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Analysis of physico-chemical properties and heavy metals content of drinking water from selected areas in Gurage Zone, Ethiopia

Sage Desalegn[1*], Lera Israel[2] and Kebede Wouduma[3]

Department of Chemistry, Wolkite University, P. O. Box 07, Wolkite, SNNP Regional Government, Ethiopia.

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Metal contamination in water is a major determinant of water quality. People who consume this water suffer from water borne diseases. There are various natural and anthropological activities at the sample collection site leading to increase in concentration of trace elements in drinking water. Activities like corrosion of metal coated pipes, herbicides, insecticides, ceramic wastes, taking gravel from near water source, etc. may lead to pollution of drinking water by heavy metals like chromium. The objective of this study was to detect metal concentration in spring and tap water from selected residential areas in the Gurage Zone. Tap water samples were collected from seven different locations during the rainy season. Samples were analyzed using atomic absorption spectrometry to determine the concentration of dissolved metal. Metal analysis was done to detect chromium, copper, zinc, lead, cadmium, magnesium and calcium. The results obtained were compared with guidelines for drinking water quality such as the World Health Organization (WHO) guidelines.

Key words: Cadmium, copper, lead metal concentration, chromium, Gurage Zone.

INTRODUCTION

Heavy metal is any metallic element that has a relatively high density and is toxic or poisonous even at low concentrations (Lenntech, 2004). Heavy metals exist as natural constituents of the earth crust and are persistent environmental contaminants, because they cannot be degraded or destroyed. While these elements occur naturally, they are often bound up in inert compound by forming complexes (Mason et al., 2012). Human exposure to harmful heavy metals can occur in many ways, ranging from the consumption of contaminated food, exposure to air-borne particles, and contact or consumption of contaminated water which accumulate over a period of time (Lenntech, 2004). Water related diseases can often be attributed to exposure to elevated heavy metal concentrations of both organic and inorganic contaminants (Galadima et al., 2011). Many of these compounds exist naturally, but their concentration has increased as a result of anthropogenic activities (Huang et al., 2014).

Heavy metal discharged into the aquatic environment is

*Corresponding author. E-mail: desdem0028@gmail.com.

