Levels of Hexavalent Chromium, Copper, and Total Hardness in Springs and Underground Water in Zanzibar Island

Abdul A. J. Mohamed[1*], Ibrahim Abdul Rahman[2], Sadri A. Said[3], Lee H. Lim[4], Islam S. Mchenga[5]

[1]Faculty of Science (FOS)
Universiti Brunei Darussalam
Jalan Tungku, Brunei Darussalam, BE1410

[2]Faculty of Science (FOS)
Universiti Brunei Darussalam
Jalan Tungku, Brunei Darussalam, BE1410

[3] School of Pharmacy, College of Pharmacy, and Nursing
University of Nizwa, Birkat Al Mouz,
PB 33, PO 616, Nizwa, Sultanate of Oman

[4]Faculty of Science (FOS)
Universiti Brunei Darussalam
Jalan Tungku, Brunei Darussalam, BE1410

[5] First Vice President Office Zanzibar, Tanzania

ABSTRACT— ***This study aimed at assessing the level of total hardness and heavy metals (hexavalent chromium and copper) in springs and underground water sources in some areas of tropical Island, Zanzibar. Thirty water samples were analyzed. The Palintest photometer procedures were used to determine the concentrations of hexavalent chromium and copper. The level of total hardness was determined by ethylenediaminetetraacetic acid (EDTA) titration using Eriochrome black-T indicator. Levels of copper, hexavalent chromium and total hardness in the studied samples ranged between 1.38 - 11.0 mg/L, 0.05 - 0.4 mg/L and 32.02 - 1009 (as mg/L $CaCO_3$), respectively. About 77% of all samples have total hardness values higher than the World Health Organization (WHO) guidelines, while the proportion of samples with dangerous concentrations of copper and hexavalent chromium were 70% and 96.6%, respectively. Eighty percent of the water samples fell in the "very hard water" category. The correlation between copper and total hardness, and electrical conductivity and total hardness, were 0.752 and 0.930, respectively. The levels of most of the studied parameters in the drinking water samples exceeded the permissible limits of the WHO drinking water quality guidelines. The results show the urgent need to take immediate mitigation measures and continue the water quality monitoring in Zanzibar, as well as establishing drinking water treatment plants.***

Keywords— Zanzibar, World Health Organization (WHO), drinking water treatment plants, hexavalent chromium.

1. INTRODUCTION

Even in the absence of anthropogenic activities, the levels of metals in underground water can pose a health risk to its users. A good example is the incident of arsenic contamination in groundwater in Bangladesh [1]. The use of underground water without the monitoring of its chemical, physical, and biological constituents may expose its users to adverse health risks. Water is a universal polar solvent. Metals, ionic compounds, and other forms of polar compounds such as humic acids, surfactants, polysaccharides, and proteins can easily dissolve and get mobilized in aquatic systems. Hence, presence of toxic substances that have naturally dissolved in water is of paramount concern in domestic water supply and consumption.

It is for these reasons that the quality of domestic water supply has to be regularly assessed at the sources, and throughout its route to the consuming population. The assessments of water quality are by water sampling and analysis, and estimated by computational modelling [2]. The important water quality parameters to be assessed are microbial loads, heavy metals, hardness, electrical conductivity (EC), trihalomethanes (THMs), persistent organic pollutants (POPs) such as pesticides and polynuclear aromatic hydrocarbons (PAHs). This study was initiated to assess the levels of hexavalent chromium and copper, and total hardness of water collected from Zanzibar.

Among the toxic metals that could find their way into the domestic water supply are transition metals such as chromium, copper, cadmium and mercury. Other important metals are calcium and magnesium, which are associated with water hardness. Chromium in soil could exist in three different oxidation states including divalent, trivalent and hexavalent form. The trivalent chromium is less mobile as compared to the highly soluble hexavalent chromium, which has a solubility of 790 g/L [3]. Furthermore, the hexavalent and trivalent chromium have different toxicity level, the former is toxic, and the trivalent chromium is an essential nutrient [4]. Hexavalent chromium is reported to be carcinogenic, and the prolonged exposure to chromium (VI) compounds may lead to lung cancer [5].

