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Investigation of Heavy Metal Composition and Associated Health Risks from Selected Groundwater Wells in Temeke, Dar-es-Salaam

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ABSTRACT

Water quality continues to be the challenge to residents in Dar es Salaam due to various anthropogenic activities in the city. This study was conducted to assess groundwater quality by determining concentrations of heavy metals. Both probability and Nonprobability sampling techniques were used to collect samples from 40 groundwater wells in 24 wards of Temeke municipal and analysed using Microwave Plasma Atomic Emission Spectrometer (Agilent 4210 MP-AES) at the Geochemistry Laboratory of the University of Dar es Salaam. Results indicated varying heavy metal concentrations ranging from 0.71 ± 0.08 to 6.64 ± 0.21 mg/l for As, 0.02 ± 0.01 to 0.07 ± 0.01 mg/l for Co and 0.16 ± 0.01 to 0.02 ± 0.01 mg/l for Pb. The As, Co and Pb concentrations exceeded (P < 0.05) the recommended TBS standards of 0.05 mg/l, 0.003 mg/l and 0.01 mg/l respectively. Other concentrations ranged from 0.01 ± 0.01 to 0.88 ± 0.01 mg/l for Cu, 0.02 ± 0.01 to 3.55 ± 0.02 mg/l for Fe, 0.00 ± 0.00 to 4.63 ± 0.03 mg/l for Mn and 0.01 ± 0.01 to 3.00 ± 0.01 mg/l for Zn. The Cu, Fe, Mn and Zn concentrations were below (P > 0.05) the allowable TBS limits of 0.05 mg/l, 0.3 mg/l, 0.1 mg/l and 3 mg/l respectively. Health risk analysis revealed potential adverse health effects from long term consumption of As, Mn and Pb with Hazard Quotient exceeding 1 (HQ > 1). The Hazard Index (HI) for all groundwater samples was also above 1 (HI > 1) indicating a higher likelihood of adverse health effects. The study concluded that groundwater wells in Temeke Municipal are affected through natural and anthropogenic activities leading to high levels of heavy metal concentrations. Also, this study provides valuable information on risk associated by continued usage of groundwater in Temeke region and hence informs respective stakeholders on groundwater quality and potential risks thereby emphasizing the need for remedial measures and stricter regulations to safeguard public health. The study recommends the need for regular groundwater quality and safety monitoring to assess the levels of heavy metals concentrations and implement sustainable groundwater management strategies to address the increasing water demand in Temeke municipal, Dar es Salaam.

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INTRODUCTION

Water crisis is increasing in developing countries, not only due to unsustainable use and poor management of water but also due to the challenge of providing safe and sufficient water to people (Shan *et al.*, 2020). According to United Nations (2022), by 2022 there were at least 2 billion people globally who did not have access to safely managed drinking water services. And about 1.6 billion people globally will have no safely managed drinking water supplies by 2030. Dar es Salaam is one of the fastest growing cities in Africa with a population of over 5.83 million people in 2023 (NBS, 2022a). However, despite the population growth rate of 2.3%, the availability of safe and quality water to sustain the growing population has been declining since the late 1990s (DAWASA, 2023; NBS, 2022; Mkude and Saria, 2015). Water supply in Dar es Salaam comes from three surface water treatment plants namely; Upper Ruvu, Lower Ruvu and Mtoni which obtain water from Ruvu and Kizinga River (DAWASA, 2023). As Dar es Salaam city expands, the demand for natural resources such as water is also increasing. According to DAWASA (2023) the city's water demand is estimated to be 545,000 m^3/day while the total capacity of the three plants is 475,000 m^3/day which is supplied in five city's municipals, namely, Temeke, Ubungo, Ilala, Kigamboni and Kinondoni. Thus, the city faces water shortages during which water demand is hardly satisfied.

According to NBS (2022), the Temeke Municipal has a total population of 1.63 million with average water consumption 326,000 m^3/day. Unfortunately, DAWASA can only supply about 272,000 m^3/day (, leaving a deficit of about 54,000 m^3/day during its maximum operation due to prolonged draught condition, poor water infrastructure and supply systems, poor technology and low economic status of the residents of Temeke (DAWASA, 2023). As a result, residents in the Municipal find other affordable water sources such as groundwater. However, the potential of groundwater as a long-term source of water supplies in the city is being undermined by various natural and anthropogenic activities which results to an increase in groundwater contamination overtime since groundwater is affected by characteristics of the media through which the water passes on its way to the groundwater zone of saturation.

The Effluents from industries, domestic sewage systems, dump sites, and fertilizers all contribute to the contamination of groundwater by infiltrating into the underground aquifer and posing a potential risk to the consumers. The groundwater aquifer system once contaminated remains so for a long period of time, even if the source of pollution is eliminated. Such various natural and anthropogenic activities expose consumers to various pollutants including heavy metals (Isibor *et al.*, 2023). Heavy metals are a public health concern regarding to the water contamination include As, Cd, Ni, Hg, Cr, Zn, Cu, and Pb. The main sources of these heavy metals in water are soil erosion, weathering, mining, industrial wastewater, urban runoff, sewage discharge, municipal wastes and agrochemicals. Heavy metals generate reactive oxygen species in living organisms thereby causing oxidative damage (Onoyima and Ibraheem, 2021). Various studies have examined the levels of heavy metals in groundwater and identified patterns of contamination in the Temeke Municipal area. Hossein (2014) found that a fair number of heavy metals including Zn, Cr, Cd and Cu were within acceptable limits, however the amount of Pb in deep well exceeded the WHO guidelines. The study by Mahugija (2018) revealed highest concentrations of Pb and Fe in tap water from Temeke municipal and supposed that high concentrations might have been caused corrosion of lead based plumbing materials (pipes and fittings) and the perforation or leakage of pipes. Also, contamination by the release of large amounts of iron into the environment from activities such as garages works (Mahugija, 2018).

Further, Sahu and Kacholi (2016) conducted a study to examine the factors that contribute to heavy metal contamination in groundwater by determining the amounts of heavy metals in vegetables. Results showed that *Amaranthus* species grown in the local garden in the Chong'ombe-Mchicha area of Temeke Municipal had higher amounts of heavy metals (Cu, Zn, Pb, Fe and Co). High concentrations of heavy metals in vegetables were suggested to have been due to irrigation using of wastewater from a nearby stream that flows past industrial zones before reaching the garden, suggesting that sewage and industrial waste may be ending up in the water channel and contaminating the vegetables.

Efforts have been made by the government to regulate some anthropogenic activities so as to reduce pollution to the environment especially waste and effluent disposal. However, response from stakeholders has been minimal leading to continued pollution to the environment and hence resulting in water pollution through leaching processes. While water quality and safety entails physical, chemical and Biological characterization, this study focused on chemical quality parameters and specifically heavy metal concentration due to their toxicity and carcinogenic nature, non-biodegradable and their ability to bio-accumulate in the human body (Teym *et al.*, 2021).

This study therefore aims at investigating the concentration of heavy metals in groundwater resources in the Temeke Municipal which is found in Dar es Salaam by using Microwave Plasma Atomic Emission Spectroscopy (MP-AES), as well as assessing the health risk induced by heavy metals ingestion of groundwater using the hazard quotients (HQ) and the total hazard index (HI).

METHODS AND MATERIALS

The materials, design and methods employed in this study were selected based on the requirements and nature of the research. This study employed cross-sectional research design whereby data collection was undertaken at once.

