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Assessment of bacteriological quality and physico-chemical parameters of domestic water sources in relation to human health risk in Kigamboni, Tanzania

Joseph A Mwakosya*

Dar es Salaam Institute of Technology, P. O. Box 2958 Dar es Salaam, Tanzania
Department of Science and Laboratory Technology

Keywords

Domestic water; Physico-chemical parameters; Bacteriological quality; Total coliforms; Waterborne diseases

Abstract

Data on bacteriological quality and physico-chemical parameters is crucial for protection and sustainable utilization of water resources. This study determined bacteriological quality and physico-chemical parameters of well and tap water sources in relation to human health risk in Kigamboni, Tanzania. Thirty water samples were collected randomly and analyzed using SPSS software. The mean values for well water samples of pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, Chloride, Sulphate, Nitrate, Phosphate, and Calcium Carbonate were 7.2, 960.27 mg/L, 528.13 mg/L, 1.52 NTU, 288.00 mg/L, 30.13 mg/L, 0.05 mg/L, 0.08 mg/L, and 160.07 mg/L, respectively. The mean values for tap water samples of pH, EC, TDS, turbidity, Chloride, Sulphate, Nitrate, Phosphate, Calcium Carbonate were 7.34, 954.40 mg/L, 522.47 mg/L, 1.71 NTU, 294.40 mg/L, 37.93 mg/L, 1.85 mg/L, 0.07 mg/L, and 127.33 mg/L, respectively. Bacteriological assessment of well water samples showed that 3 (20%) of the samples were contaminated with coliform bacteria, while 2 (13.3%) with *Escherichia coli*, no coliform or *E. coli* was found in any tap water samples. This study indicated that well water samples were of poor quality, which could raise the risk of waterborne diseases for consumers. The study recommends regular water testing and monitoring its quality.

Introduction

Water is an essential resource for domestic, industrial, and agricultural applications (Zhang et al. 2022). Moreover, it plays a critical role in human metabolism and the proper functioning of cells (Uddin et al. 2018). Consequently, the availability and accessibility of clean, fresh water are not only crucial for economic growth and societal welfare but also fundamental to health, food production, and alleviating poverty (UN General Assembly 2010, United Nations 2023). Due to its importance, access to adequate supply of safe drinking water for all is one of the primary goals of the World Health Organization (WHO and UNICEF 2020).

Various studies documented that global water demand is rising as a result of population growth and climate change (Leonard 2022, Musie 2023). This situation resulted in difficulties for the population to obtain safe and high-quality water for drinking and sanitation (Leonard 2022). Dar es Salaam, the capital and largest city of Tanzania, is encountering similar water issues as other developing nations (Leonard 2022). As a result, the city has undertaken several initiatives through the Ministry of Water and Irrigation in partnership with

*Corresponding author: mwakosyajoseph@yahoo.com; joseph.mwakosya@dit.ac.tz
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DAWASA to tackle the water supply, including various water sources such as wells and tap water (Nyangi and Leopord 2023). Nonetheless, numerous studies have reported the potential for low-quality water in the Dar es Salaam region due to various activities occurring in the area (Akhtar et al. 2021). The high expansion of built-up area with rapid emerging of informal settlements and urban slums and use of onsite sanitation has jeopardized water quality in Dar es Salaam (Nyangi and Leopord 2023). However, the region is marked by a high population density and a prevalent use of onsite sanitation systems, primarily pit latrines and septic tanks, along with the improper disposal of solid waste and sewage from industrial, commercial, and residential zones, all of which could adversely affect water quality. Additionally, it has been observed that saline water from the Indian ocean can infiltrate the water table, potentially affecting the groundwater quality in the Dar es Salaam and coastal region (Akhtar et al. 2021). Moreover, factors such as urbanization, urban agriculture, industrial activities, and household waste may indirectly impact the groundwater quality within the city (Akhtar et al. 2021). Despite these possible risks, there is limited information available regarding the assessment of bacteriological quality and physico-chemical properties of domestic water sources in the Dar es Salaam region. Information concerning water quality assessment could be very helpful to policymakers in developing management strategies for controlling and reducing water pollution, identifying problems and formulating measures to minimize deterioration of water quality. Therefore, this study intended to investigate physico-chemical parameters (pH, conductivity, TDS, turbidity, Cl^-, SO_4^{2-} NO_3^-, PO_4^{3-}, and $CaCO_3^{2-}$) along with the bacteriological quality of domestic water sources in the Kigamboni district of the Dar es Salaam region in Tanzania. The selection of bacteriological quality and physicochemical parameters was influenced by multiple studies, including international standards and the 2008 guidelines from Tanzania, which outline their detrimental effects on users. Nevertheless, the selected water quality parameters in this study are significant since they can quickly determine the suitability of water for domestic uses, but also other properties of water.

about their problematic effects to the user

Materials and Methods

The cross-sectional study was conducted in selected sites of Kigamboni municipal council of the Dar es Salaam region (Figure 1). The study site was selected due to the reliance of most residents on wells for their water supply, with only a small number having access to tap water, as the local authority is unable to provide adequate fresh water through a piped system (Bakari et al. 2012).