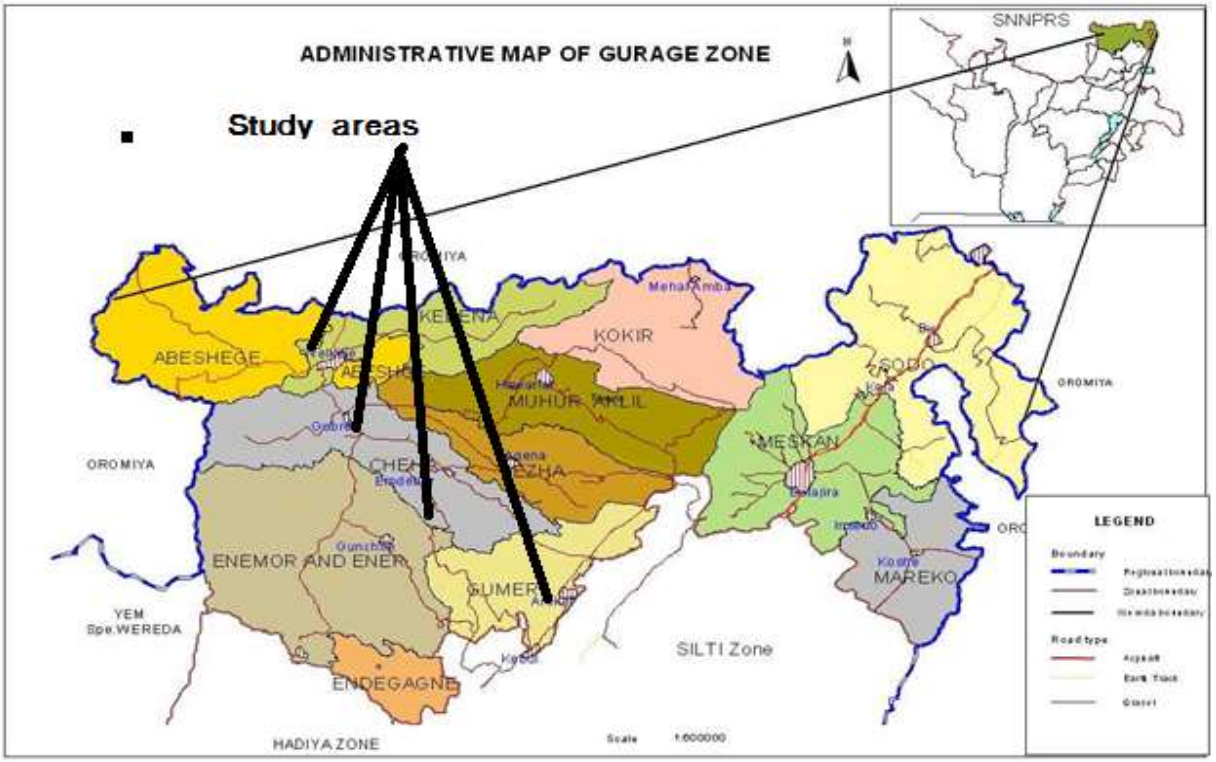

Figure 1. Map of Gurage Zone showing sampling sources.

of great concern all over the world, and have a great ecological significance due to their toxicity and accumulative behavior. Thus, it can damage both aquatic species diversity and ecosystems (Matta et al., 1999). Heavy metals pollution of water resources have been on front burners lately due to the health risks associated with their presence. In Northern West Ethiopia especially Gurage Zone, most rural communities depend largely on spring water as source of drinking water. The areas receive water contaminants generally through the aquatic environment by natural and anthropogenic activities. The main natural sources of pollutants in the study areas which are dissolved solids, leaching of humic substances from rusted pipes, soil itself at sample site which is naturally beachy (used as source of gravel), soil and wind erosion due to deforestation around sample sites, water logging, anthropologic activities including agricultural activities, wastes from local markets, insecticide, herbicide, painting, cement wastes, ceramic dusts, etc, are expected to increase the concentration of heavy metals in ground water during rainy season, this is why the sample was collected during rainy season.

Different healthy officers, doctors and patient files at different health centers and hospitals in this zone indicated that about 80% of patients suffer from water borne diseases like kidney damage, liver damage, stomach ache, diarrhea, vomiting, high fever and gastrointestinal distress. So far, no sufficient study has been conducted on heavy metal level in drinking water of Gurage zone. Therefore the main aim of this study was to (1) investigate the levels of heavy metals such as Cd, Pb, Zn, Cu and Cr in selected areas of Gurage Zone, Ethiopia; (2) evaluate some physico-chemical properties.

RESEARCH METHODOLOGY

Location of the study site

This research was conducted in Gurage Zone around Wolkity City, located in SNNPR, Ethiopia. Welkite (also called Wolkite) is a town and separate woreda in south-western Ethiopia, 158 km from Addis Ababa, capital city of Ethiopia. Wolkite is administrative center of the Gurage Zone of the Southern Nations, Nationalities and Peoples' Region (SNNPR); this town has a latitude and longitude of 8°17′N 37°47′E and an elevation between 1910 and 1935 m above sea level. The study was conducted using spring water from Gumer Wereda Cheha Wereda, tank water from Endibir and tap water from Gubrie and Wolkite city residential areas (Figure 1).

Apparatus and chemicals

All the chemicals and reagents were analytical grade reagents. The apparatus required for this study are automatic pipette (model 27152 Germany), atomic absorption spectrometer (Model ZEEnit 700 P, Anaytic Kjena Germany) and conductivity meter (model-EC 214). Salts of lead(II) nitrate, zinc chloride, copper(ii) sulfate penta-hydrate, chromium(III) nitrate non-hydrate, cadmium nitrate and nitric acid are chemicals used in this study (APHA, 1998).

Sampling, sample collection and preparation of standard solutions

From all communities, water was sampled during rainy season in two months (June to July 2015). Only one water sample was collected from each of the seven sources. A total of seven samples were collected in 2 L polyethylene bottles formerly washed with detergent and double-distilled water followed by 2 M nitric acid, then double-distilled water and finally, bottles were rinsed with sample water three times then kept in 10% (v/v) nitric acid solution for 24 h. Temperature and pH of samples were measured at sample site using portable pH meter which has glass electrode and measures T° and pH simultaneously at sample site (ASTM, 1976; HMSO, 1978; APHA, 1989). Before directly immersed in sample bottle, pH meter was repeatedly rinsed with sample water. All samples were preserved with few drops of concentrated nitric acid until pH is < 2 to dissolve metal and prevent microbial growth; then kept in ice-chests before transportation to Analytical Laboratory of Addis Ababa University. Each sample was used for analysis of two essential metals (Ca and Mg) and five trace metals such as Cd, Cr, Cu Pb and Zn, totaling seven metals. The samples were then stored in a refrigerator at 4°C until the analyses were completed (Samuel et al., 2015)