Study area

The study was conducted in Temeke municipality in Dar es Salaam city. Temeke municipal is one of the five districts in Dar es Salaam city. It is located between 6° to 7°S and 39° to 43°E, bounded by the Indian Ocean on the east and by the Coast Region on the other sides. It covers an area of about 786.5 km^2. According to the National Bureau of Statistics, Temeke has a population of 1,346,674 where 655,137 are males and 691,537 females (NBS, 2022a). Figure 1 below shows the map at Temeke Municipal, Dar es Salaam-Tanzania.

Temeke municipal is divided into two (2) administrative divisions, namely, Chang’ombe and Mbagala which are further divided into twenty-four (24) wards and 122 sub-wards. The climatic conditions in Temeke district is tropical with hot and humid weather throughout the year. There are two rainy seasons, one from March to May and another from October to December with the dry seasons in between. The average annual precipitation ranges from 1114 mm to 1200 mm with the highest rainfall in April. The hottest season is from October to February with temperatures up-to 35°C the average temperature is 29°C, with cooler temperatures between May and August. The average maximum temperature is around 32°C and the minimum is 20°C (Lyatuu, 2012).

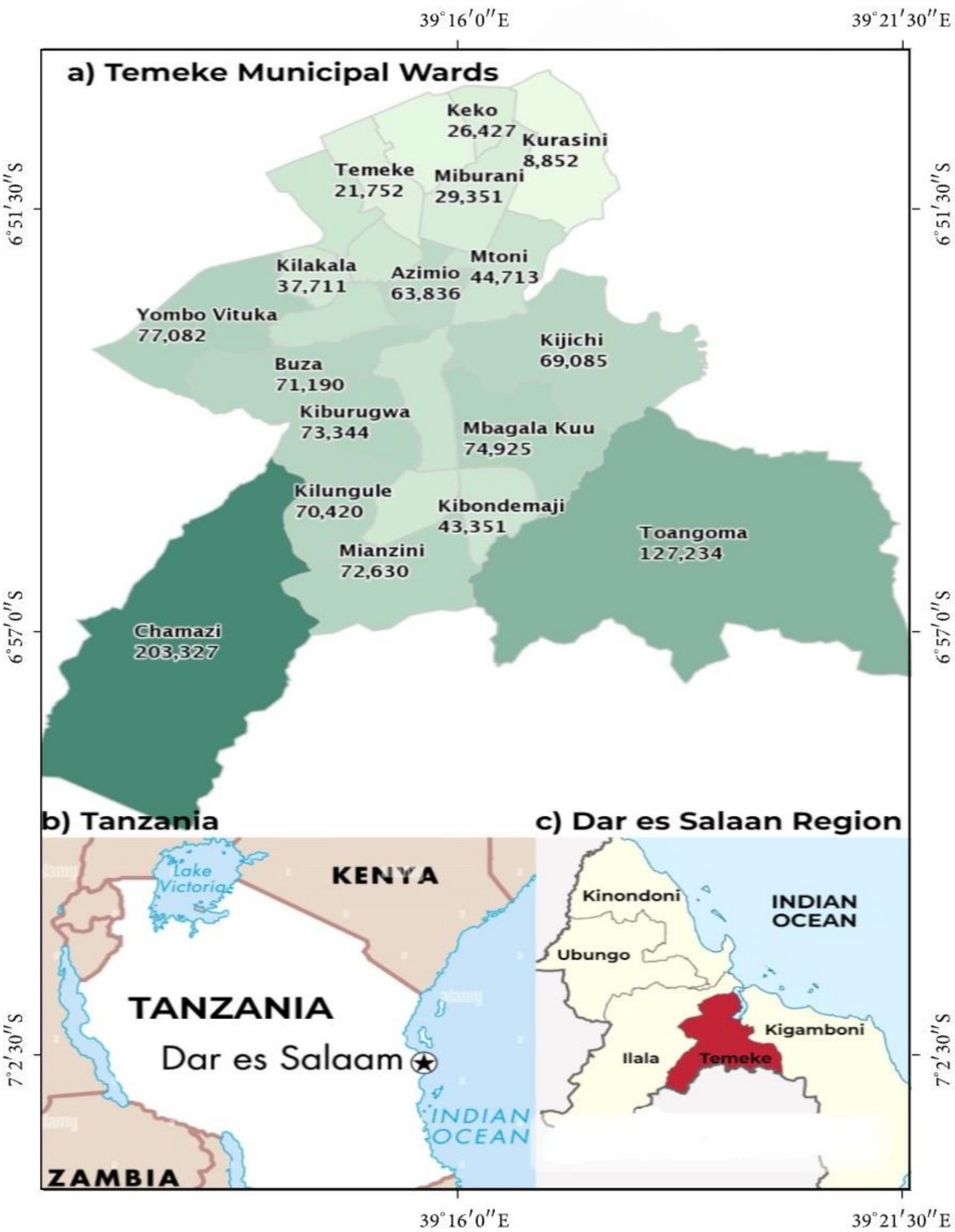

Figure 1: Map of Temeke municipal region, Dar es Salaam-Tanzania (NBS, 2022).

The socio-economic activities carried out in Temeke municipal includes agricultural, industrial and infrastructure constructions which greatly contribute to environmental pollution leading to heavy metal deposition in the area. Agricultural practices involve the use of metal-containing pesticides and fertilizers, which can accumulate in the soil and subsequently be washed into water bodies. Industrial processes release heavy metals into the environment as by-products or effluents, often ending up in water sources. Additionally, infrastructure activities such as construction and transportation can lead to the erosion of metal-laden materials, allowing heavy metals to leach into the surrounding environment and water systems.

Study population, sample size and sampling procedure

The study population mainly targeted 85 groundwater wells which are distributed across 23 wards in the study area. The sampling frame for this study included all 34 sub-wards which had groundwater wells. The list of groundwater wells was obtained from Wami/Ruvu Water Basin Authority Office which works under the ministry of water in Tanzania. This authority is responsible for monitoring and managing ground water quality.

A sample size of 40 groundwater samples was obtained from Temeke Municipal using Equation (1) below according to Ajay and Micah (2014).

$$n_s = \frac{z^2 \times p \times q \times N}{e^2 \times (N-1) + z^2 \times p \times q} \quad (1)$$

Where: n_s = Sample size, N = Total population, i.e. 85; Z = Z-score at a given confidence interval, P = Sample proportion, i.e., 0.95; e = level of precision and $q = 1 - p$. For the 95% confidence interval the Z = 1.96, the level of precision, e = 5%, and for the sample proportion, p = 95%, the sample size was determined to be n_s = 40 samples.

Forty groundwater samples were collected from forty groundwater wells using both purposive and probability sampling techniques. All subwards with groundwater wells were grouped into two strata whereby subwards with single well were grouped in the first strata, i.e., 21 subwards and those with more than one wells were grouped in the second strata, i.e., 34 subwards with 64 wells. Then purposive sampling technique was used to collect 21 samples from the first strata consisting of 21 subwards while probability sampling technique was used to select 19 samples from the second strata consisting 64 ground water wells summing up to 40 water samples.

The sample used for moisture content determination was heated in a covered crucible to avoid contact with air during devolatilization. The covered crucible was placed into a furnace at 450°C for three hours. The crucible was then taken out and cooled in desiccators. The weight difference after decomposition was referred as volatile matter.

Determination of heavy metal concentration

Analyses were carried out using Agilent Microwave Plasma Atomic Emission Spectrometer (MP AES model: Agilent 4210) using APHA (2017) methods number 3010B and 3030A at the Geochemistry laboratory in the Department of Geoscience of the University of Dar es Salaam

Sample preparation

Samples were first filtered using 45 μm membrane filter and then acidified with 1.5 ml/L of Concentrated HNO_3 (HNO_3 67%-69% Analytical grade), filtered and acidified samples were then stored in the refrigerator at 4°C until analysis. After analysis the concentrations of heavy metals in all 40 samples were determined.