Collection of water Samples and Preservations

A total of 30 water samples including 15 from well water and 15 from tap water were randomly collected from 30 randomly selected sites and placed in 500 mL sterile glass bottles tied up with a rope as recommended by Pant (2004) and WHO (2008). The total number of samples (15 from well water and 15 from tap water) was adequate to clearly evaluate the bacteriological quality and physical-chemical characteristics of domestic water sources. Napacho and Manyele (2010) indicated that seven samples of tap water are sufficient for a reliable assessment of drinking water quality. Furthermore, Sohana et al. (2018) demonstrated the bacteriological quality and physical-chemical parameters of tap water by utilizing just ten samples. Conversely, Srinianti et al. (2021) examined the bacteriological quality and physical-chemical characteristics of well water, analyzing just 14 water samples. Additionally, Peter et al. (2012) assessed the quality of well water by utilizing only 11 water samples. The process of collecting water samples adhered to the guidelines set by WHO (2017). Water samples were collected from the taps after disinfecting their outer surfaces with 95% ethanol. Then, the tap was turned on for three minutes to flush out any debris before collecting the water. Subsequently, in a sterile setting, 75% of the 500 mL glass bottles volume was filled with water. A sample from a dug well was fetched using a 25-meter-long string and a cup. The cup was carefully lowered into the well without making contact with the sidewalls or bottom. After that, the cup was lifted, and the water was poured into a sample collection bottle. Details about the water samples, such as their collection sites, type, identification number, collector's name, and collection date, were recorded in the field survey data sheet. Two aliquots of samples were collected in each case; the first set was utilized for on-site measurement of field parameters and subsequently discarded, while the second set was promptly placed into an insulated box with cooling elements for preservation and transported to the Dar es Salaam Institute of Technology (DIT) for laboratory analysis on the same day for those collected in the morning. In contrast, samples collected in the evening were stored under refrigeration at standard conditions (at 4 °C) to ensure a stable temperature prior to analysis the following day.

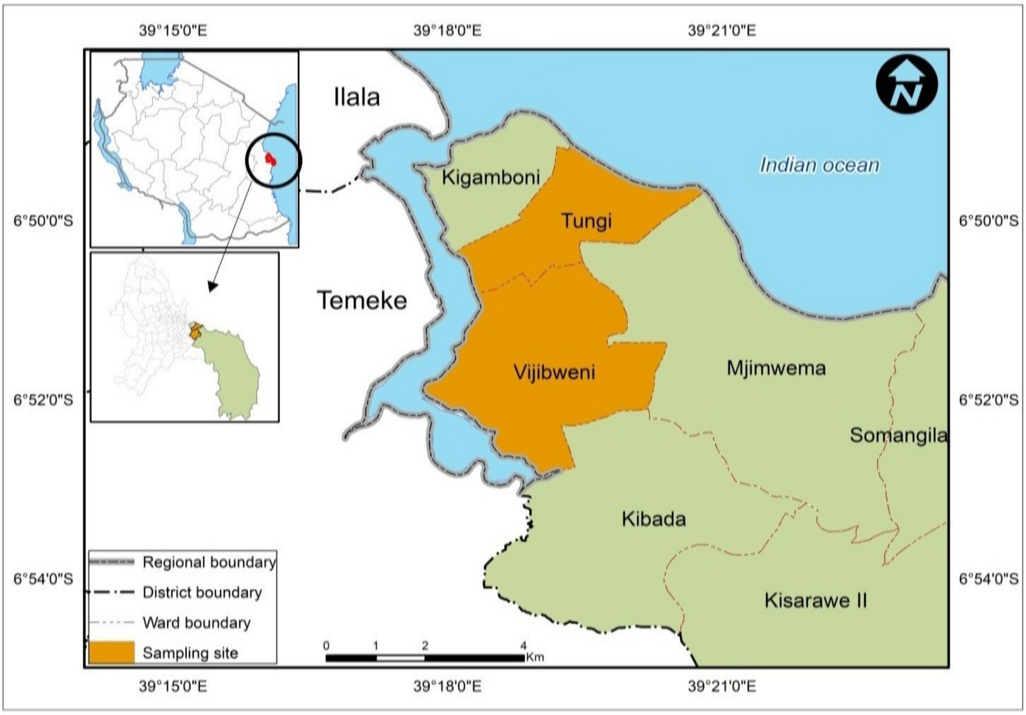

Figure 1: The map of part of Tanzania showing the study sites in Kigamboni district

