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The Quality of Groundwater from Wells in Squatter and Non-Squatter Settlements in Dar es Salaam City, Tanzania

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Abstract - **An assessment of groundwater quality from shallow wells and boreholes was carried out in selected squatter and non squatter settlements within Dar es Salaam. Water samples from thirty shallow wells and twenty two boreholes, both randomly selected, were analysed for biological (total and faecal coliforms), chemical (Cl^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, pH and electrical conductivity) and physical (total dissolved solids, colour and turbidity) parameters using standard methods. Sampling was carried out during both dry (July to October) and wet (March to June) seasons. Results indicate that water from shallow wells is heavily polluted by both total and faecal coliforms, the pollution load increasing during rainy season. On the other hand, whereas chemicals in water sampled from most boreholes are within the guidelines set by World Health Organization (WHO) and Tanzania Bureau of Standards (TBS) for drinking water, levels of various chemicals in the water sampled from shallow wells were relatively high. The contamination is associated with haphazard disposal of domestic and industrial wastes as well as geological features. This implies that the water could be hazardous if taken raw and in large quantities.**

Key Words: total and faecal coliforms, boreholes, shallow wells, squatter and non squatter settlements

I. INTRODUCTION

Water is the essence of life and safe drinking water is a basic human right essential to all. Waterborne diseases as a result of consumption of contaminated water and poor hygiene practices are the leading cause of deaths among children worldwide, after respiratory diseases [1]. Indeed consumption of contaminated water has resulted in thousands of deaths every day, mostly in children under five years in the developing countries [2]. For water to be safe it must be free fromvisible suspended matter, colour, taste, odour, objectionable dissolved matter, and pathogens indicative of pollution [3].

In most developing countries the growth of urban populations is far from being matched by sound water supply and sewerage infrastructure. It has been reported that in the developing world, the urban population that is connected to sewerage facilities is only 40%, a situation that has caused environmental pollution to shallow aquifers, rivers, lakes and terrestrial environment [4]. The situation in Tanzania is not very different. It is estimated that about 40% of Dar es Salaam city dwellers are not supplied with potable water [5].Currently, the population of Dar es Salaam stands at 4.4 million with annual growth rate of 5.6% [6].

Given the high population growth, pressure on the existing water supply and sewerage infrastructure in Dar es Salaam city is ever increasing. In the face of this shortage many peoplehave resorted to other sources of drinking water. The sources include surface, ground and bottled water. Whereas the last category is unaffordable to many, groundwater has become the source of choice to the majority of the population, especially those living in squatter settlements.

In principle groundwater is thought to be least polluted relative to surface water. However, groundwater is prone to contamination from both domestic and industrial wastes due to runoff and seepage. In Dar es Salaam city the sources of groundwater include shallow wells, pit wells and boreholes [7]. Whereas shallow wells are water holes not more than 18 feet deep with concrete rings sunk into them, pit wells are hand dug and are much shallower in depth. On the other hand, boreholes are normally more than 18 feet deep and their construction is somehow mechanized.

Some studies that have been conducted to assess the quality of groundwater in Dar es Salaam city revealed that in some areas the water is contaminated by biological and/or chemical contaminants[7-9]. The problem tends to increase as the population density increases. However, these studies were limited to a few places and did not show the effect of seasonal variation across the year on the water quality status. This study therefore is aimed at establishing the quality status of groundwater in shallow wells and boreholes in selected squatter and non-squatter settlements in Dar es Salaam city, Tanzania in both dry and wet seasons.

II. METHODOLOGY

The study was conducted in selected squatter and non-squatter settlements in Dar es Salaam City (Fig. 1) during both dry (July to October) and wet (March to June) seasons. A total of 30 boreholes and 22 shallow wells were sampled. The choice of the squatter areas within the city was based on the characteristics described by Hunter [10], whereas specific locations at chosen squatter areas were selected based on the availability of the boreholes or shallow wells as well as the frequency of their use. The squatter areas included Manzese, Tandale, and Buguruni whereas the non-squatter settlements were Magomeni, Tabata and Temeke areas, all within Dar es Salaam city, Tanzania (Fig. 1).