Standard solutions of the studied metals were prepared from their salts in aqueous solutions containing 2% of nitric acid. With serial dilution of the standard solutions into a series of seven 50 ml volumetric flasks, calibration curve was done for Ca, Cu, Mg, Cd, Pb, Cr and Zn. The determinations were carried out according to the standard methods for water quality (Kimete et al., 2010; Ekere et al., 2014)

To ensure the removal of organic impurities from the samples and thus prevent interference in the analysis, the samples were digested with concentrated nitric acid. 10 ml concentrated HNO_3 was added to 50 ml of water in a 250 ml conical flask. The mixture was evaporated to half of its volume by hot plate then allowed to cool and finally diluted with double deionized water in 50 ml volumetric flask (Kimete et al., 2010). Finally, diluted water sample solutions were analyzed for the presence of each metal using the Atomic Absorption Spectrophotometer (Figueroa, 2008). All analyses were done in laboratory of Chemistry Department, Addis Ababa University.

RESULTS AND DISCUSSION

The pH of most optimum drinking water lies within the range 6.5 and 8.5 (WHO, 1986). As shown in Table 1, all water sources in the study area fall within the acidic range of 5.3 and 6.9 but pH of two samples (Endibir tunk after treatment and WKU student cafeteria) is in the range of potable drinking water recommended by Environmental Protection Agency (EPA) and World Health Organization (WHO). Lower pH value may be due to the presence of different ions/cations not included in the present study. Values below 5.6 slightly deviate from range for potable drinking water which may cause corrosion of pipe and valves. Gumer Wereda especially, Wegefecha Kebele near the sample source has the highest environmental pollution due to deforestation of natural forest for farming purposes. This activity increases concentration of carbon dioxide (CO_2) which reduces pH level.

In this study, chromium was detected in five of the sampling areas and two sample sources (Endibir source and Welkite University student cafeteria) did not have detectable amount of chromium metal. Chromium level varies from 0.004 in Ogefecha to 0.006 mg/L in camp, which are above the WHO (2008) maximum admissible limit of Cr in drinking water (0.002 mg/L). Of all the samples analyzed, 71.43% contain chromium level above WHO (2008) maximum admissible limit with the highest level recorded in samples from Ogefecha (detected concentration, 0.006 mg/L). Chromium III is an essential micronutrient for animals and plants, and is considered as a biological and pollution significant element. Sub-chronic and chronic exposure to chromic acid can cause dermatitis and ulceration of the skin. Long-term exposure can cause kidney, liver, circulatory and nerve tissue damages.

Under normal conditions, chromium exists in two stable oxidation states: chromium III (trivalent) and chromium VI (hexavalent). Chromium VI exists on the chromate anion, which is more water soluble and mobile than chromium III. It is found in rocks, soil, plants, animals and emissions from volcanoes. Chromium is used in making steel and alloys, furnace bricks, dyes, chrome plating, leather tanning, preserving of wood, and as inhibitor in cooling towers. Chromium is released into the environment through manufacturing process, disposal of chromium wastes and burning of fossil fuel (Morry, 1999; IARC, 1980). In the sample site, there are various natural and anthropogenic activities that may cause high level of chromium in drinking water. Naturally, the soil is beachy and is currently used as source of gravel for road construction. Anthropogenic activities like soil acidification, overgrazing, painting, cement wastes, ceramic dusts, herbicides, metallic pipes, and storm water and land erosion are considered to increase chromium concentration in drinking water.

The fate of chromium in soil and ground water depends on the form of chromium present. Chromium III may also be oxidized to chromium VI under other naturally occurring oxidizing conditions and during chlorination of drinking water supplies (Chung et al., 2000). Originally, hydrologists and geologists assumed that chromium VI results mainly from industrial contamination. It was also thought that where chromium exists naturally, the chromium VI portion is relatively small. In soil, chromium (III) predominates. Chromium (VI) can easily be reduced to chromium (III) by organic matter (IARC, 1980).