Determination of Physico-chemical of water samples

The assessment of physico-chemical parameters was carried out using established methods as suggested by various researchers (WHO 2007, Yuncong and Migliaccio 2011). The pH, electrical conductivity (EC), and total dissolved solids (TDS) of the collected water samples were measured using a multiparameter device (LMMP-30) that had been calibrated beforehand with buffer solutions, which included manufacturer-supplied buffers with pH values of 4.0 and 7.0, as well as standard NaCl solutions with known conductivity. Turbidity was measured by turbid meter (Axiom GMbh) after calibrated by manufacturer’s supplied turbidity standards. Meanwhile, the chemical parameters such as Nitrate, Chloride, Phosphate, and Sulphate were analyzed using a Spectrophotometer, as outlined by Basset et al. (1979). All the parameters mentioned earlier were assessed in triplicate, and the average for each parameter was calculated to ensure accuracy in sample testing for every measurement. Subsequently, the averages of each parameter were evaluated against the thresholds established by the WHO (2011) and the Tanzania Standard (TZS 789:2008) regarding drinking water.

Detection and enumeration of bacterium in water

E. coli from well and tap water sources was identified through cultural and biochemical methods as outlined by Olowe et al. (2015). The bacterial count and total coliform were determined using the serial dilution method and pour plate techniques, following the guidelines established by Compaoré et al. (2021). A 100 microlitre sample of water from each source was placed into test tubes containing 5ml of sterilized nutrient broth, and then incubated at 37°C overnight to promote bacterial growth, as suggested by Bachtarzi et al. (2015). To determine the total bacterial count, ten-fold serial dilutions (10^{-1}, 10^{-2} and 10^{-3}) were made for each sample as outlined by Marzan et al. (2017). Subsequently, one hundred microliters of the original sample along with the various dilutions (10^{-1}, 10^{-2} and 10^{-3}) of each sample were placed into separate petri dishes containing EMB and MacConkey Agar media and evenly spread using a glass spreader that had been previously sterilized with 70% alcohol and burned in bunsen burner. Once the petridishes were spread, they were incubated overnight at a temperature of 37°C, and each plate was then examined as recommended by UNICEF (2016). Subsequently, the total coliforms were quantified using the most probable number (MPN) method as suggested by Odonkor and Ampofo (2013). For the complementary test, all tubes showing growth were isolated, and their colonies were then inoculated onto MacConkey and EMB agar plates to verify the presence of coliform bacteria. The identification of bacterial colonies was performed using the macro morphology method, followed by microscopic examination of various bacterial cells (micro morphology). Additionally, an Indole test was conducted to confirm the presence of *E. coli*, as recommended by Alkhiry (2020).

Quality assurance and control

To guarantee the quality of the samples and the validity of the data collected, different quality control and assurance measures were implemented at every stage of the study, including sample collection, laboratory analysis, and data verification. During the sampling process, all sample containers were rinsed with water from the collection site. Samples of well and tap water were collected and stored in appropriate bottles to permit accurate analysis. Samples were carefully handled by ensuring correct labeling of the sample bottles, along with careful packaging and transport to the laboratory. The instruments were recalibrated prior to each use and subsequently assessed with certified reference materials (standard solution). The quality of the bacteriological test was guaranteed by maintaining the specified temperature throughout the incubation period.

Statistical analysis

To guarantee the accuracy of sample testing, each parameter was tested in triplicate and the average of each parameter was computed. The calculated mean values for each parameter were compared with the established permissible limits (standard values) set by WHO and Tanzania for drinking water. Statistical evaluation was conducted using SPSS software version 22 and Microsoft excel programme version 10. A p-value of less than 0.05 was deemed statistically significant. For the analysis of bacteriological quality, the percentage of contaminated water samples from both well and tap water was determined.

Results

The findings from this study indicated that the pH levels of well water samples ranged from 6.2 to 8.8, with a mean of 7.2, whereas the pH levels of tap water samples ranged from 6.5 to 8.2, averaging 7.34