Quality assurance

For analytical quality assurance, tools were washed with detergent, rinsed with enough deionized water to remove contaminants and interferences. Deionized water was used for determination of the blanks. In view of data quality assurance, each sample was analysed in triplicate.

Assessment of health risk induced by heavy metal ingestion

To assess the health risk induced by heavy metal the Average Daily Dose ADD was first established according to Tripathee *et al.* (2016) using Equation (2). ADD is expressed as mass of contaminant per unit body weight over time (mg/kg-day).

$$ADD = \frac{C_{avg} \times IngR \times EF \times ED}{BW \times AT} \quad (2)$$

where ADD = Average Daily Dose, C_{avg} = Average Concentration, $IngR$ = Ingestion Rate, AT = Average Time, ED = Exposure Duration, EF = Exposure Frequency and BW = Body Weight.

Parameters used in Equation (2) are defined in Table 1 with values valid on the assumption that the people in consideration drink and use water from groundwater well (Boateng *et al.*, 2019).

Table 1: Factors used to determine the average daily dose amount (Boateng *et al.*, 2019; Tripathee *et al.*, 2016)

Exposure parameters	Symbols	Units	Value
Ingestion rate	IngR	L/day	2.2
Average time	AT	Years	365 × ED
Exposure duration	ED	Years	70
Exposure frequency	EF	Days/year	365
Body Weight	BW	Kg	70

The human health risk of metals in the water samples is assessed as non-carcinogenic using ADD as shown in Equation (3) (Pongpiachan *et al.*, 2018).

$$HQ = \frac{ADD}{Rfd} \tag{3}$$

where: HQ = Hazard Quotient and Rfd = Reference Dose.

The Average Daily Dose (ADD) of each heavy metal was calculated using Equation (2); thereafter the hazard quotient (HQ) was calculated using Equation (3). Table 2 below shows the values of Reference Daily Dose for each heavy metal.

Table 2: The reference dose of different heavy metal (Source: USEPA, 2011)

Heavy Metals	As	Co	Cu	Fe	Mn	Pb	Zn
***Rfd* (mg/kg-day)**	0.003	0.03	0.04	0.7	0.0014	0.014	0.3

The hazard index (HI) represents an unacceptable or acceptable risk of non-carcinogenic effects. When HQ or HI > 1 implies that the non-carcinogenic risk of contaminant exceeds the acceptable limit and when HI = 1, HQ or HI < 1 implies that the non-carcinogenic risk of contaminant is within the acceptable limit. HI is obtained as the sum of the HQ values of the elements as shown in Equation (4) (Pongpiachan *et al.*, 2018).

$$HI_i = \sum_{i=1}^{n} HQ_i \tag{4}$$

where HI_i = Hazard Index for i = 1 to 7 metals and HQ_i = Hazard Quotient of metal i

Data analysis and interpretation

After the experiments, data collected were statistically analysed through descriptive and inferential statistic techniques using Microsoft excel 2021 program. Data were then presented in Tables and bar/chart graphs in order to examine distributions and trends so as to establish better understanding and to draw meaningful conclusion.

RESULTS AND DISCUSSION

Heavy metal concentrations in groundwater

Table 3 presents concentrations of Arsenic, Cobalt, Copper, Iron, Lead, Manganese and Zinc in all 40 groundwater wells involved in the study.

Arsenic (As)

The Arsenic concentration in all 40 groundwater samples ranged from 0.71 ± 0.08 to 6.64 ± 0.21 mg/l. The observed concentrations in all 40 wells were significantly higher ($p < 0.05$) than the TBS standards limit of 0.05 mg/l indicating potential contamination. Limited data on arsenic concentrations in groundwater from Temeke municipal limited comparative analysis from previous studies. Possible factors contributing to high levels of As include industrial facilities releasing arsenic-containing effluents and the infiltration of arsenic-rich surface water due to shallow water tables and permeable aquifers (Ukah *et al.*, 2019).

Arsenic exposure via contaminated water raises significant health concerns due to its potential health effects like cardiovascular problems, diabetes, anaemia, neurological and respiratory system impairments. The severity of these effects depends on arsenic's chemical form, dosage, and duration of exposure (Ukah et al., 2019). Figure 2 present the levels of Arsenic concentrations in groundwater from Temeke.

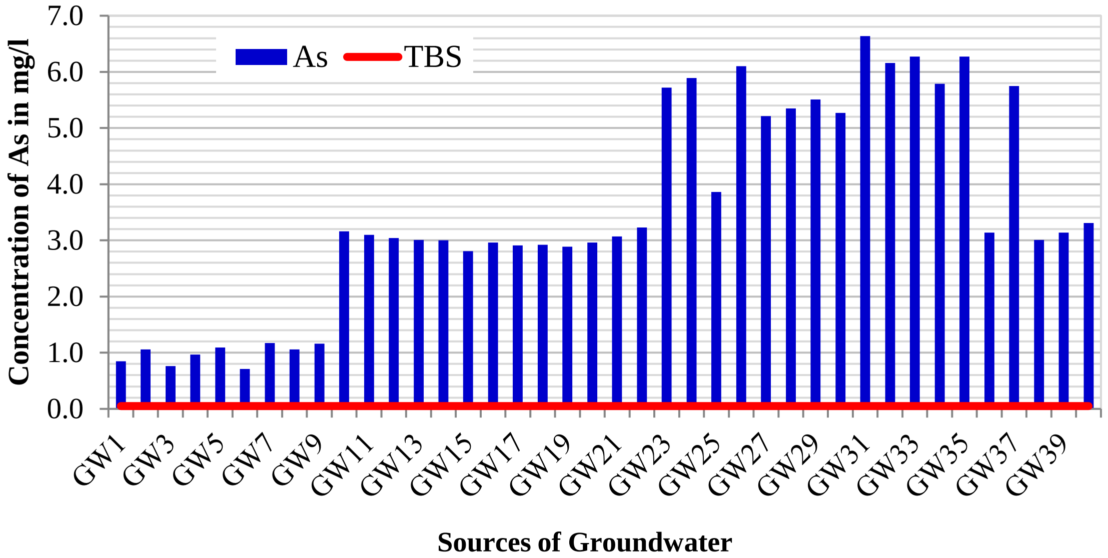

Figure 2: Arsenic concentrations in groundwater samples from Temeke Municipal.

Cobalt (Co)

Cobalt occurs naturally in the environment in air, water, soil, plants, and animals, entering groundwater through runoff. Accumulation of cobalt, both from natural and human sources, in water bodies is concerning. While vital for vitamin B_{12}, high cobalt exposure leads to health issues like vomiting, nausea, vision, and heart problems. This study found high concentrations in all 40-groundwater ranging from 0.02 ± 0.01 to 0.07 ± 0.01 mg/l. These levels were significantly higher ($p < 0.05$) than the TBS standard level of 0.003 mg/l. Literature present different concentration in groundwater from different areas. The study conducted by Taiwo *et al*. (2023), reported high mean concentrations of Cobalt ranging from 0.1157 mg/l to 0.3472 mg/l in groundwater samples in Nigeria. While Taiwo *et al*. (2023) reported higher Co concentrations than the concentrations observed from this study, the study concluded that Cobalt may not pose a threat to human health, given the absence of an established permissible standard by WHO. However, it's essential to note that the absence of a specific standard doesn't mean there is no health risks linked to Cobalt contamination. Cobalt is a heavy metal with potential health implications, particularly when consumed in high concentrations over a prolonged period (Onoyima and Ibraheem, 2021). Figure 3 below shows the concentrations of Co from the groundwater samples from Temeke Municipal in Dar es Salaam.

