# Water Quality in Selected Shallow Wells in Dar es Salaam

***Saria, J. A.***
Email: joseph.saria@out.ac.tz
***and Thomas, I. M.***
isabela.thomas@out.ac.tz
Faculty of Science, Technology and Environmental Studies
The Open University of Tanzania,

***Abstract:*** *Majority of Dar es Salaam residents depend mostly on ground water for their domestic use because, they are not connected to the city water supply system, or the supply system is not reliable. Due to widespread use of groundwater (shallow and deep wells), the scientific determination of quality of this mass consumed product is essential. In this study the water quality parameters: physical, chemical and biological contaminants on the shallow wells were investigated around Dar es Salaam City.*

*Except for Total Dissolved Solids (TDS) and Total Hardness, other physical parameters tested were within the WHO acceptable range. Levels of phosphate in samples from Temeke district ranges from 0.42 – 1.20 ppm, while samples from Ilala ranges from 0.16 – 0.36. Meanwhile chloride levels in samples from Temeke ranges between 158.40 – 624.14 ppm and Ilala ranges between 142.34 – 359.52 ppm. This could be due to human activities such as small industries and unplanned waste dumping sites close to water source.*

*All water samples were contaminated with both Total Coliform (TC) and Fecal Coliform (FC). The highest TC and FC levels were detected in the sample from Vikunai Village in Temeke municipality (2160/100ml and 67/100ml respectively). This was due to proximity of pit latrines and runoff during rainfall because shallow wells are neither covered nor built up above ground level to create barriers against storm water inflow.*

*Generally, water from shallow wells in Dar es Salaam City is bacteriologically and chemically contaminated. The source of contamination is on-site waste disposal and poor hygiene education. It is recommended that water from wells must be treated prior to consumption in order to prevent potential infections. Residents ought to be provided with water quality management education so that they could know how to treat, store and maintain the quality of drinking water.*

**Key words**: shallow well, phosphate, water quality, nitrate, faecal coliform, chloride.

## INTRODUCTION

Dar es Salaam city has grown from a town of about 50,000 inhabitants in the early 1950s to a city of over four million to date. Until the late 1970s, the city's water supply services more or less kept pace with the rate of population growth of about 4.3%. But thereafter, availability and quality of water began to deteriorate (Nielsen, *et al.,* (1992).

The City obtains its tap water supply from three intakes, namely: Upper Ruvu, Lower Ruvu and Mtoni which get water from Ruvu River and Kizinga River. Much of these infrastructure in the city was established during colonial years, more than 30 years ago, and is located in the city's more affluent areas (Bourque, 2010). Total water production for the city comes to around 300,000 $m^3$/day (Mbwette, 2010) although approximately half of this is lost through leakages. At the same time, demand (including industrial consumption) is more than 450,000 (Ngana and Cress, 2010; UNDP, 2011).

Through the Ministry of Water and Irrigation together with DAWASA, the City has implemented several programmes (URT, 2006) to solve the water supply problem - however, the problem persists. Mbwette (2010), estimated that only 50 – 60% of Coast residents (Dar es Salaam, Kibaha and Bagamoyo) have access to tap water supply due to poor maintenance or simply overloading. Poor operational and maintenance lead to 20% of the installed rural supply schemes not functioning and Dar es Salaam is not exceptional (Mbwette, 2010).

In rapidly developing cities like Dar es Salaam, most of the people use boreholes or shallow wells as sources of water in their daily lives as the authority cannot supply sufficient fresh water through a piped system. However, due to most of the waste water not being disposed off in an adequate manner, groundwater is being polluted which leads to the outbreak of water borne diseases (Bossman, 2011).

The safety of water from shallow wells is questionable. Thomas, (2011) found out that groundwater (deep and shallow wells) quality at Ukonga Dar es Salaam, have been contaminated with bacteria, chloride, nitrate and fluoride. These sources may be contaminated due to infiltration of sewage from pit latrines or septic tanks and/or wash-down of contaminated soil by surface run off. Another source of contamination can be the soil because it can consists of a mixture of weathered minerals and varying amounts of organic matter (Saria, 2011a). Also, soils can be contaminated as a result of spills or direct contact with contaminated waste streams such as airborne emissions, process solid wastes, sludges, or leachate from waste materials. The solubility of metals in soil is influenced by the chemistry of the soil and groundwater (Evans, 1989). Lifting device can push down soils and rubbish during water collection and spilled water running back into the sources again leads to pollution. The use of contaminated drinking water constitutes a serious health risk and can result in outbreaks of water borne diseases like dysentery, cholera and typhoid (Madavine, 2008).