(Tables 1 and 2). The tap water samples exhibited the highest mean pH concentration (Figure 2), and a statistically significant difference ($p < 0.05$) was observed in the average pH values between well and tap water samples. The results showed that the pH level of one well water sample (W15) exceeds the reference limits set by the drinking water guidelines of both WHO and Tanzania, while two other well water samples (W5 and W12) exhibited pH levels below the standards established by TZS (6.5-9.5) and WHO (6.5-8) for drinking water (Table 1). However, all mean values of well and tap water samples fell within stipulated permissible limit of WHO (6.5-8) and Tanzania (6.5-9.5) for drinking water. The electrical conductivity of well water samples varied between 138μS/cm and 3200 μS/cm, averaging at 960.27μS/cm (Table 1). In contrast, the conductivity of tap water samples ranged from 872 μS/cm to 1074 μS/cm, with an average of 954.40 μS/cm (Table 2). The highest mean electrical conductivity was recorded in the well water sample (Figure 3), with significant differences ($p < 0.05$) noted between well water and tap water samples. One well water sample (W15) had an electrical conductivity that exceeded the permissible limits for drinking water set by WHO and Tanzania (Table 1). Nevertheless, all average values were within the acceptable limits established by WHO (2500 mg/L) and Tanzania (3000 mg/L) for drinking water. The total dissolved solids (TDS) in well water samples varied from 69 mg/L to 1620 mg/L, with an average of 528.13 mg/L, whereas tap water samples had TDS values between 436 mg/L and 687 mg/L, averaging 522.47 mg/L (Tables 1 and 2). The mean TDS value in well water was higher compared to that of tap water (Figure 4), and there were significant differences ($p < 0.05$) between the well and tap water samples. The total dissolved solids (TDS) of well water samples namely W1 (626 mg/L), W2 (637 mg/L), W7 (663 mg/L), and W15 (1620 mg/L), were found to be higher than the maximum allowable and recommended limits set by WHO (Table 1). Nonetheless, the average TDS values for both well water and tap water samples fell within the acceptable limits established by WHO (600 mg/L) and Tanzania (1000 mg/L) standards. Additionally, the turbidity values from the analyzed well water samples varied from 0.7 NTU to 3.50 NTU, with an average of 1.52 NTU, while the tap water samples ranged from 0.8 NTU to 3 NTU, averaging 1.71 NTU (Tables 1 and 2). The findings of this study indicated that tap water exhibited greater turbidity compared to well water (Figure 5), and significant differences ($p< 0.005$) were noted between the samples from well and tap water. The mean values analyzed fell within the acceptable limits set by both WHO (5 NTU) and TZS (5-25 NTU) standards. The concentration of chlorine in well water samples varied from 212 mg/L to 315 mg/L, with an average of 288.00 mg/L, while tap water samples had chlorine levels ranging from 254 mg/L to 320 mg/L, averaging 294.40 mg/L (Table 1 and 2). The tap water sample showed the highest average concentration of chlorine (Figure 6), and a highly significant difference ($p < 0.05$) was observed between the average chlorine levels in the tap water and well water samples. The mean chloride concentrations found in both well and tap water samples exceeded the WHO and Tanzania standards for drinking water, which is set at 250 mg/L. The findings indicated that the concentration of Sulphate in well water samples varied from 17 mg/L to 54 mg/L, with an average of 30.13 mg/L, whereas tap water samples had Sulphate concentrations ranging from 24 mg/L to 52 mg/L, averaging 37.93 mg/L (Tables 1 and 2). The mean value for tap water was higher than that of well water samples (Figure 7); however, there was no significant difference ($p > 0.05$) in Sulphate concentration between well and tap water samples. All water sample mean values fell within the acceptable standards for drinking water set by TZS (400 mg/L) and WHO (250 mg/L). Conversely, the nitrate concentrations in well water varied from 0.002 mg/L to 0.15 mg/L, with an average of 0.05 mg/L, while tap water samples ranged from 0.02 mg/L to 3.40 mg/L, with a mean of 1.85 mg/L (Tables 1 and 2). The findings of this study indicated that tap water contained higher levels of nitrate compared to well water (Figure 8), although the differences were not statistically significant ($p > 0.05$). The average concentrations of well and tap water samples were found to be within the accepted limits set by the WHO (<50 mg/L) and Tanzania (45 mg/L). The phosphate levels in well water samples varied from 0.01 mg/L to 0.14 mg/L, with an average of 0.08 mg/L, whereas the tap water samples showed a range from 0.02 mg/L to 0.14 mg/L, averaging 0.07 mg/L (Tables 1 and 2). The current study revealed that the levels of phosphate in well water samples were markedly greater ($p< 0.05$) compared to tap water (Figure 9). The average concentrations for all water samples were within the safe limits for drinking according to WHO (<5 mg/L) and Tanzanian (2.2 mg/L) guidelines. The concentration of Calcium Carbonate (total hardness, TH) in the well water samples were ranged from 104 to 220 mg/L, with an average of 160.07 mg/L, while the tap water samples showed a range from 70 mg/L to 250 mg/L and an average of 127.33 mg/L (Tables 1 and 2). The findings of this study indicated that well water contained a greater amount of Calcium Carbonate compared to tap water (Figure 10), although the differences were not statistically significant ($p > 0.05$). The mean values for both well and tap water samples were within the acceptable limits set by the WHO (<500 mg/L) and the standards established by Tanzania (600 mg/L).