Table 3: Heavy metal concentrations in groundwater from Temeke Municipal

Ground water samples	Metal Concentration (mg/l)						
	As	**Co**	**Cu**	**Fe**	**Mn**	**Pb**	**Zn**
GW1	0.85 ± 0.08	0.04 ± 0.02	0.03 ± 0.02	0.35 ± 0.01	0.03 ± 0.01	0.07 ± 0.01	0.05 ± 0.01
GW2	1.06 ± 0.13	0.04 ± 0.01	0.02 ± 0.01	0.46 ± 0.01	0.08 ± 0.02	0.05 ± 0.01	0.02 ± 0.01
GW3	0.76 ± 0.15	0.05 ± 0.01	0.02 ± 0.02	0.08 ± 0.01	0.00 ± 0.00	0.06 ± 0.01	0.05 ± 0.02
GW4	0.97 ± 0.19	0.03 ± 0.02	0.02 ± 0.01	0.07 ± 0.02	0.11 ± 0.01	0.05 ± 0.02	0.03 ± 0.01
GW5	1.09 ± 0.14	0.05 ± 0.02	0.03 ± 0.01	0.05 ± 0.02	0.01 ± 0.01	0.05 ± 0.01	0.22 ± 0.01
GW6	0.71 ± 0.08	0.03 ± 0.02	0.02 ± 0.01	0.12 ± 0.01	0.04 ± 0.05	0.05 ± 0.01	0.09 ± 0.01
GW7	1.17 ± 0.04	0.05 ± 0.01	0.02 ± 0.02	0.06 ± 0.02	0.43 ± 0.01	0.05 ± 0.02	0.01 ± 0.01
GW8	1.06 ± 0.06	0.05 ± 0.03	0.01 ± 0.01	0.04 ± 0.01	0.02 ± 0.01	0.05 ± 0.01	0.00 ± 0.00
GW9	1.16 ± 0.06	0.05 ± 0.03	0.02 ± 0.01	0.06 ± 0.01	0.50 ± 0.01	0.06 ± 0.01	0.02 ± 0.01
GW10	3.16 ± 0.14	0.04 ± 0.01	0.01 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.03 ± 0.01	0.04 ± 0.02
GW11	3.10 ± 0.11	0.04 ± 0.02	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.04 ± 0.01	0.05 ± 0.01
GW12	3.04 ± 0.12	0.04 ± 0.02	0.01 ± 0.01	0.03 ± 0.01	0.42 ± 0.01	0.03 ± 0.01	0.03 ± 0.01
GW13	3.01 ± 0.06	0.04 ± 0.02	0.19 ± 0.01	3.45 ± 0.05	0.52 ± 0.01	0.08 ± 0.02	0.37 ± 0.01
GW14	3.00 ± 0.03	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.01 ± 0.01	0.04 ± 0.01	0.03 ± 0.01
GW15	2.81 ± 0.06	0.03 ± 0.02	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.04 ± 0.01	0.06 ± 0.02
GW16	2.96 ± 0.13	0.03 ± 0.02	0.01 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.05 ± 0.02	0.04 ± 0.01
GW17	2.91 ± 0.03	0.04 ± 0.01	0.02 ± 0.01	0.13 ± 0.02	0.01 ± 0.01	0.05 ± 0.01	0.03 ± 0.01
GW18	2.92 ± 0.04	0.04 ± 0.01	0.01 ± 0.01	0.04 ± 0.01	0.01 ± 0.01	0.05 ± 0.02	0.04 ± 0.01
GW19	2.89 ± 0.05	0.05 ± 0.01	0.01 ± 0.01	0.04 ± 0.01	0.01 ± 0.01	0.05 ± 0.01	0.06 ± 0.01
GW20	2.96 ± 0.06	0.05 ± 0.01	0.01 ± 0.01	0.13 ± 0.01	0.31 ± 0.02	0.05 ± 0.01	0.07 ± 0.01
GW21	3.07 ± 0.11	0.05 ± 0.02	0.01 ± 0.01	0.19 ± 0.01	0.22 ± 0.02	0.04 ± 0.01	0.06 ± 0.01
GW22	3.23 ± 0.07	0.04 ± 0.01	0.01 ± 0.01	0.05 ± 0.01	0.01 ± 0.01	0.04 ± 0.02	0.04 ± 0.01
GW23	5.72 ± 0.12	0.04 ± 0.01	0.03 ± 0.02	0.03 ± 0.01	0.08 ± 0.02	0.04 ± 0.01	0.07 ± 0.02
GW24	5.89 ± 0.07	0.04 ± 0.02	0.01 ± 0.01	0.03 ± 0.01	0.62 ± 0.01	0.04 ± 0.01	0.09 ± 0.01
GW25	3.86 ± 0.14	0.07 ± 0.01	0.33 ± 0.03	3.55 ± 0.02	4.63 ± 0.03	0.16 ± 0.01	0.55 ± 0.02
GW26	6.10 ± 0.08	0.05 ± 0.02	0.88 ± 0.01	2.93 ± 0.02	1.19 ± 0.01	0.12 ± 0.01	0.21 ± 0.01
GW27	5.21 ± 0.07	0.05 ± 0.01	0.03 ± 0.01	0.11 ± 0.01	0.08 ± 0.01	0.05 ± 0.01	0.01 ± 0.01
GW28	5.35 ± 0.06	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.01 ± 0.01	0.05 ± 0.01	0.00 ± 0.00
GW29	5.51 ± 0.03	0.03 ± 0.01	0.01 ± 0.01	0.03 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.00 ± 0.00
GW30	5.27 ± 0.02	0.05 ± 0.01	0.02 ± 0.01	0.04 ± 0.01	0.01 ± 0.01	0.06 ± 0.01	0.05 ± 0.01
GW31	6.64 ± 0.21	0.03 ± 0.01	0.02 ± 0.01	0.14 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.03 ± 0.01
GW32	6.16 ± 0.10	0.04 ± 0.01	0.04 ± 0.01	0.10 ± 0.01	0.06 ± 0.02	0.04 ± 0.01	0.02 ± 0.01
GW33	6.27 ± 0.06	0.03 ± 0.01	0.02 ± 0.01	0.05 ± 0.01	0.10 ± 0.11	0.03 ± 0.01	0.01 ± 0.01
GW34	5.79 ±0.09	0.04 ± 0.01	0.02 ± 0.01	0.05 ± 0.01	0.36 ± 0.01	0.04 ± 0.01	0.01 ± 0.01
GW35	6.27 ± 0.10	0.02 ± 0.01	0.01 ± 0.01	0.03 ± 0.01	0.00 ± 0.00	0.03 ± 0.01	0.00 ± 0.00
GW36	3.14 ±0.11	0.02 ± 0.02	0.02 ± 0.01	0.04 ± 0.01	0.01 ± 0.01	0.04 ± 0.01	0.05 ± 0.01
GW37	5.75 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.04 ± 0.01	0.56 ± 0.01	0.05 ± 0.01	0.06 ± 0.01
GW38	3.01 ± 0.07	0.03 ± 0.01	0.05 ± 0.02	0.04 ± 0.01	0.34 ± 0.01	0.06 ± 0.01	0.35 ± 0.01
GW39	3.14 ± 0.11	0.03 ± 0.02	0.02 ± 0.01	0.04 ± 0.01	0.02 ± 0.02	0.05 ± 0.01	0.04 ± 0.01
GW40	3.31 ± 0.03	0.03 ± 0.01	0.00 ± 0.00	0.02 ± 0.01	0.22 ± 0.02	0.02 ± 0.01	0.02 ± 0.01
WHO	0.05	0.003	0.05	0.3	0.1	0.01	3