This study was carried out in Temeke and Ilala districts in Dar es Salaam city. As is the case with most rural communities in the country, the research area residents mainly use shallow wells as a source of domestic water and other purposes as well as pit latrines for sanitation. The geological setup and soil type in the study area, compounded by the generally high water table, are thought to have caused several pit latrine failures such as cracking and sinking especially during rainy season.

The study assessed levels of TC, FC, physical parameters (pH, Conductivity, TDS, turbidity and hardness), chemical parameters ($PO_4^{3-}$, $NO_3$-N, $Cl^-$ and $SO_4^{2-}$). The parameters were chosen because a wide range of studies internationally have demonstrated that they are problematic with regards to on-site sanitation. Some of the parameters also tend to have an effect on the apparent water quality and health.

## AIM OF THE STUDY

Most of research work undertaken on surface water quality in Tanzania and developing countries at large has focused on tap and borehole water with barely work being undertaken on shallow wells. Shallow wells are one of the most important types of water supplies for domestic purposes for rural districts in Tanzania. This research work was undertaken to develop a data-base on water quality from shallow wells. This type of water supply system was referred as Owned Private Wells (PS1) category, having significance impact to water supply to Dar es Salaam residences, but still they are the most problematic to Urban Water and Sewage Authority (UWSA) to operate (Mbwette, 2010). There is a need to determine the quality of this category so as to concertize the user and government at large on the risk which may be posed by using water for domestic purposes from this source (Mbwette, 2010).

## METHODOLOGY

### Description of Study Area

Dar es Salaam City is located in the eastern part of Tanzania mainland, between latitudes $6^o$.36'S and $07^o00$S and longitudes $39.00^o$E and $33^o$.33'E, on the east it borders with the Indian Ocean. Figure 1 shows the location of Dar es Salaam city on a map of Tanzania and its three municipalities Ilala, Kinondoni and Temeke.

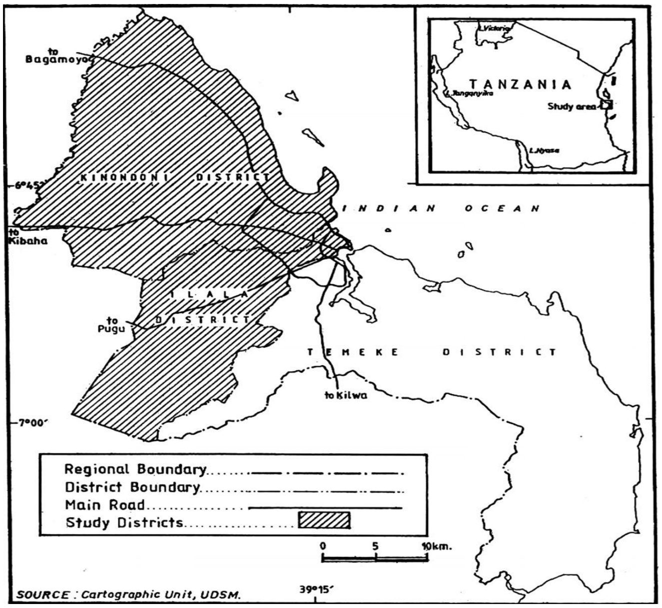


**Figure 1: Location of Dar es Salaam City with its Municipalities**

## Sampling Method

In order to assess the quality of the well-water in the study area, five samples each from six sampling points (labeled as P1 – P6) were collected each week during the dry season from 21st February to 19th April. Three shallow wells from two Municipalities (Ilala and Temeke) were selected by purposive sampling technique (Table 1)

**Table 1: Field Inventory of the Sampling Points**

| District | Label | Location | Owner | No. Users Per Day | Depth (M) | Distance (M) from Latrine | Lining Material |
|---|---|---|---|---|---|---|---|
| **Ilala** | P1 | Kipawa | Mr Shomari | 7-15 | 3.0 | 5 m | Car tyre |
| | P2 | Segerea | Mr Koba | 50-75 | 5.0 | >10 m | Cement |
| | P3 | Majumba Sita | Mr Adams | 40 - 60 | 5.0 | > 10m | cement |
| **Temeke** | P4 | Kigamboni | Mwongozo Village | 15 - 20 | 1.5 | > 10 m | none |
| | P5 | Tuangoma | Vikunai Village | 10 - 25 | 3.0 | 4 m | Cement |
| | P6 | Mtoni | Stephen Mosha | 20 - 30 | 2.5 | < 6 | Bricks |
| **Kinondoni** | W1 | Makongo | Mama Lina | 1-10 | 1.5 | nd | Bricks |
| | W2 | Ubungo | - | 1-10 | 2.0 | nd | Cement |
| | W3 | Msewe | Mr Herman | 10-30 | 8.0 | nd | Cement |

This sampling method was used because of the difficulty of identifying every home using pit latrine and shallow well in the community. Location, average number of users per day, depth, distance from latrine, and lining material were taken into account in the assessment of the water quality. Secondary data from literature (Nielsen, *et al.,* 1992) from Kinondoni Municipality were included and labeled as W1 – W3 for comparison purposes.