Copper is an essential item in human diet where the recommended level is 1.0 mg of copper per day, however, high intakes of copper can damage the kidneys and liver [6]. Table 1 shows a comparison of drinking water quality guidelines for copper, hexavalent chromium and total hardness as given from different local and international organizations.

Hard water is a good source of micronutrients like, calcium, iodine, and zinc. The typical level of water harness for drinking water is 400 mg/L (as $CaCO_3$), and this potentially provides 96 mg of dietary magnesium per day, which may be an essential supplement to the magnesium in-take through food [7].

The use of hard water at the same time results in accelerated corrosion, and scale deposition of water distribution systems [8]. Water hardness also contributes to the retention of metal or salt on the skin, and on clothes, because water harness causes difficulty in rinsing, and as result leading to contact irritation [9]. Table 2, shows the categories of water hardness as per WHO drinking water quality guidelines [10].

Underground aquifers are the main source of domestic water in Zanzibar. The quality of these water sources is now increasing at risk from the deteriorating environmental conditions, and through water contaminants by natural causes. Therefore, it is vital and essential to conduct frequent assessment of groundwater bodies in Zanzibar. This document reports on the levels of hexavalent chromium, copper and total hardness of water samples collected from underground aquifers in Zanzibar.

2. MATERIALS AND METHODS

2.1 Study area

Thirty water samples were collected from different areas of Zanzibar urban west and their territories. Sampling positions are shown in figure 1. Geographic coordinates of all sampling points were recorded using Global Positioning System (GPS).

2.2 Collection of water samples

In June 2012, underground water samples from the thirty locations were collected in pre-cleaned polyethylene bottles. The samples were taken from springs, public bore wells, private bore wells and hand dug wells (closed and opened ones). The samples were stored at 4^oC prior to analysis to minimize physiochemical changes [11].

2.3 General experimental procedures

Analytical water test tablets (photometer grade) reagents for a specific test were used for the preparation of all solutions. Each sample was analysed for copper and hexavalent chromium using procedures outline in the Palintest Photometer Method (Palintest 5000, Camlab, UK) for the examination of clean water and wastewater. Determination of total hardness was carried out by EDTA titration using Eriochrome black-T indicator (ACS reagent, Germany).

3 RESULTS AND DISCUSSION

Table 1 shows the values of total hardness, hexavalent chromium, electrical conductivity, and copper for each of the studied samples. The range of total hardness falls between 32.03 and 1009 mg/L as $CaCO_3$ (Figure 2). The highest level of total hardness (1009 mg/L) was measured from sampling site 16 (Chukwani) and the lowest (32.03 mg/L) was from sampling site 3 (Kwarara). Figure 2 shows that almost 77% of the water samples had levels of water hardness beyond the WHO (200 mg/L) permissible value. Generally, 80% of the collected water samples fell in the “very hard water” category (Table 3).

Figure 3 depicts the level of hexavalent chromium in the water samples. The concentration of hexavalent chromium ranged from 0.05 to 0.4 mg/L. Water sample from site 30 (K/hewa juu) showed the lowest concentration of Cr (VI).. The highest level of hexavalent chromium observed was from sites 21 and 24 (K/samaki and Malindi). Over ninety six percent (96%) of the water samples had elevated concentration of chromium (VI) compared to the WHO recommended limit (0.05 mg/L, Table 2).

Levels of copper ranged between 1.38 to 11 mg/L (Table1 and Figure 4). Water samples from sites 25 and 27 (A/bovu and M/kwerekwe) showed the lowest level of copper, the highest value was from site 16 (Chukwani). Highest level of copper as well as the highest EC level (8860 µS/cm) at Chukwani might be because of the salt intrusion. As this site is very close to the seashore, there is an apparent influence of the nearby sea to some physico-chemical parameters of the water sample from this site.