Table 1: Results for physical- chemical parameters of well water samples collected from different sampling sites (n=15)

Sample ID	**Parameters**								
	pH	**EC µS/cm**	**TDS (mg/l)**	**NTU**	**CL^- (mg/L)**	**SO_4^{2-} (mg/L)**	**NO_3^- (mg/L)**	**PO_4^{3-} (mg/L)**	**$CaCO_3$mg /)**
WI	7.4	952	626	1.14	277	18	0.02	0.14	124
W2	7.1	974	637	3.40	307	26	0.04	0.06	160
W3	7.4	826	413	0.90	309	54	0.03	0.01	169
W4	7.4	774	387	3.50	302	40	0.01	0.03	220
W5	6.2	748	374	0.8	292	20	0.04	0.14	176
W6	6.5	860	430	1.2	307	20	0.04	0.05	116
W7	7.5	926	663	0.8	297	45	0.15	0.08	104
W8	6.7	946	573	0.9	305	32	0.01	0.01	178
W9	6.3	834	417	0.9	282	28	0.01	0.03	204
W10	7.5	960	480	0.7	212	17	0.002	0.11	166
W11	7.5	910	455	1.1	267	18	0.02	0.07	168
W12	6.4	138	69	0.8	315	20	0.12	0.06	176
W13	8.2	890	545	2.8	253	32	0.02	0.12	160
W14	7.1	466	233	2	290	38	0.14	0.13	136
W15	8.8	3200	1620	1.8	305	44	0.05	0.09	144
Mean	7.2	960.27	528.13	1.52	288.00	30.13	0.05	0.08	160.07
WHO 2011	6.5-8	2500	600	5	250	250	<50	<5	500
TZS 2008	6.5-9.9	3000	1000	5-25	250	400	45	2.2	300

Table 2: Results for physical- chemical parameters of tap water samples collected from different sampling sites (n=15)

Sample ID	**Parameters**								
	pH	**EC µS/cm**	**TDS (mg/l)**	**NTU**	**CL^- (mg/L)**	**SO_4^{2-} (mg/L)**	**NO_3^- (mg/L)**	**PO_4^{3-} (mg/L)**	**$CaCO_3$mg/)**
W1	7.2	952	476	1.5	314	44	2.03	0.04	90
W2	7.0	902	480	3.0	286	43	2.7	0.06	250
W3	6.8	932	570	0.9	310	45	1.1	0.01	90
W4	6.6	1074	687	1.2	320	35	0.20	0.02	160
W5	8.1	952	576	0.8	270	44	3.40	0.02	70
W6	7.6	912	456	2.6	298	24	0.60	0.1	78
W7	7.5	952	526	1.2	296	42	1.1	0.06	70
W8	7.3	932	566	2.0	302	43	2.64	0.05	80
W9	8.2	1020	560	1.3	282	52	1.04	0.03	94
W10	7.8	1008	550	1.3	304	36	2.20	0.1	110
W11	6.9	972	486	2.8	306	34	2.8	0.16	150
W12	7.5	872	436	2.3	290	34	1.68	0.09	98
W13	7.2	912	456	1.7	254	28	1.30	0.13	174
W14	6.8	872	436	1.4	288	32	1.6	0.14	220
W15	7.7	1052	576	1.6	296	32	3.4	0.07	176
Mean	7.34	954.4	522.4	1.71	294.4	37.93	1.85	0.07	127.3
WHO 2011	6.5-8	2500	600	5	250	250	<50	<5	500
TZS 2008	6.5-9.5	300	1000	5-25	250	400	45	<5	300

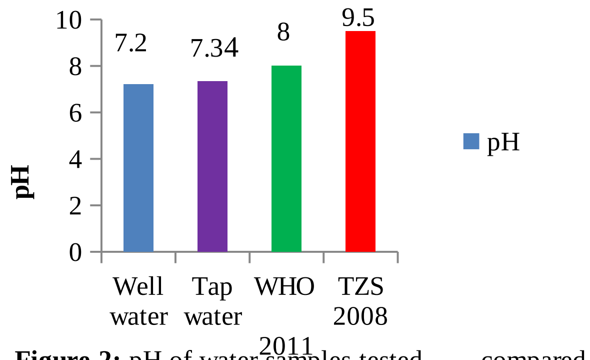

Figure 2: pH of water samples tested compared with the maximum standard value of national and international drinking water quality guidelines