**Sample Collection and Storage**

Samples were collected early in the morning before many people use the sources and to enable samples to be submitted to the laboratory the same day. Samples for physical and chemical parameters were collected in cleaned polyethylene bottles. Bacteriological samples were collected in autoclaved ½ L glass bottles transferred to the laboratory in an icebox and processed within 18 – 24 hours and samples were analyzed according to the standard method (AWWS, 2006) by membrane filtration method to give direct count for total and feacal coliforms.

For physical-chemical parameters, water sampling was done according to the WHO guidelines for drinking water quality standards (AWWS, 2006). Physical parameters (pH, conductivity and TDS) were measured on-site using the Perkin-Elmer (1983) standard procedure. Ionic compounds ($NO_3$-N, $SO_4^{2-}$ and $Cl^-$) were determined at the Ardhi University Laboratory using a Spectrophotometer as indicated in the literature (Basset, *et al.*, 1979). Phosphate ($PO_4^{3-}$) was determined as described in literature (Bassett, 1979) by the molybdenum blue phosphorous method in conjugation with UV-Visible Spectrophotometer.

## RESULTS AND DISCUSSION

### Physical Parameters

Table 2 indicates summary of results of five physical parameters; pH, electric conductivity (EC), total dissolved solids (TDS) and water hardness analysed from each source from Ilala and Temeke.

**Table 2: Average Values for Physical Parameters (N = 5)**

| District | Lables | pH | EC µS/cm | TDS (mg/l) | Turbidity (NTU) | Hardness mg/L - $CaCO_3$ |
|---|---|---|---|---|---|---|
| **Ilala** | P1 | 7.39 | 1872.00 | 960.50 | 5.51 | 464.75 |
| | P2 | 6.84 | 919.10 | 494.50 | 4.45 | 260.50 |
| | P3 | 6.78 | 1205.21 | 581.00 | 2.03 | 269.50 |
| **Temeke** | P4 | 7.01 | 987.63 | 728.02 | 3.27 | 321.00 |
| | P5 | 6.72 | 826.50 | 329.21 | 4.63 | 586.55 |
| | P6 | 6.54 | 972.14 | 442.34 | 4.76 | 152.36 |
| **Kinondoni*** | $W_1$ | 7.6 – 8.1 | 550 - 850 | n.d. | 4 - 34 | n.d. |
| | $W_2$ | 7.0 – 7.3 | 630 - 710 | n.d. | 4 - 11 | n.d. |
| | $W_3$ | 6.8 – 7.4 | 650 - 1080 | n.d. | 8 - 20 | n.d. |
| **WHO** | | **6.5 – 8.0** | **2500** | **600.00** | **5.00** | **500.00** |
| **TZS** | | **6.5 – 9.5** | **3000** | | **5-25** | **600** |

*Nielsen, *et al.*, (1992)

According to WHO guideline, the acceptable level of drinking water for pH is 6.5 – 8.0 (WHO, 2006). Ahmed *et al.,* (2000) indicated that, water with pH < 6.5 is acidic, soft, and corrosive. Therefore, the water could leach metal ions such as: iron, manganese, copper, lead, and zinc from the aquifer, plumbing fittings, and piping. Therefore, water with a low pH could include levels of toxic metals (Saria *et al.*, 2011b) and have associated quality problems such as a metallic or sour taste. Water with a pH > 8.5 indicates that the water is relatively hard. Hard water does not pose a health problem to consumers, but can cause quality problems. These problems include: Formation of a "scales" or precipitates in piping and fittings causing water blockage and interior diameter of piping to decrease. Also this type of water has an alkali taste. Formation of a scale or deposit on dishes, utensils, and laundry basins is also common (Nordstrom, 2000). In the samples analysed, mean *p*H value of water samples varied from 6.54 at sampling point P6 in Temeke to 7.39 in Ilala at sampling point P1. All these *p*H values analysed are within the range of both WHO and TZS (Mbwette, 2010).