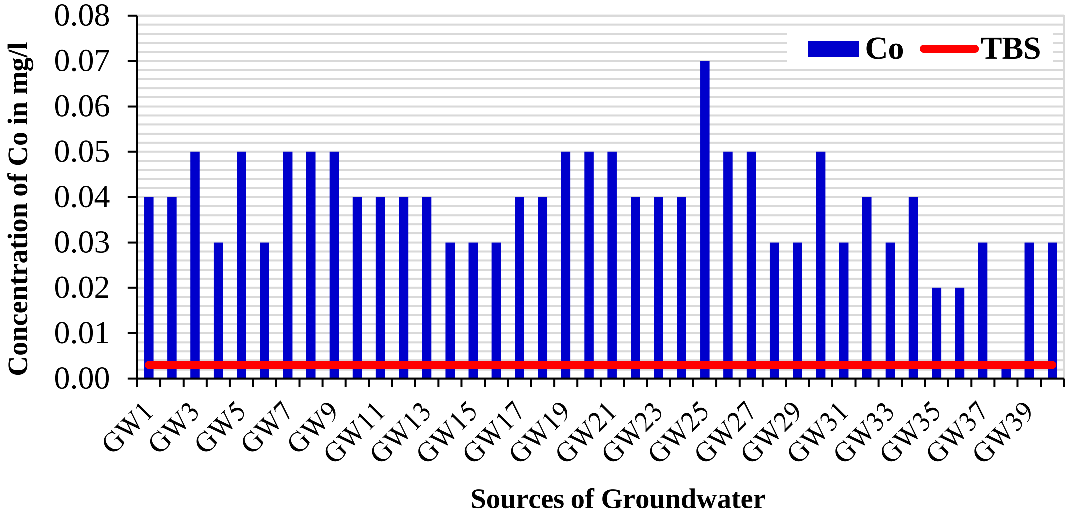

Figure 3: Cobalt concentration in groundwater samples from Temeke Municipal.

Copper (Cu)

Excessive copper intake, often from sources like water, can result in serious health problems such as kidney and liver damage, despite the fact that it is essential for various biochemical and physiological processes (Bilal and Rahman, 2013). The analysis of 40 groundwater samples from Temeke Municipal revealed a wide range of copper concentrations, with values ranging from 0.01 ± 0.01 to 0.88 ± 0.01 mg/l. The observed concentrations had no significant difference ($p > 0.05$) from the TBS standards (0.05 mg/l). However, some samples showed relatively high copper concentrations such as groundwater sample number 25 with copper level of 0.33 ± 0.03 mg/l, groundwater sample number 26 with copper level of 0.88 ± 0.01 and some remained within the regulatory limit. When comparing these results with previous studies, Mkude (2015) found Copper concentrations ranging from 0.0 to 0.013 mg/L in groundwater from Temeke residential areas where it was concluded that Copper concentrations were within permissible limits. Similarly, Hossein (2014) conducted a study on groundwater quality in Temeke and reported Copper concentrations ranging from 0 to 0.004982 mg/l indicating a fair amount of Copper within acceptable TBS limits. These observations suggests that copper levels in Temeke Municipal generally align with acceptable TBS limits. Copper levels in this study were not significantly different ($P > 0.05$) from TBS standards. High copper concentrations in groundwater is associated to industrial activities, plumbing activities and agricultural runoff with copper-based pesticides or fertilizers (Studi *et al.*, 2013). More details on copper distribution in 40 groundwater samples from Temeke is shown in Figure 4.

Iron (Fe)

Iron (Fe) is naturally present in the environment and can be found in air, water, soil, plants, and animals (Chaki, 2015). Industrially, iron is widely produced and used in various applications. However, excessive intake of iron can lead to health effects, including stomach and intestinal problems, as well as potential organ damage. Through this study Fe concentrations were observed in the range from 0.02 ± 0.01 to 3.55 ± 0.02 mg/l. The observed Fe concentration from groundwater samples indicated no significant difference ($P > 0.05$) from TBS standard limit of 0.3 mg/L. This suggests that the iron levels observed in groundwater from Temeke Municipal are within the TBS standard. Previous study by Chaki (2015) reported lower Fe concentrations ranging from 0.14 to 0.23 mg/L in groundwater from Temeke. The increase in Iron concentration might have been accelerated by anthropogenic activities in the area, such as sawmills, woodworks, and auto-repair workshops (Chaki, 2015). High Fe concentration in water affects water taste, odour, and appearance. Figure 5 shows more details on the observed Fe concentrations.

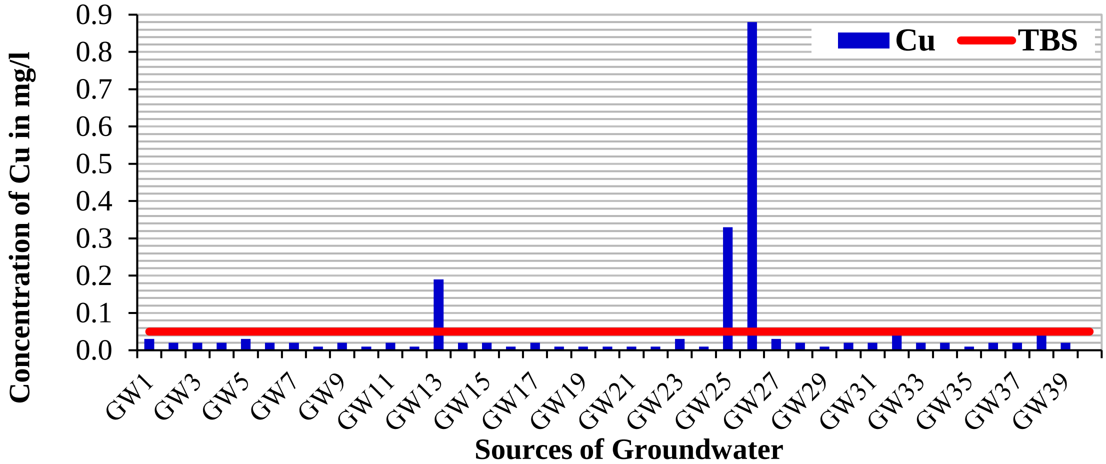

Figure 4: Copper concentration in groundwater samples from Temeke Municipal.

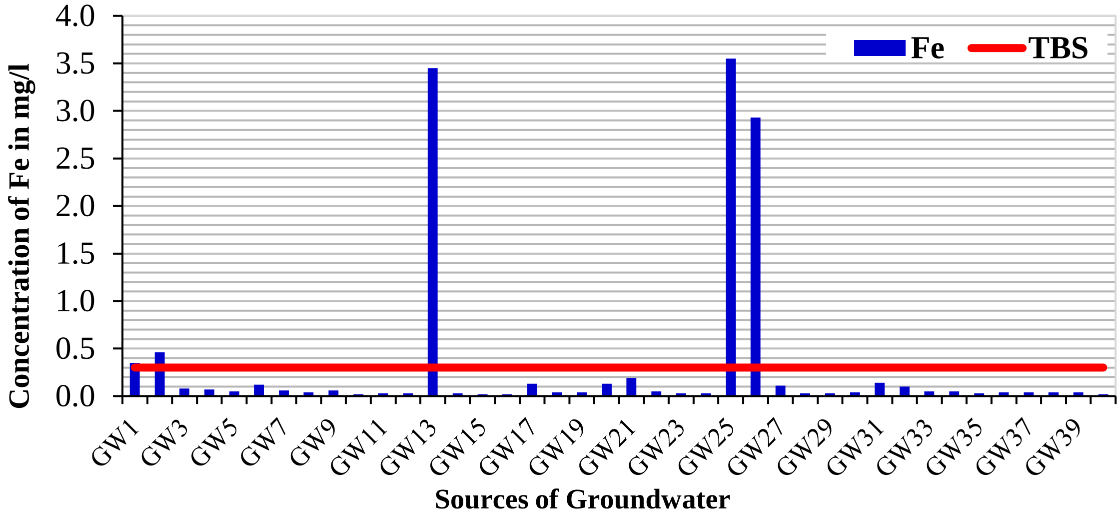

Figure 5: Iron concentration in groundwater samples from Temeke Municipal.