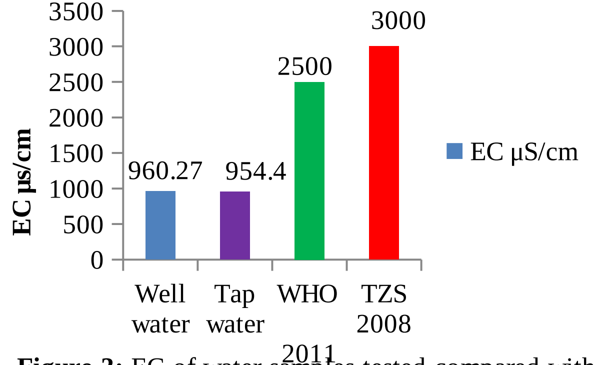

Figure 3: EC of water samples tested compared with the maximum standard value of national and international drinking water quality guidelines

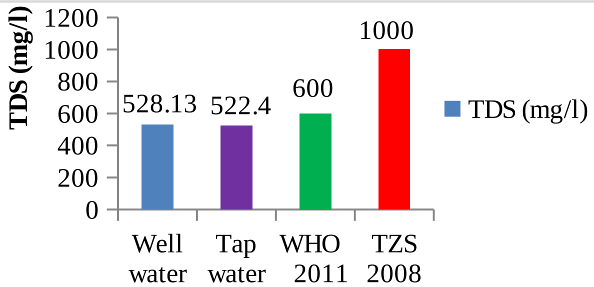

Figure 4: TDS of water samples tested compared with the maximum standard value of national and international drinking water quality guidelines

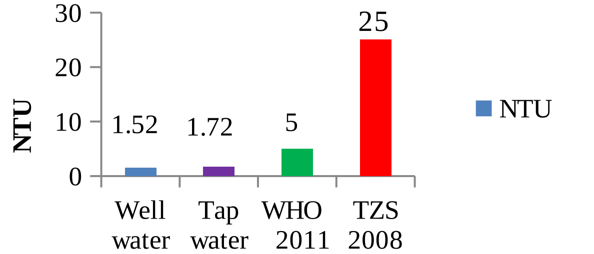

Figure 5: Turbidity of water samples tested compared with the maximum standard value of national and international drinking water quality guidelines

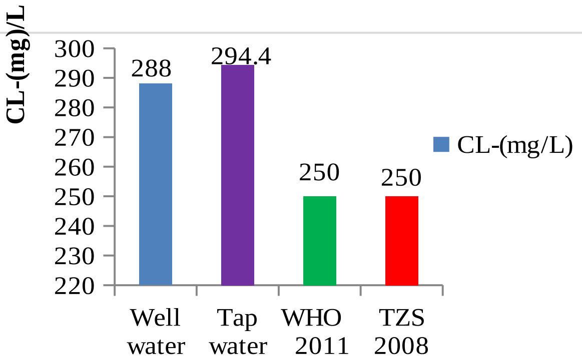

Figure 6: Chlorine of water samples tested compared with the maximum standard value of national and international drinking water quality guidelines

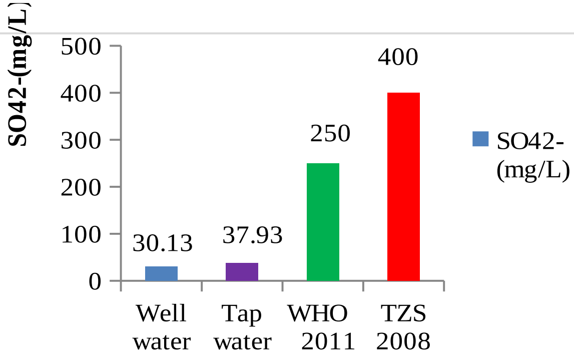

Figure7: Sulphate of water samples tested compared with the maximum standard value of national and international drinking water quality guidelines

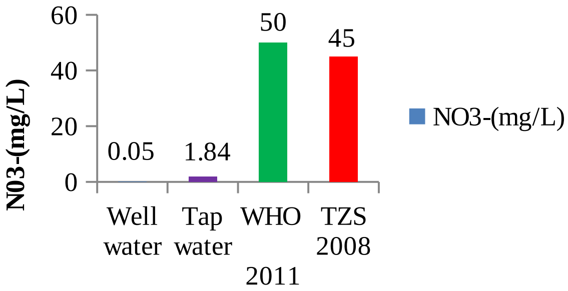

Figure 8: Nitrate of water samples tested compared with the maximum standard value of national and international drinking water quality guidelines

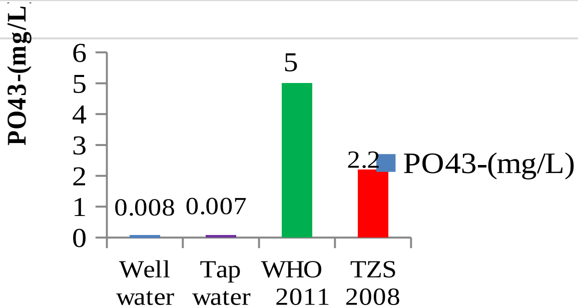

Figure 9: Phosphate of water samples tested compared with the maximum standard value of national and international drinking water quality guidelines