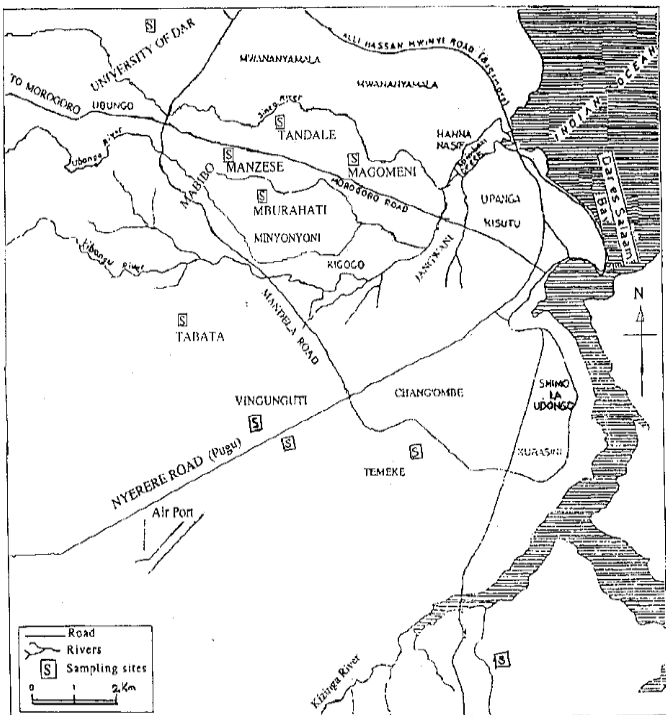

Fig. 1.The map of Dar es Salaam city showing sampling areas.

One litre of each of the water samples from the boreholes or shallow wells was taken to give a composite sample. Plastic bottles that were used for collection and storage had previously been washed and rinsed with 5% nitric acid and then thoroughly washed with distilled water. The samples were preserved at 4^{o}C pending analysis.

Non conservable parameters such as pH, temperature, and electrical conductivity were determined at the time of sampling. The pH of water samples was measured with a pH meter previously calibrated with buffer solutions. Conductivity was measured with a conductivity meter calibrated with potassium chloride solution. Total dissolved solids (TDS) were determined by a TDS-meter, and colour was determined by a Hach kit colour meter calibrated using distilled water. Turbidity was determined as Formazin Attenuation Unit (FAU) using a Hach kit. Anions namely, Cl^-, SO_4^{2-}, NO_3^-, and PO_4^{3-}as well as bacterial contamination(as total and faecal coliforms)were analysed using standard methods [11]. All determinations were done in triplicate and recorded as mean values.

III. RESULTS AND DISCUSSION

A number of physicochemical parameters were analysed in order to assess the extent of pollution of the water drawn from shallow wells and boreholes in squatter and non-squatter settlements during both dry (July to October) and wet (March to June) seasons. Parameters investigated included pH, conductivity, TDS, turbidity, colour and levels of chemical pollutants including SO_4^{2-}, Cl^-, NO_3^- and PO_4^{3-}. These are some of the important parameters that could give an indication of the chemical status of water. The results obtained were compared to standard limits as provided by the World Health Organization (WHO) [12] and the Tanzania Bureau of Standards (TBS) [13]. Biological contamination was also assessed as total coliform(TC) and faecal coliform(FC) counts. Coliform organisms have long been recognized as a suitable microbial indicator for drinking-water quality, largely because they are easy to detect and enumerate in water. The results obtained for the physicochemical and biological water quality in both dry and wet seasons are given in Tables 1 and 2 for the shallow wells and boreholes, respectively.

Generally, the results obtained showed various levels of chemical pollutants in the boreholes and shallow wells. In some areas the levels were outside the ranges recommended by WHO or/and TBS. In Table 1 it is shown that the pH ranges for water samples obtained from various locations during the dry season are as follows: shallow wells in squatter areas (4.5 – 7.7), shallow wells in non-squatter areas (4.9 – 7.4), boreholes in squatter areas (4.6 – 7.7) and borehole in non- squatter areas (5.7 – 8.1). As seen, some pH values are lower than those recommended by WHO, *i.e*., pH range of 6.5 – 9.5 [12]. Lower pH values indicate that the water is slightly acidic and hence could be corrosive to metal piping as well as enhancement of mineral dissolution from the soil. The data on pH values does not show an influence of seasonal variations nor type of settlement.