Lead (Pb)

Lead occurs naturally and due to human actions in air, water, soil, and organisms. It's used in industries like batteries and construction. Yet, lead exposure causes serious health problems, impacting the nervous system and causing developmental, cognitive, and long-term health issues (Taiwo *et al*., 2023). Since the late 1970s, lead exposure has notably decreased due to various actions, including eliminating lead from gasoline and reducing lead in paints, cans, and plumbing. However, despite of various measures taken to reduce Lead concentration in various materials, there are still Lead exposure risks from various sources including groundwater. The revealed Lead concentrations in 40 groundwater from Temeke Municipal ranged from 0.16 ± 0.01 to 0.02 ± 0.01 mg/l exceeding the TBS standard level of 0.01

mg/l. Inferential statistical analysis showed significantly ($P < 0.05$) higher concentration compared to TBS standard limit. This study found relatively lower concentrations compared by values reported by Kacholi and Sahu (2018) who reported Lead concentrations ranging from 0.46 mg/l to 0.55 mg/l. The differences in Lead concentrations might be associated to various factors such as improved environmental regulations and industrial practices, such as stricter controls on lead emissions and the ban on leaded gasoline in Tanzania since 2003. The ban of leaded gasoline aimed to align with global efforts to reduce lead pollution and protect citizens' well-being and the environment. Transitioning to unleaded gasoline might have successfully reduced lead emissions, contributing to improved air and water quality in Dar es Salaam (Gerutu *et al.*, 2023). More details of Pb concentrations in groundwater from Temeke is shown in Figure 6.

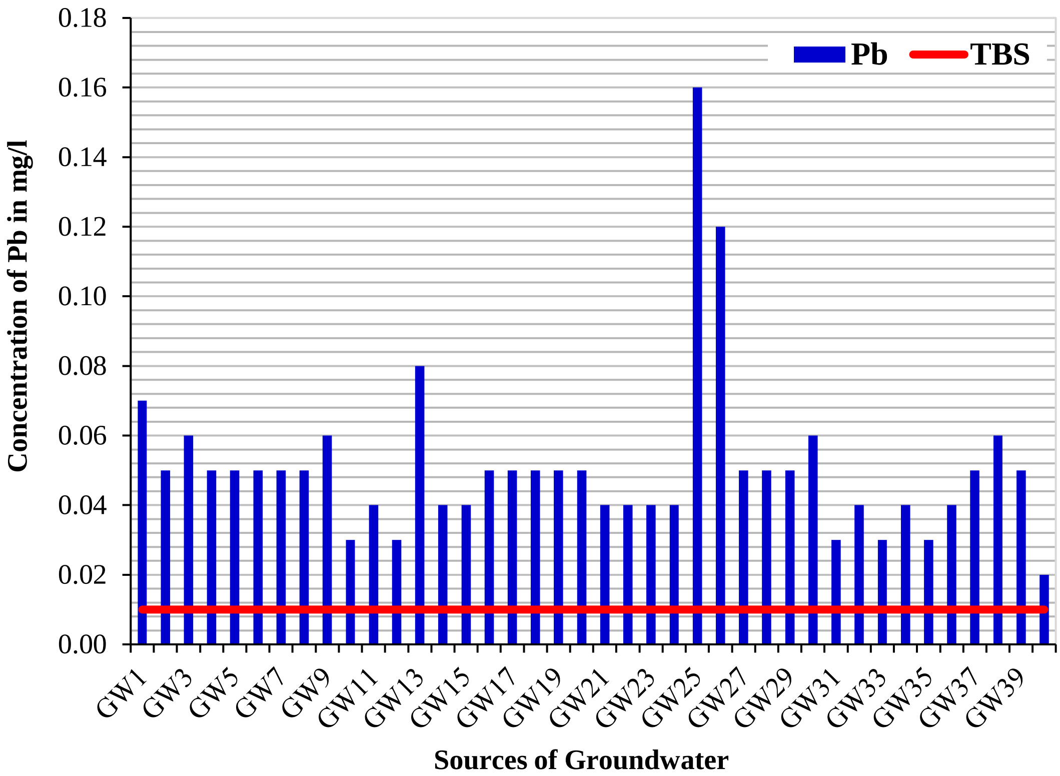

Figure 6: Lead concentration in groundwater samples in Temeke municipal.

Manganese (Mn)

Manganese is naturally present and introduced in air, water, soil, and organisms by humans. It's used industrially but high exposure can lead to health problems like neurological and respiratory problems. The measured concentration of Manganese in groundwater from Temeke municipal revealed varying concentrations from 0.00 ± 0.00 to 4.63 ± 0.03 mg/l. When compared with TBS standard, results from this study showed no significant difference ($P > 0.05$) with TBS standard limit of 0.1 mg/l. The observed concentrations were within acceptable limits according to the TBS standard. However high concentrations were observed in groundwater from well number 13, 25 and 26 with concentration level of 0.52 ± 0.01 mg/l, 4.63 ± 0.03 mg/l and 1.19 ± 0.01 mg/l respectively. The study done by Chaki (2015) in the same area, reported mean manganese concentrations ranging from 0.07 ± 0.02 mg/L to 0.08 ± 0.02 mg/L. However, the study revealed elevated manganese concentrations in certain sampling sites within Temeke Municipal, the trend which was also observed in this study. Potential factors contributing to high concentration of Mn includes industrial activities, agricultural practices and the use of manganese-based compounds such as manganese chloride. Figure 7 illustrates the concentrations of manganese in the groundwater samples from Temeke Municipal.