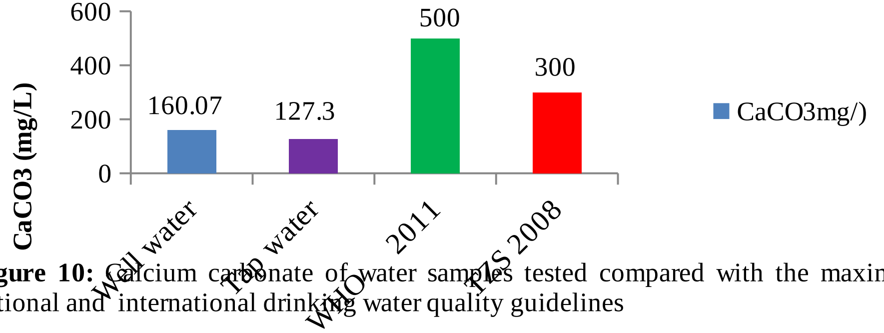

Figure 10: Calcium carbonate of water samples tested compared with the maximum Ssandard value of national and international drinking water quality guidelines

In a total of 15 water samples taken from wells, 3 samples (20%) showed contamination by coliform bacteria, while 2 samples (13.3%) contained *E. coli* (Table 3). Both coliform bacteria and *E. coli* were found in the well water samples. Conversely, in the 15 tap water samples tested, there were no detections of either coliforms or *E. coli* in any of the water samples (Table 3).

Table 3. Bacteriological parameters results of well and tap water samples

	Water source							
	`Well water				**Tap water**			
Result	**Coliform**		***E. Coli***		**Coliform**		***E. Coli***	
	No	%	No	%	No	%	No	%
Negative	12	80	13	86.7	15	100	15	100
Positive	3	20	2	13.3	0	0	0	0
Total	15	100	15	100	15	100	15	100

Discussion

In the present study, physico-chemical analysis of well and tap water source are discussed in relation to proposed values documented by Tanzania Standard (TZS 789:2008) and WHO (2008 2011) for drinking water quality.

Two sampling locations, W5 and W12, exhibited a lower water pH (Table 1) than the standards established by TZS and WHO for drinking water. There are many possibilities which might explain these observations. One possible explanation may stem from the characteristics of the rocks and soil that the water flows through. As many minerals and organic materials in rocks can dissolve under suitable geochemical conditions, groundwater may consequently lead to this result. A related finding was reported by Zhang et al. (2022), who indicated that the pH levels of groundwater are influenced by several factors, including the type of soil and rocks in which water are coming out. Moreover, the present results could be associated with the accumulations of organic material of the soil. As organic substances decay, carbon dioxide is released and combines with water to produce weak acid which is called carbonic acid. Various studies reported about the effect of accumulations of organic materials in rising of water acidity (Sojobi et al. 2014). Conversely, the W15 water sample demonstrated higher pH levels than those recommended by TZS and WHO standards. A potential explanation for these results could be due to fertilizer runoff from nearby farms and the influence of limestone gravel rocks. The findings of the present investigation align with the observations made by Sojobi et al. (2014), who noted the impact of fertilizer and limestone gravel rocks on rising up soil pH. One water sample namely W15, was found to have high electric conductivity value than that documented by WHO and Tanzania standards for drinking water limit. The explanation for this result could be the existence of salts in the soil that seep toward the water source or might be groundwater seepage or sewage intrusion, particularly during the wet season as reported in various studies (Idowu et al. 2022, Nyangi and Leopord 2023). Numerous scientific research have suggested that for effective disinfection, the pH should not exceed 8.0 (Lantagne and Clasen 2012, Mohamed et al. 2014). Additionally, it has been shown that chlorine's disinfection capabilities drastically decrease at pH 8.5 and that its disinfecting strength decreases as the pH rises (NEMC 2007, Mohamed et al. 2014). Furthermore, all *E. Coli* strains have been shown to be more resistant to free chlorine at pH values above 8.5, meaning that chlorinating water with a pH above 8.5 cannot guarantee the safety of drinking water (Lantagne and Clasen 2012, Mohamed et al. 2014). TDS levels at four test locations namely W1, W2, W7, and W15 were found to be higher than the WHO-recommended threshold for drinking water. Sewage inflow or groundwater seepage, especially during the rainy season, may be the cause of the current observation. The current observation may have resulted from the impacts of seepage of water from the Indian Ocean on the TDS of groundwater along the Dar es Salaam and coastline region, as reported by Akhtar et al. (2021). The high mean value of TDS recorded from well water than that of tap water could be attributable by agricultural runoff as these substances are removed during treatment in tap water as documented by Akhtar et al. (2021). The present study evidenced lower average concentration of turbidity in well water than that of tap water. The possible reason for this observation could settle of suspended matter in well water as reported by WHO (2007). However, their mean values are below the WHO (5 NTU) and TZS (5-25 NTU) requirements. Various studies documented different turbidity index for indication of qualities of water which including if the water is Good (< 1 NTU), Fair (1-5 NTU), or Poor (>5 NTU) (WHO 2007, Lantagne and Clasen 2012). Furthermore, researchers reported that, as water turbidity increases, the risk to human health also increases especially newborns, the elderly, and people with compromised immune systems such as those with HIV/AIDS, undergoing cancer chemotherapy, or taking organ antirejection drugs. Nevertheless, it was reported in various studies that, bacteria, viruses, and parasites such as *Giardia and Cryptosporidium* can attach themselves to the suspended particles in turbid water and hence interferes with disinfection by shielding contaminants from the disinfectant such as chlorine (Lechevallier et al. 1981). Furthermore, excessive turbidity (>5 NTU) makes it difficult to disinfect drinking water because it shields microorganisms from the effects of chlorine, promotes bacterial development, and increases the need for chlorine (Lechevallier et al. 1981, WHO 2007). Therefore, drinking water with turbidity levels between 5 and 25 NTU is not guaranteed to be safe.

