., 2008). On site observation of the boreholes and well showed that a good number of these sources are not protected and lack concrete floor around the dug well. This reflects poor environmental sanitation of the same and hence higher contamination rate. The use of buckets which have been left on ground in collecting water from the unprotected water sources might have increased the contamination levels. Attachment of micro-organisms on the surface walls of such materials and eventual contamination of the water is likely to have occurred (Taulo et al., 2008)

While a link was observed between contamination levels and distances from pit latrines / toilets and septic tanks, no link was established the age of water sources and microbial contamination implying that proper management of water sources has a greater positive impact on water microbial quality than the age itself.

CONCLUSION

The bacteriological quality of underground water sources for Dar es Salaam city residents generally shows poor quality as reflected by the overall mean values for both total and faecal coliforms. The overall mean values for total coliform and feacal coliform for Temeke, Ilala and Kinondoni were 424 and 379cfu/100 ml, 5 and 8 cfu/100ml and 175 and 113 cfu/100 ml respectively which are higher than WHO recommended levels of zero MPN index/100ml (WHO, 1993).

The findings also suggest that toilets and septic tanks, lack of protection of water sources and poor unhygienic practices (such as keeping the water collection equipment on ground) are the possible sources of microbiological contamination of the underground water sources. The majority of the wells and boreholes are within 10 to 20m from toilets and septic tanks. According to the WHO (1971) guidelines for drinking water, underground water sources (borehole and well) are supposed to be located at least 30m away from latrine and 17m from septic tanks. Contamination can also be attributed to poor management of the water sources such as lack of protection and concrete floors around them.

While the age of the water source could have a negative impact on the water quality however proper management of the water sources overrides the age effects. To ensure water quality from underground sources the focus should thus be placed on legal requirements on exploiting the same sources, public health training, awareness creation among the public on the possible sources of contamination, improve residential infrastructure and adhere to the recommended distances of septic tanks and toilets from the water sources and also the general hygienic practices. This should take into account the obligation of owners of underground water supplies to test water regularly for quality, use appropriate treatment (e.g. filtration and disinfection) and monitor and maintain the water sources.

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