Electric conductivity (EC) is an indication of the Total Dissolved Solids (TDS) and inorganic elements dissolved in the water. The parameters have no health based guideline, WHO guideline value of 2500 µS/cm and 600 mg/l for EC and TDS respectively are based on taste rather than health (Thomas, 2011). Two sampling points P1 and P4 were found to have high TDS values recorded as 960.50 mg/l and 728.02mg/l both of which exceed the WHO recommended limit of 600 mg/l for drinking water. This can be due to the inflow of sewage, urban runoffs or ground water seepage particularly during the rainy season.

Turbidity in water is apparent, the reduction of transparency due to the presence of particulate matter such as clay or silt, finely divided organic matter, plankton or other microscopic organisms. High turbidity may affect the effective disinfection of water by adsorptive characteristics of some colloids and because the solids may partly shield organisms from the disinfectant (WHO, 2006). Turbidity does not have a health based guideline, but it is recommended that it should ideally be below 0.1 NTU for effective disinfection and below 5 NTU for acceptability . The values of turbidity from analysed samples range from 2.03 NTU to 5.51 NTU. Regarding disinfection efficiency, all analysed samples showed amounts greater than recommended value of 0.1 NTU.

Several studies have reported on a possible association between water hardness or minerals contributing to water hardness and mortality related to ischemic heart disease (IHD) or stroke (Leurs, *et al.*, 2010; Miyake & Iki, 2003; Eisenberg, 1992; Anderson & Hewit, 1975). In contrast, soft water, with hardness less than 100 mg-$CaCO_3$/l, has a greater tendency to cause nuisance due to the mineral build up on plumbing fixtures (WHO, 2006). When calcium or magnesium is up to 1000 mg/l it can be tolerated without a salty taste to the water.

Total hardness of analysed samples ranged from 152 mg/l to 464.75 mg/l in both districts. According to Tanzania Water quality standards lower limit 500mg/l and upper limit 600mg/l (Mbwette, 2010: 69) and WHO guideline (<500 mg/l). All samples were within the acceptable range.

**Chemical Parameters**

Four chemical parameters; phosphate ($PO_4^{3-}$), Nitrate as nitrogen ($NO_3$-N), chloride ($Cl^-$) and sulphate ($SO_4^{2-}$) were analysed from each source and detailed results are shown in Table 3 from shallow wells in two districts of Ilala and Temeke.

**Table 3: Average Levels for Chemical Parameters (Units in mg/l) (N = 5)**

| District | Labels | $PO_4^{3-}$ | $NO_3$-N | $Cl^-$ | $SO_4^{2-}$ |
|---|---|---|---|---|---|
| **Ilala** | P1 | 0.36 | 6.96 | 245.21 | 55.24 |
| | P2 | 0.16 | 1.85 | 142.34 | 96.27 |
| | P3 | 0.22 | 2.13 | 359.52 | 232.16 |
| **Temeke** | P4 | 0.42 | 4.12 | 589.82 | 27.44 |
| | P5 | 1.20 | 5.14 | 624.14 | 65.16 |
| | P6 | 1.02 | 3.34 | 158.40 | 53.11 |
| **WHO** | | NA | 10.0 | 600.00 | 200.00 |
| **TZS** | | - | 10-75 | 200-800 | 200-600 |

Phosphate ranged from 0.16 mg/l to 1.2 mg/l in both Municipalities. There was a slightly elevated level in phosphate on Temeke compared to Ilala samples. Urban farming in Dar es Salaam city is a common practice, with vegetable production in home-gardens and open spaces as the main agricultural activity (Howorth *et al.*, 2001). Most of Dar es Salaam farmers as other Tanzanian farmers use organophosphates insecticides including malathion, diarithion and parathion (Ngowi *et al.,* 2007). These chemicals may get washed by rain water and reach shallow well water through agricultural run off. Detergents are important contributor of phosphate in water samples. Most of used detergents containing phosphates are flushed into the sewer systems or open space from bathrooms kitchens, laundry's, factories, and other industrial establishments and hence to the well water. WHO has no guideline set for phosphate but Tanzania has set it as 50 mg/l.

Nitrates occur in water as the end product in the biological breakdown of organic nitrogen, being produced through the oxidation of ammonia. Although not particularly toxic to adults, WHO set guidelines for nitrate nitrogen ($NO_3^-$-N) to be 10.0 mg/l for safety of drinking water. Nitrate levels at or above this level have been known to cause a potentially fatal blood disorder in infants under six months of age called maethemoglobinemia or "blue-baby" syndrome (Lamond *et al.*,1989). In our samples, levels ranged from 1.83 to 6.96 ppm, which was lower than the WHO permissible value.