In the case of TDS, 60% of the samples collected from boreholes in squatter areas during the dry season had values higher than those recommended by WHO. Only 15% of the samples collected from non-squatter areas in the dry season had values above the recommended ones. Generally, there was about 1.5-fold increase in the TDS values during the rainy season in both squatter and non-squatter areas. In the case of shallow wells more than 80% of the samples were within the WHO limit. However, the values also increased by about 1.5 times during the wet season. Overall the TDS mean values found in water samples from boreholes were consistently higher than those of water from shallow wells. The high TDS and conductivity values in borehole water are due to dissolution of minerals from the soil, wastes and probable marine intrusion. Groundwater from the recent sediments in the coastal plain is vulnerable to marine intrusion, particularly where groundwater-pumping rates are high. Evidence of marine intrusion has been found in the coastal aquifer of the Kigamboni Peninsula (Dar es Salaam) with elevated Cl^-, SO_4^{2-} and Na^+ concentrations with TDS values up to 1700 mg/l [14].

Colour values were also investigated and comparisons made between values found in shallow wells and boreholes in both dry and wet seasons. Most water samples from boreholes had colour values within the maximum permissible level by WHO/TBS (50 Pt/Co units), regardless of whether the borehole is located in squatter or non-squatter settlement. However, in both dry and wet seasons over 45% of water samples from shallow wells had higher colour values than those permitted by WHO/TBS. The reason for having high colour values in shallow wells is due to contamination from organic debris that is deposited into improperly covered wells. As a result tannins, humic acid and humates impart yellowish brown colour into the water. Domestic organic wastes have also being identified as a source of colour in shallow wells. In the case of boreholes, some had high colour values due to poor construction such that water tends to be mixed with clay soil during pumping.

The mean turbidity values in shallow wells at both squatter and non squatter areas were about 8-fold higher than the maximum allowable WHO limit of 5 FAU, regardless of the season. This is explained by the way the wells are poorly constructed without any sanitary covers. In the case of boreholes, however, the situation is much better. In non squatter areas, almost all samples had turbidity values within the WHO permissible range in both seasons. However, in squatter areas, about 30% of the samples had values that were higher than the WHO permissible limit.

Tables 1 and 2 also show the ranges of values for Cl^-, SO_4^{2-}, PO_3^{3-} and NO_3^-. Most values for Cl^- in water samples drawn from shallow wells are lower than those from boreholes, regardless of the season and location. In all cases the mean Cl^- concentrations were within acceptable limits by WHO/TBS except for borehole water drawn from squatter settlements which has a mean Cl^-concentration of 724±43 mg/L during the dry season and 656±32 mg/L in the wet season. Generally, the levels were moderate. However, for the areas with concentrations beyond the WHO/TBS (i.e. above 600 ppm) limits, this can be attributed to marine intrusion as explained earlier. NO_3^- levels were within WHO/TBS permissible levels although the levels were generally higher in shallow wells than in boreholes, seasonal variation notwithstanding. The relatively high level of NO_3^- in shallow wells is probably due to pollution from domestic waste as well as surface decomposing organic matter. It should be noted that the shallow wells are located very close to human settlements where sewerage systems are poor or lacking. In addition there is haphazard dumping of domestic waste. Other inorganic chemicals, namely, SO_4^{2-} and PO_3^{3-}, were all within the acceptable levels in both seasons at squatter and non squatter areas. However, in each case levels are higher in shallow wells than in boreholes. In addition, the mean values were always high in squatter settlements than in planned areas.

Total and faecal coliform counts are also given in Table 1 and Table 2 for water from shallow wells and boreholes, respectively. The results indicate that water from the shallow wells from both squatter and non squatter areas is grossly polluted with TC and FC (Table 1). The pollution load increased during the wet season as observed also elsewhere [15]. No single shallow well was found to be free from bacteriological contamination. The high biological contamination is not accidental given the poor sanitation of the surrounding environment as explained earlier. In the case of boreholes, the situation is a bit better. About 70% of samples from boreholes in squatter and non-squatter areas had no bacteriological infection during the dry season. However, the contamination level increased by 20% during the wet season. The results also show that biological pollution in squatter areas is slightly higher than in non-squatter areas.

Generally, the sources of groundwater contamination in the wells and boreholes are associated with the pollution levels in the neighborhood [16, 17]. Most wells and boreholes are placed very close to human settlements. These settlements lack important facilities for wastewater and solid waste disposal. Pit latrines and improperly constructed or maintained septic tanks were often found in the neighborhood. Their discharges do interfere with the underground aquifers thus leading to pollution of water sources. It should be noted that human excreta, livestock and poultry wastes do increase the amount of inorganic species such as Cl^-, NO_3^- and PO_3^{3-} in the environment. In addition, it was observed that domestic wastes are damped haphazardly especially in squatter areas, thus increasing the environmental pollution load. Shallow wells also encounter similar situation although this suffers more contamination as compared to boreholes for the reasons explained earlier.