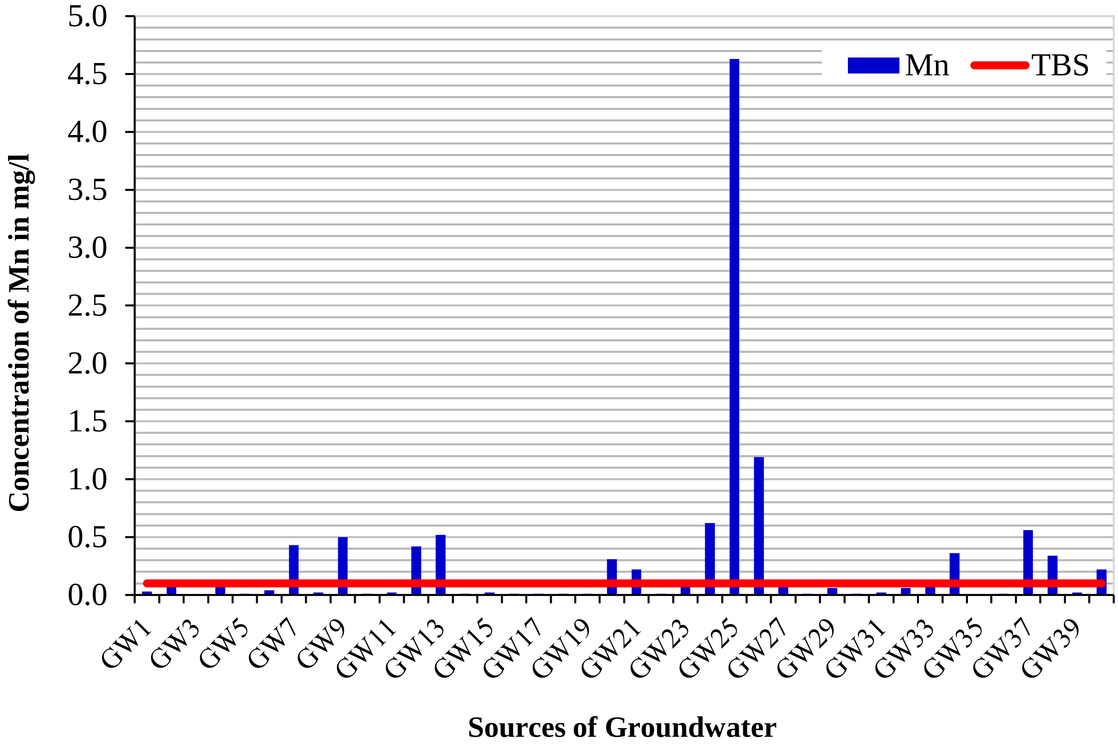

Figure 7: Manganese concentration in groundwater samples from Temeke municipal

Zinc (Zn)

Zinc (Zn) is naturally occurring metal which is introduced in air, water, soil, and organisms through human activities. Zinc is widely used across industries, with applications including galvanizing steel, manufacturing batteries and producing cosmetics. However, excessive exposure to zinc can lead to health effects such as digestive issues and, in extreme cases, neurological problems (Taiwo *et al*., 2023). This study observed Zinc concentration in groundwater in the range from 0.01 ± 0.01 to 3.00 ± 0.01 mg/l. When compared to TBS standards the observed concentrations were significantly lower ($p < 0.05$) than TBS standard of 3 mg/l. Previous study by Kacholi and Sahu (2018) reported higher zinc concentrations ranging from 0.35 to 1.19 mg/l, which are relatively higher than the observed concentration in this study. The observed difference in results could be attributed to several factors including variations in sampling locations, change in pollution sources or improvements in environmental management and industrial practices over time. For example, the establishment of Kurasini wastewater treatment plants in Temeke Municipal, contributes to reducing pollutant discharge into the environment, consequently, contamination of groundwater sources is reduced (Wawa, 2020). Figure 8 provides more details of Zinc concentrations in groundwater samples from Temeke Municipal.

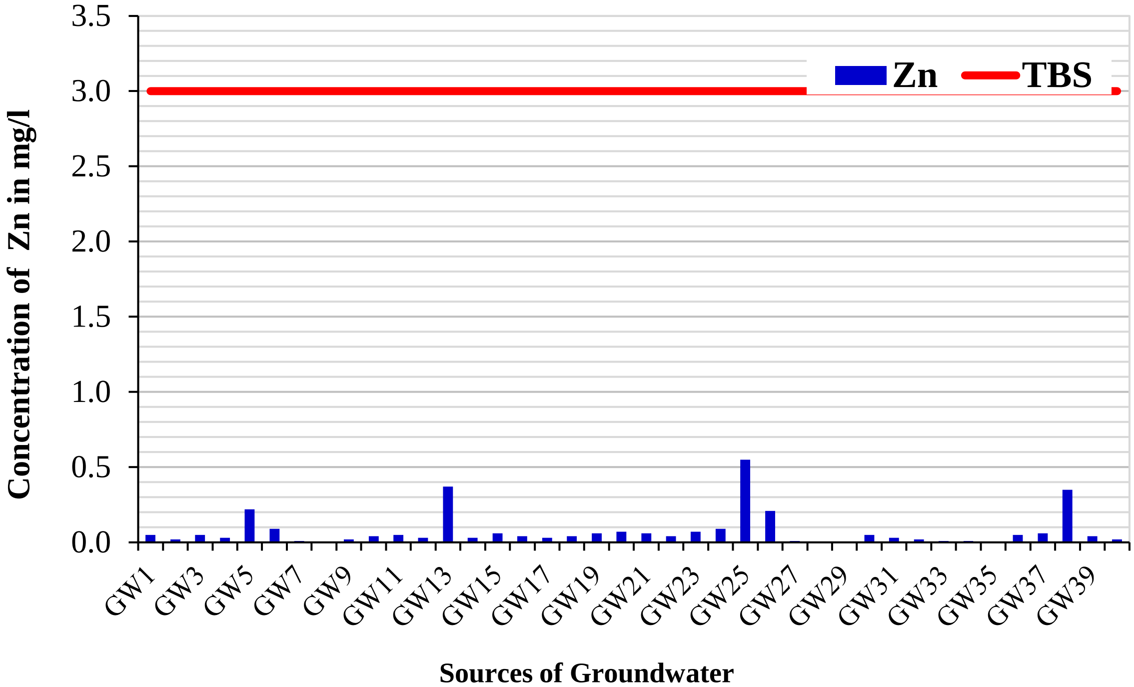

Figure 8: Zinc concentration in groundwater samples from Temeke municipal.

Health risk induced by heavy metal ingestion

The health risk assessment was done by determining the HQ and HI in all 40 groundwater samples using heavy metals concentration determined in this study. Obtained results are presented in Table 4.

Hazard Quotient (HQ)

The findings showed that the Hazard Quotient (HQ) values for Arsenic (As), Cobalt (Co), Copper (Cu), Iron (Fe), Manganese (Mn), Lead (Pb) and Zinc (Zn) are in the following decreasing order As > Pb > Mn > Cu > Fe > Co > Zn. For Arsenic (As), Lead (Pb) and Manganese (Mn) the calculated HQ values were greater than 1 (HQ >1), indicating a considerable potential health risk due to elevated concentrations in respective groundwater. Unlike, Cobalt (Co), Copper (Cu), Iron (Fe) and Zinc (Zn) where the calculated HQ values were less than 1 (HQ < 1), suggesting a relatively lower health risk associated with exposure. More details on the obtained HQ and HI are shown in Table 4.

Hazard Index (HI)

The Hazard Index in all 40 samples was greater than 1 (HI > 1). Higher HI value suggests a higher likelihood of adverse health effects from exposure to heavy metals. It is important to note that HI values exceeding 1 indicate a potential health risk, emphasizing the need for appropriate measures to ensure the safety of groundwater sources in Temeke Municipal (Barzegar *et al.*, 2019; Boaten *et al.*, 2019). Figure 9 presents the Hazard Index of the groundwater from Temeke municipal, Dar es Salaam**.** These findings are similar to the results obtained by Hossein (2014) who also found a considerable number of heavy metals including Zn and Cu were present as contaminants within acceptable limits while the amount of Pb in water from Temeke exceeded the recommended limits. On the other hand, the findings appear to support the results by Mahugija (2018) who revealed the highest concentration of Pb and Fe in water from Temeke municipality. Hence, it is essential to impose a strict regulatory control on the safety of groundwater sources around Temeke municipal.