Generally, the levels of measured parameters (total hardness, copper, and hexavalent chromium) were higher than those recommended by the WHO and the Tanzania drinking water quality guidelines. There were some variations in the measured parameters from different sampling points. Factors such as anthropogenic activities within and around the water sources, water chemistry and soil chemistry, geological variations (such as soil type) and nature of the wells can influence the transportation, distribution and the fate of the chemicals and other species in the water bodies. For example, water sources located at the vicinity of landfill and sewer show relatively higher degree of contamination than those allocated far from these areas [13]. In the present study, the high level of EC at site 29 (K/hewa chini) is linked to infiltration of wastewaters from the nearby wastewater channel.

Most of the water samples from Kwarara areas (sampling sites 1, 2, 3 and 4) showed lower levels (32.0 – 100.1 as $CaCO_3$ mg/L) of total hardness. Water sampling sites 16 and 22 (both allocated at Chukwani) differed remarkably in their level of copper and total hardness. The level of copper and total hardness from site 22 was 2.4 and 272.27 mg/L respectively. For site 16, the level of copper and total hardness was 11 and 1009 mg/L respectively. This indicates the relationship, distribution, and transportation of the chemicals present in sampling areas can vary remarkably despite their close vicinity.

Statistical analysis of copper, chromium (VI), hardness, and electrical conductivity (EC) data from the thirty water samples showed a strong correlation (Pearson correlation coefficient of 0.752) between copper and total hardness. There was also a strong correlation with Pearson correlation coefficient of 0.930 between total hardness and EC as shown in Figure 5. The EC is a function of total dissolved solids, which inturns might have a positive influence on the level of total hardness.

4 CONCLUSION

Analysis of groundwater samples from Zanzibar have shown high concentrations of copper and chromium (VI) ions as well as elevated levels of hardness. In most cases, the detected levels of these water quality parameters were higher than those recommended by local and international organizations. These results raise an urgent task to domestic water stakeholders in Zanzibar to initiate a quick mitigation response to control this alarming water risks. Furthermore, establishing the drinking water treatment plants are of great importance for reducing the risk of consuming water with elevated levels of contaminants.

5 ACKNOWLEDGMENT

We are very obliged to His Majesty Government of Brunei Darussalam for funding this project, the Office of second vice president of Zanzibar for accepting and giving permission to undertake this study, Zanzibar Water Authority ZAWA for providing necessary assistance.