TABLE 1. PHYSICO-CHEMICAL AND BACTERIOLOGICAL PARAMETERS OF WATER SAMPLES FROM SHALLOW WELLS IN DAR ES SALAAM CITY.

Parameter	Range in Dry Season		Range in Wet Season		WHO limit	TBS limit
	Squatter	Non-squatter	Squatter	Non-squatter		
pH	4.5 – 7.7	4.9 – 7.4	5 – 7	4.4 – 7.2	6.5 – 9.5	6.5 – 9.5
Cond. mS/cm	0.18 – 3.2.	0.3 – 1.59	0.2– 3.4	0.5 – 1.69		
TDS mg/L	107 - 1620	160 - 1320	134 - 1720	169 - 1342	1500	2000
Colour Pt/Co	23 – 995	40 - 690	35 – 1123	65 - 760	50	50
Turbidity, FAU	1 - 300	1 - 106	50 - 450	5 - 136		
Cl^- mg/L	14 - 368	24 – 680	67- 567	45 – 789	600	600
SO_4^{2-} mg/L	106 - 389	32 – 126	nd	nd	400	600
NO_3-N mg/L	3.2 - 120	2.8 – 50	5 - 210	3.2– 630	45	100
PO_4^{3-} mg/L	0.1 – 4	0.2 – 2	0.1 – 6	0.2 – 7	4	10
TC, counts/100ml	346 - TNC	66 – TNC	TNC	TNC	0	0
FC counts/100 ml	124 - TNC	23 - TNC	TNC	TNC	0	0

TNC = Too numerous to count.
nd = not determined

TABLE 2. PHYSICO-CHEMICAL AND BACTERIOLOGICAL PARAMETERS OF WATER SAMPLES FROM BOREHOLES IN DAR ES SALAAM CITY

Parameter	Range in Dry Season		Range in Wet Season		WHO limit	TBS limit
	Squatter	Non-squatter	Squatter	Non-squatter		
pH	4.6 – 7.7	5.7 – 8.1	5.0 – 7.5	5.6 – 8.0	6.5 – 9.5	6.5 – 9.5
Cond. mS/cm	0.98 - 6.06	0.13–4.61	0.54 - 5.06	0.16–4.91		
TDS mg/L	490 - 4990	60 – 2380	546-3456	79-3210	1500	2000
Colour Pt/Co	5 – 69	0 – 64	nd	nd	50	50
Turbidity, FAU	0 - 90	0 - 4	0 - 970	0 - 2		
Cl- mg/L	127 – 3404	31 – 1421	87 – 2300	23 – 1478	600	600
SO42- mg/L	76 – 789	11 – 490	76 – 645	141 – 456	400	600
NO3-N mg/L	8.8 – 77	0.3 – 36	5.6– 65	0.5 – 25	43	100
PO43- mg/L	0.09 – 2.4	0.1 – 1.9	0 – 2.8	0.1 – 1.9	4	10
TC, counts/100ml	0 - TNC	0 – 53	10 - TNC	20 – 70	0	0
FC counts/100 ml	0 - 600	0 - 120	0 - TNC	10 - 110	0	0

TNC = Too numerous to count
nd = not determined

IV.IV. CONCLUSION

The supply of potable water of good quality is important for public health. Unfortunately, the supply of piped water in Dar es Salaam City is inadequate necessitating the use of groundwater. An assessment of the quality of the groundwater from shallow wells and boreholes in selected squatter and non-squatter settlements within Dar es Salaam has revealed heavy pollution by both total and faecal coliforms, a pollution that increases during the rainy season. The chemical status was variable from place to place and season to season. Whereas chemicals in most borehole water are within the guidelines set by World Health Organization (WHO) and Tanzania Bureau of Standards (TBS) for drinking water, levels of various chemicals in the water sampled from shallow wells were relatively high. The level of contamination generally increased during the rainy season. The major sources of biological and chemical contamination were found to be haphazard disposal of domestic and industrial wastes, poor sewerage and sanitary systems as well as proximity to the sea. Thus water from most groundwater sources is not safe for drinking without prior treatment.

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