In the literature, it was mentioned that chromium III is an essential element and has no effect on human health. High amount of chromium in water sample is due to existence of high amount of chromium III. Major source of chromium VI is industrial activity but there is no industrial activity near the sample site. Lower pH of water also causes corrosion of pipes which lead to leaching of metals into water because at sample site, water is connected to metallic pipes. In addition, as discussed earlier, the easy oxidizing property of chromium VI to chromium III makes the water samples to have a

Table 1. Physico-chemical parameters of samples.

S/N	Sample name	Parameter			
		Color	Temperature	pH	Solution conductivity
1	Megenase	No	23.5	6.3	8.74
2	Source to welkite City	No	23.2	5.6	6.54
3	Endibir tunk water after treatment	No	23.2	6.9	32.7
4	Wolkite cump	No	23.7	6	5.79
5	Endebir city	No	23.3	5.9	13.75
6	Ogefecha	No	23	5.3	5.89
7	WKU student cafeteria	No	22	6.8	2.43
	WHO	No		6.5 - 8.5	0 - 800

No = Not observed.

Table 2. Concentration of heavy metals Ca, Mg, Cd, Cu, Cr, Cu and Zn (mg/L) in drinking water samples from selected rural and cities in Gurage zone, Ethiopia

S/N	Sample sources	Concentration of metals (mg/l)						
		Ca	Mg	Cr	Cu	Pb	Cd	Zn
1	Ogefecha	6.85	ND	0.004	ND	ND	ND	0.085
2	Endibir city	7.58	0.24	ND	ND	ND	ND	0.34
3	Source Wolikite city	9.86	0.74	0.005	ND	ND	ND	1.156
4	Students cafeteria	28.57	8.87	ND	ND	ND	ND	0.7
5	Sources in Welkite before treatment	7.0	0.40	0.006	ND	ND	ND	0.3
6	Megenase	10.47	0.57	0.004	ND	ND	ND	0.76
7	Wolkite Camp	9.54	0.64	0.006	ND	ND	ND	0.85
	WHO			0.002	1.00	0.050	0.003	5

ND = Not determined.

maximum concentration of chromium III and there is no experiment on identification of chromium III and VI.

The overall concentration of lead and cadmium as shown in Table 2 for both sources (spring and tape water) was below detection limit. So, the present study showed that samples were free of lead and cadmium contamination. At higher concentrations, cadmium is known to have a toxic potential. The main sources of cadmium are industrial activities; the metal is widely used in electroplating, pigments, plastics, stabilizers and battery industries. There are no industries around the sample sources which may be the reason why this metal is not present in the drinking water samples. Cadmium is highly toxic and responsible for several cases of poisoning through food. Small quantities of cadmium cause adverse changes in the arteries of human kidney. It replaces zinc biochemically and causes high blood pressure and kidney disease. Recommended value of cadmium and lead is low (3 μg/L) and Pb (10 μg/L).

Zinc is one of the important trace elements that play a vital role in the physiological and metabolic process of many organisms. In this study, a minimum of 0.085 mg/L and maximum of 1.156 mg/L zinc concentration were recorded in water samples from Ogefecha and Welkite source, respectively. The level of zinc in all the sample sources is below recommendable concentration of WHO. This indicates there is no health problem related with zinc in this study.

Conclusion

Two essential and five trace metals were assessed in water sample from rural and city settlements. Physico-chemical parameters like color, temperature and conductivity of all water sample showed that the sample is good for drinking, except the pH that was between 5.3 and 6.9, which is below recommended value of potable drinking water by WHO, and corrosion of pipe, has no negative health effect on human in this range. The result of heavy metals: cadmium, lead and copper assay showed low detection limit, except chromium which present value above the recommended value of potable drinking water. As shown in Table 2, chromium level is above the recommended value of potable drinking water by WHO. Chromium exists in two common stable oxidation states: chromium III and VI, but it is toxic only in VI oxidation state; therefore, high concentration in this study is due to high level of chromium in essential form or III state.

RECOMMENDATIONS

The following are recommended for all responsible authorities: (1) Identify whether high level of chromium concentration is due to its III or VI oxidation state; (2) Prevent careless waste disposal in river water, canals or any reservoirs that supply domestic drinking water, specially ceramic waste, herbicides and insecticide; (3) Avoid excess chlorination because it oxidizes chromium III to chromium VI and it is better to use plastic tube rather than metallic or steel tube coated with chromium; (4) Give training on effect of deforestation on quality of drinking water at Gumer Wereda, especially to Wegefecha Kebele people; (5) Collect samples based on seasonal variation and use replicate readings; (6) Conduct further study on other physical, chemical and biological parameters of significant health concern.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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