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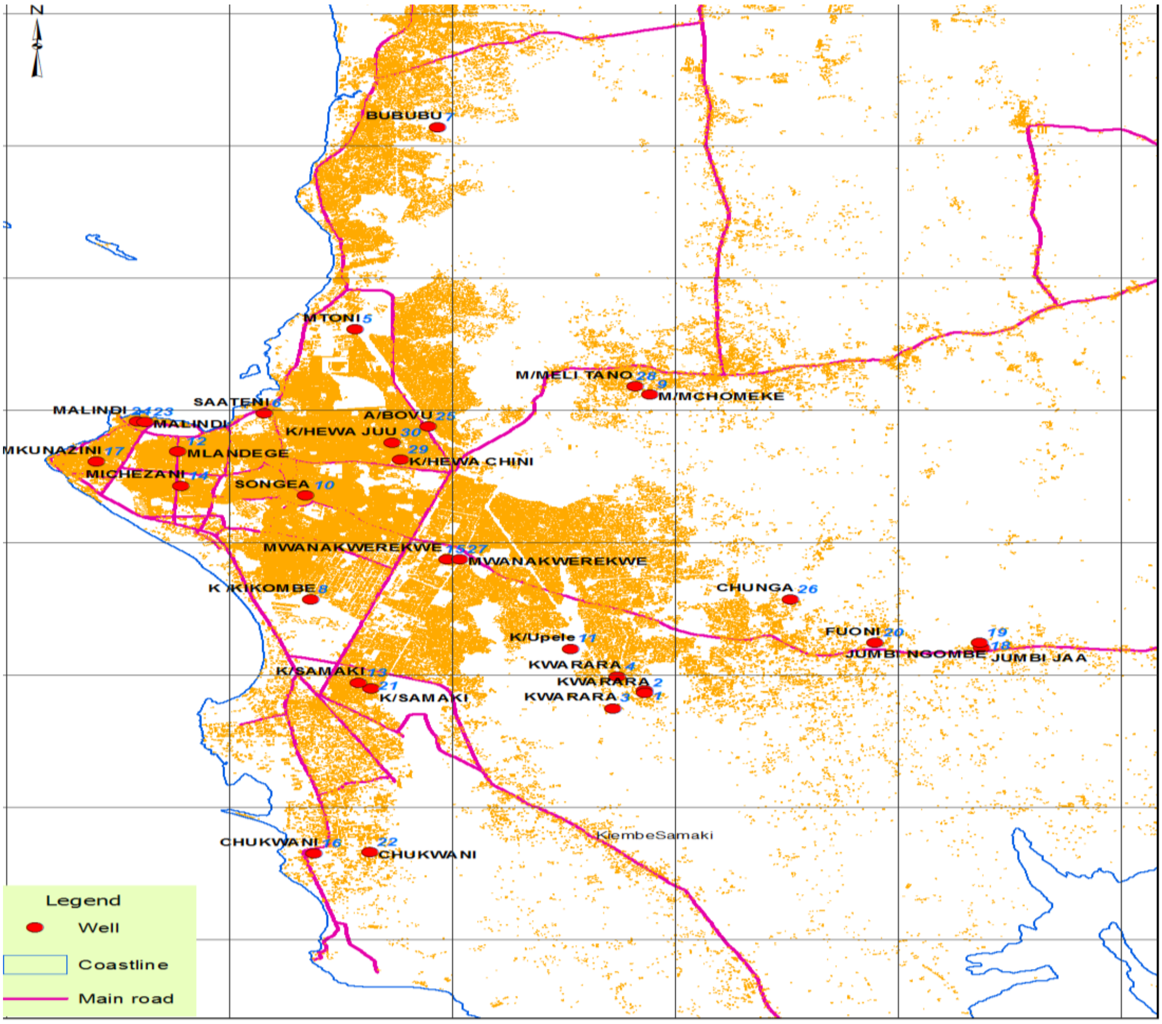

Figure 1: Locations of water sampling sites in Zanzibar Island.

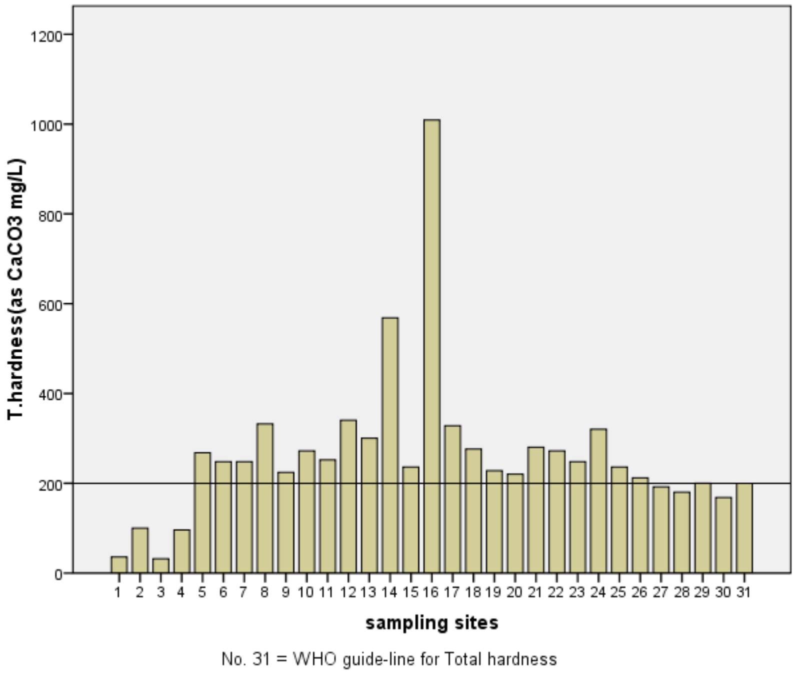

Figure 2: Level of total hardness (as $CaCO_3$ mg/L) for the thirty water-sampling sites