The results showed that the ranges of turbidity, calcium carbonate (hardness (TH)), chloride, sulphate and Nitrate that were detected fell within the permitted range of both WHO and TZS guidelines. These indicate that, the waters were in compliance with regulatory standards.

Three (20%) and two (13.3%) of the fifteen water samples that were taken from wells were contaminated by coliforms and *E. coli*, respectively. The by absence of sanitary protection could be the reason for this observation. The lack of well cover, which was evidenced in a few wells during the sampling process, may allow chemical, physical, and biological contaminants to freely enter the well. This observation is not surprising since Kilungo et al. (2018) documented the contaminations of well water due to lack of sanitary protection to the wells.

In other hand, no coliforms and *E. coli* detected in any water sample collected from tap. The successful treatment of the water, which included several steps like coagulation, flocculation, and sedimentation by filtration, and disinfection, may be the reason for the present observation. Several scholars have previously reported the same observation (Richter and de Azevedo Netto 2021). The presence of *E. coli* in well water samples suggests that human or animal excrement may have polluted the water. The presence of *E. coli* in well water samples indicate that, the water could be contaminated by waste from humans or animals. Harmful bacteria in polluted water can lead to health risk for Infants, young children, and individuals with severely weakened immune systems may be at an increased health risk. The significant presence of thermotolerant *E. coli b*acteria in the well water samples identified in this study might suggest a greater likelihood of disease-causing pathogens being present in the water. Waterborne diseases that can arise from contaminated water include skin infections, ear infections, cholera, dysentery, typhoid fever, viral and bacterial gastroenteritis, and hepatitis A (Lechevallier 1981, WHO 2007). According to the Tanzania Bureau of Standards (TBS) and the National Environmental Management Council (NEMC), there should be no fecal coliform in drinking water; hence, it must be zero (NEMC 2007, WHO 2007, TBS TZS 789:

2008). According to the WHO, water used for food preparation, personal hygiene, or human consumption should be free of any substances that could endanger human health, as there is no acceptable minimum limit for pathogens in such water (Lechevallier 1981, WHO 2007).

Limitation

The burden of their existence in drinking water at various times cannot be captured by one-time sampling, despite the fact that it is incredibly helpful. The current investigation was restricted to identifying a small number of pathogens, such as *E. coli* and total coliforms. Furthermore, it was challenging to compare studies because no research has been done on the molecular detection of harmful pathogens from Dar es Salaam water samples.

Conclusions and Recommendations

The results of this study demonstrated that, with the exception of a chloride concentration that exceeded WHO-permissible standards for drinking water, the physico-chemical characteristics of the home water sources under investigation were within acceptable bounds. While tap water tests showed no signs of contamination and demonstrated high compliance with quality control and regulatory standards, well water samples that were evaluated were contaminated by *E. coli* and coliform which means they did not meet quality control and regulatory standards. Therefore, relevant authorities must implement the necessary pollution control measures to maintain the water quality within acceptable bounds. Future research is advised to study the water quality in various sites and throughout various seasons. Other *Enterobacteriacea* species in the study area should be the focus of future research.

Conflict of interest

The author declares no conflicts of interest.

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