Chloride was one of the major anions to be found in water and sewage. Chloride existence in large amounts may be due to natural processes such as the passage of water through natural salt formations in the earth or it may be an indication of pollution from sea water incursion, industrial or domestic waste operations. The range of chloride in samples analysed ranged from 142.34 – 624.14 ppm. Highest levels were detected at Temeke Municipality. Evidence of a general increase in chloride concentrations in groundwater and drinking-water has been found elsewhere (Brooker and Johnson, 1984).

**Microbiological Parameters**

There is a widespread perception that pit latrines should not be used in areas where groundwater is used for domestic water consumption or else they should be properly heated. In Dar es Salaam city, the use of groundwater is inevitable due to water scarcity in almost all areas. Table 4, shows the average bacterial data detected in selected wells in study area.

**Table 4: Average Bacteriological Parameters for Selected Wells**

| District | Lable | T.C cfu/100ml | F.C cfu/100ml |
|---|---|---|---|
| **Ilala** | P1 | 213 | 59 |
| | P2 | 161 | 15 |
| **Temeke** | P4 | 850 | 42 |
| | P5 | 2160 | 67 |
| **Kinondoni*** | W1 | 7,900 | 3,200 |
| | W2 | 8,800 | 660 |

* Nielsen, *et al.*, (1992)

The specification of horizontal distance of 30 m between the pit and a water source is recommended to limit exposure to chemical and biological contamination (Still and Nash, 2002). In densely populated areas with many pit latrines, the risk of groundwater contamination remains however extremely high especially when the latrines are sited physically higher than the water point (Sugden, 2006).

The water sources in Temeke tested with high count of total coliform compared to Ilala. Up to 2160 cfu/100ml TC and 67 cfu/100ml FC was detected in Vikunai village (P5) at Tuangoma, Temeke Municipality, while WHO standard set it to zero count. Observations like number of users, distance from pit latrine, depth and cover were carried out on the sampling point by observation and unstructured interview. The distance of sample P5 is only 4 meters from latrine which indicates that contamination could be caused by polluted groundwater. The groundwater table in that area was rather high, only few meters below the surface, so transportation of bacteria from latrine to the groundwater and then to the well was possible.

For other samples P2 and P4, though they were more than 10 meters from latrine, the contamination may be due to poor protection. While P4 was not protected, P1 was half covered so that soil and rubbish could be pushed down or poured by surface run-off into the well.

Nielsen *et al.*, (1992), in a similar study (Sinza and Msewe) showed that the contamination was due to groundwater polluted from a pit latrine due to distance from wells being less than 8 meters. In order to determine the source of FC in water, whether from human or animal they determine the ratio of FC/FS (Faecal Streptococcus). The higher the ratio, the higher the risk of human-faeces contamination (Ingraham *et al.*, 1987). The mean FC/FS for Msewe sample was 0.59, while that of Sinza was 1.07; hence water from Sinza was likely to be more contaminated with human faeces hence the risk of water born diseases.

**CONCLUSION**

Water supply and sanitation in Tanzania is characterized by:

- decreasing access to improved water sources in the 2000s (especially in urban areas),
- steady access to some form of sanitation (around 93% since the 1990s),
- irregular water supply and generally low quality of service.

In the current study, results showed significantly elevated levels of turbidity, nitrates, TC and FC bacteria in shallow wells which are the alternative source of domestic water used by Dar es Salaam residents where tap water is not sufficient. Majority of physical chemical parameters are within the acceptable limits by WHO standard.

High levels of TC detected was 2160 cfu/100ml and 75 cfu/100ml FC, which is due to combination of transportation of bacteria from latrine to the groundwater to the well due to proximity as well as other factors like cover on well and number of users. The high FC/FS ratio, shows that well waters are contaminated with human faeces hence pose risks of water born diseases.

Some shallow wells in the study were located less than 30 m from pit latrines and waste dumps. There is a need for the local government to enforce standard construction procedures in order to minimize pollution of water sources. Unsewered sanitation can cause groundwater contamination by chlorides, nitrates and pathogenic microorganisms.

To improve the quality of shallow wells water in Dar es Salaam city, rehabilitation covers as a better protection and/or pot chlorination is recommended. It is also recommends that the mass education on water quality should be provided and treatment of water at the household level should be well practiced. Authors are recommending that there is a vital need to develop sustainable cost effective technologies to treat groundwater for rural communities.

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