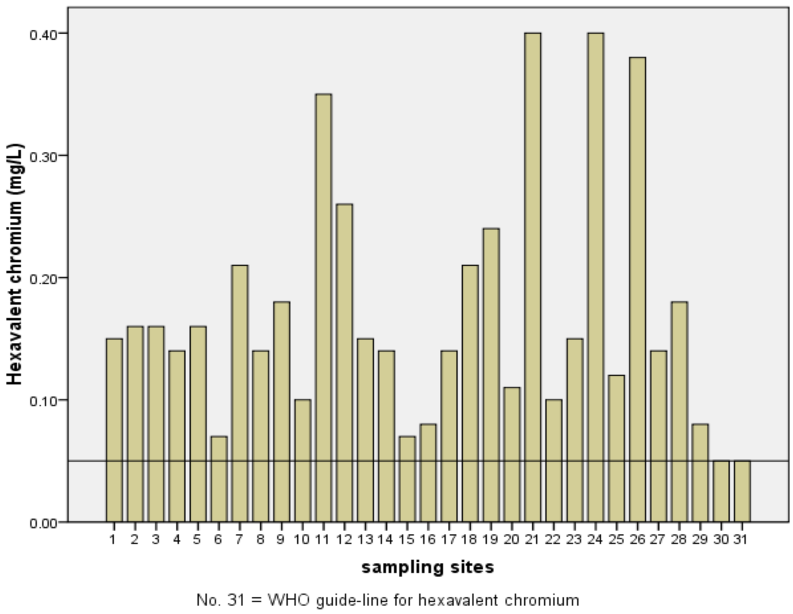

Figure 3: Concentration of hexavalent chromium in thirty water samples

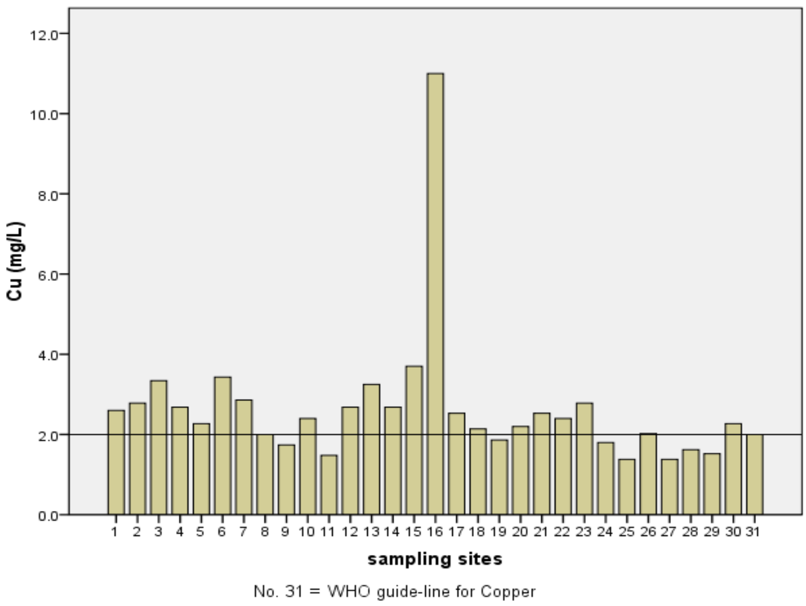

Figure 4: Concentration of copper in thirty water samples

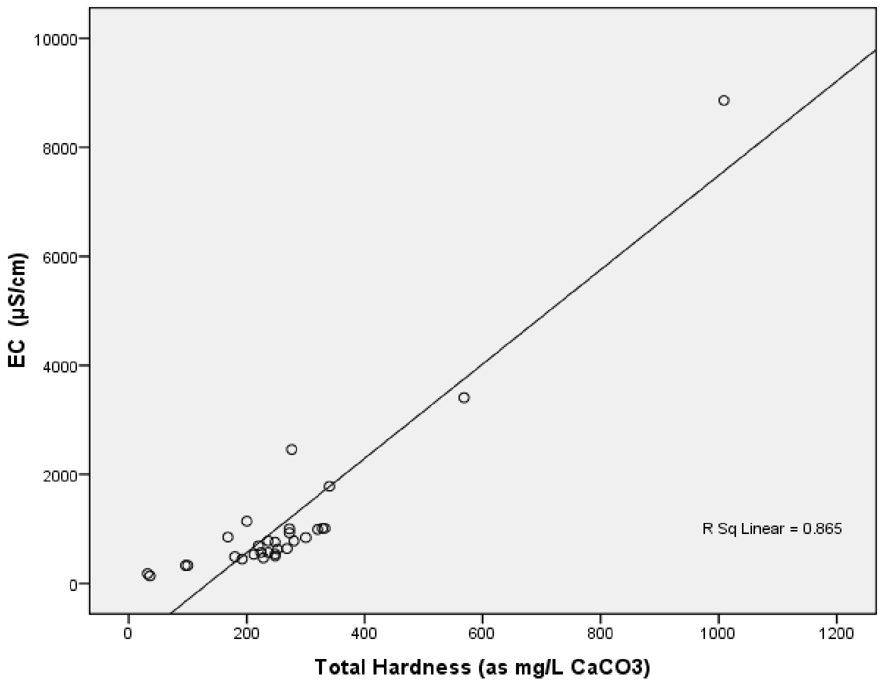

Figure 5: Correlation between EC and Total hardness from thirty water samples.

Table 1: Chemical Parameters from the analysis of groundwater samples

Site Number	SOURCE	EC(µS/cm)	Total Hardness (as mg/L $CaCO_3$)	Hexavalent chromium (mg/L)	Copper (mg/L)
1	CHDW	140	36.0	0.15	2.60
2	OHDW	330	100.1	0.16	2.78
3	OHDW	180	32.0	0.16	3.34
4	OHDW	330	96.1	0.14	2.68
5	SW	640	268.3	0.16	2.27
6	PBW	500	248.3	0.07	3.43
7	SW	540	248.3	0.21	2.86
8	PBW	1010	332.3	0.14	2.00
9	PBW	570	224.2	0.18	1.74
10	CHDW	1000	272.3	0.10	2.40
11	PBW	630	252.3	0.35	1.48
12	BWP	1780	340.3	0.26	2.68
13	CHDW	840	300.3	0.15	3.25
14	CHDW	3410	568.6	0.14	2.68
15	BWP	570	236.2	0.07	3.70
16	BWP	8860	1009.0	0.08	11.00
17	CHDW	1010	328.3	0.14	2.53