Table 4: Hazard Quotient (HQ) and Hazard Index (HI) in groundwater from Temeke Municipal

Ground water Samples	METALS							
	As	Co	Cu	Fe	Mn	Pb	Zn	
	HQ	HQ	HQ	HQ	HQ	HQ	HQ	HI
GW1	8.90	0.04	0.02	0.02	0.07	1.57	0.01	10.63
GW2	11.10	0.04	0.02	0.02	0.18	1.12	0.00	12.49
GW3	7.96	0.05	0.02	0.00	0.00	1.35	0.01	9.39
GW4	10.16	0.03	0.02	0.00	0.25	1.12	0.01	11.59
GW5	11.42	0.05	0.02	0.00	0.02	1.12	0.02	12.67
GW6	7.44	0.03	0.02	0.01	0.09	1.12	0.00	8.70
GW7	12.26	0.05	0.02	0.00	0.97	1.12	0.00	16.93
GW8	11.10	0.05	0.01	0.00	0.04	1.12	0.00	12.33
GW9	12.15	0.05	0.02	0.00	1.23	1.35	0.00	14.81
GW10	33.10	0.04	0.01	0.00	0.02	0.67	0.00	33.86
GW11	32.48	0.04	0.02	0.00	0.04	0.90	0.01	33.48
GW12	31.85	0.04	0.01	0.00	0.94	0.67	0.00	33.52
GW13	31.53	0.04	0.15	0.15	1.17	1.80	0.04	34.88
GW14	31.43	0.03	0.02	0.00	0.02	0.90	0.01	32.40
GW15	29.44	0.03	0.02	0.00	0.04	0.90	0.01	30.44
GW16	31.01	0.03	0.01	0.00	0.02	1.12	0.00	32.20
GW17	30.49	0.04	0.02	0.01	0.02	1.12	0.00	31.70
GW18	30.59	0.04	0.01	0.00	0.02	1.12	0.00	31.79
GW19	30.28	0.05	0.01	0.00	0.02	1.12	0.01	31.49
GW20	31.01	0.05	0.01	0.01	0.70	1.12	0.01	32.90
GW21	32.16	0.05	0.01	0.01	0.49	0.90	0.01	33.63
GW22	33.84	0.04	0.01	0.00	0.02	0.90	0.00	34.81
GW23	59.92	0.04	0.02	0.00	0.18	0.90	0.01	61.08
GW24	61.70	0.04	0.01	0.00	1.39	0.90	0.01	64.06
GW25	40.44	0.07	0.26	0.16	10.39	3.59	0.04	54.96
GW26	63.90	0.05	0.69	0.13	2.67	2.69	0.02	70.16
GW27	54.58	0.05	0.02	0.00	0.18	1.12	0.00	55.97
GW28	56.05	0.03	0.02	0.00	0.02	1.12	0.00	57.24
GW29	57.72	0.03	0.01	0.00	0.13	1.12	0.00	59.02
GW30	55.21	0.05	0.02	0.00	0.02	1.35	0.01	56.65
GW31	69.56	0.03	0.02	0.01	0.04	0.67	0.00	70.34
GW32	64.53	0.04	0.03	0.00	0.13	0.90	0.00	65.65
GW33	65.69	0.03	0.02	0.00	0.22	0.67	0.00	66.63
GW34	60.66	0.04	0.02	0.00	0.81	0.90	0.00	62.42
GW35	65.69	0.02	0.02	0.00	0.00	0.67	0.00	66.40
GW36	32.90	0.02	0.02	0.00	0.02	0.90	0.01	33.86
GW37	60.24	0.03	0.02	0.00	1.26	1.12	0.01	62.67
GW38	31.53	0.03	0.04	0.00	0.76	1.35	0.04	33.75
GW39	32.90	0.03	0.02	0.00	0.04	1.12	0.00	34.12
GW40	34.68	0.03	0.00	0.00	0.49	0.45	0.00	35.65

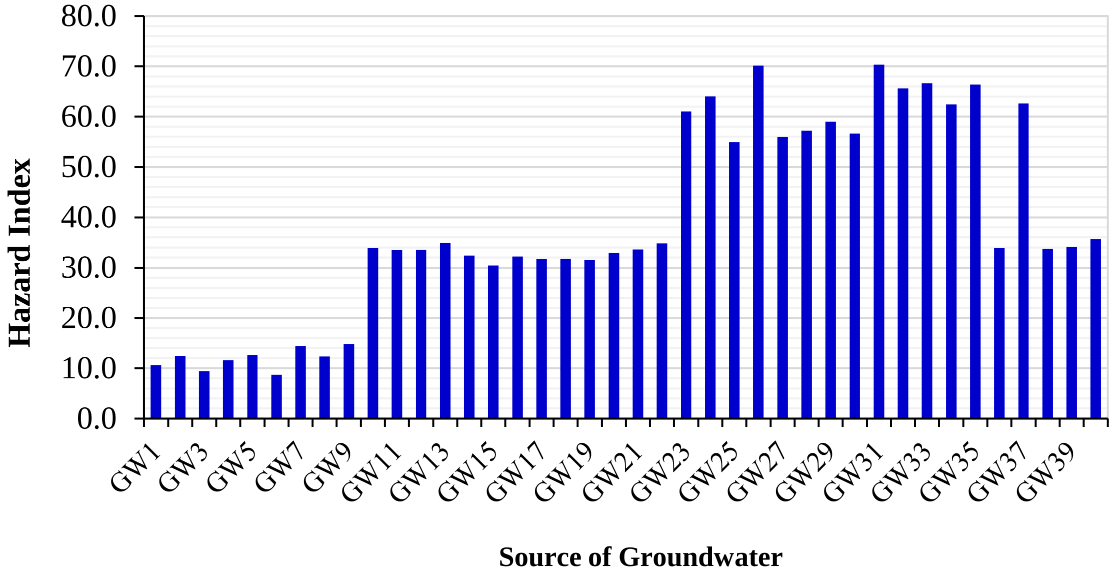

Figure 9: Hazard Index of Groundwater from Temeke municipal Dar es Salaam.

CONCLUSION AND RECOMMENDATION

This study investigated the heavy metal concentration and their associated health risk in Temeke Municipal. The groundwater sources in Temeke municipal continue to be potential alternative source of water for domestic uses due to insufficient water supply by DAWASA. However, due to various anthropogenic activities, groundwater safety is questionable due to high level of pollution including heavy metals. This study concludes that groundwater in Temeke Municipal has been polluted through various anthropogenic activities. The concentrations of As, Co and Pb are higher than the TBS standard while the concentrations of Cu, Fe, Mn and Zn are within TBS standard limit.

The Hazard Quotient (HQ) decreases in the order As > Pb > Mn > Cu > Fe > Co > Zn. The calculated HQ values for As, Pb and Mn in the groundwater from Temeke municipal is greater than 1 (HQ >1) indicating high potential health risk associated with their elevated concentrations in groundwater. The Hazard Index (HI) for all 40 samples were greater than 1 (HI > 1), suggesting higher likelihood of adverse health effects from exposure to heavy metals through groundwater consumption. Continued usage of groundwater form Temeke increases the risk of contracting various health problems.

Recommendations

The study recommends that public awareness on the risk of heavy metal be raised among the community and groundwater users on the potential health risks associated with heavy metal contamination in groundwater. Information on alternative water sources and the importance of regular water testing should be disseminated to the community. Water quality monitoring and remediation measures should be conducted to ensure water quality and safety. This will help identify any fluctuations or emerging contamination issues promptly. Strengthen regulatory measures and collaboration through enforcing existing environmental standards and regulations to minimize and control the discharge of heavy metals into the environment. This can involve stricter monitoring, imposing penalties for non-compliance, and promoting environmentally-friendly industrial practices. And also, collaboration should be fostered among government agencies, research institutions, water management authorities and industries to address the issue of heavy metal contamination in groundwater. These will encourage exchange of knowledge, data sharing and joint initiatives to develop effective strategies for pollution prevention and remediation. Water quality and safety should be the foremost priority in planning and implementation of various measures to ensure safety and health of the people.

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