18	OHDW	2460	276.3	0.21	2.14
19	OHDW	470	228.2	0.24	1.86
20	CHDW	690	220.2	0.11	2.20
21	CHDW	780	280.3	0.40	2.53
22	CHDW	930	272.3	0.10	2.40
23	BWP	760	248.3	0.15	2.78
24	BWP	990	320.3	0.40	1.80
25	BWP	780	236.2	0.12	1.38
26	PBW	530	212.1	0.38	2.02
27	BWP	450	192.2	0.14	1.38
28	OHDW	490	180.2	0.18	1.62
29	OHDW	1140	200.2	0.08	1.52
30	OHDW	850	168.2	0.05	2.27

Open Hand Dug Well (OHDW); Closed Hand Dug Well (CHDW); Bore Well Private owned (BWP); Public Bore Well (PBW); Spring water (SW)

Table 2: Comparison of drinking water quality guide for copper and hexavalent chromium and total hardness [14], [15]

Parameter	US.EPA Standards (mg/L)	EU standards (mg/L)	TZ standards (mg/L)	WHO standards (mg/L)
Copper	1.0	2.0	3	2.0
Chromium (VI)	0.1	0.05	0.05	0.05
Total hardness (as mg/L $CaCO_3$)	-	-	600	200

Table 3: The categories of water hardness as $CaCO_3$ mg/L, [15]

TOTAL HARDNESS (as $CaCO_3$ mg/L)	WATER TYPE
0-30	Soft
30-60	Moderately soft
60-120	Moderately hard
120-180	Hard
>180	Very hard