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Sodium and Potassium Analysis of Drinking Water Quality Assessment and Its Health Effects in Ethiopia: A Retrospective Study

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ABSTRACT

In this retrospective study was aimed to examine the distribution of sodium and potassium parameters and its health impact in selected drinking water sources of Ethiopia. In the study 343 water samples data were used and tested in Environmental Public Health Chemistry Laboratory at Ethiopian Public Health Institute from April 2017 to November 2019. The samples data were collected from Amhara, Oromia, Somalia and Afar regions and Addis Ababa administrative city of the country and were classified based on the source type as spring, well and piped water. The tested physicochemical parameters are sodium (Na^+) and potassium (K^+) were investigated. The sodium and potassium parameters analysis were executed based on standard method. Microsoft Excel Statistical software was used for the statistical analysis of mean, maximum and graph. All average concentration of sodium was found below 200mg/l in all regions and water type sources except Afar region in well water type source, whereas, all average concentration of potassium was found above 1.5 mg/l of drinking water standard of Ethiopia in all regions and water type sources. A very high sodium and potassium concentration in spring water sources are 40 mg/L and 9.9 mg/L, in piped water sources, 89mg/L and 17mg/L from Oromia and well water sources, 1000 mg/L from Afar and 32 mg/L from Oromia respectively. In this retrospective study the sodium and potassium concentration in the water sample varied from 0.2 mg/L to 1000 mg/L and 0.0 mg/L to 32mg/L respectively. When we compare with standards, the drinking water analysis cause serious health problem because the results are not conforming to national standard this result in public health problem in long time exposure. Therefore, the Ethiopia water authority shall work focus on water quality assessment and controlling mechanism.

Keywords: Potassium, Sodium, Piped, Drinking water, Parameter, Ethiopia

Abbreviations: FDEP: Florida Department of Environmental Protection; WHO: World Health Organization; APHA: American Public Health Association; ES: Ethiopian Standard

INTRODUCTION

Water is an essential component of the environment and it sustains life on the earth. Human beings depend on water for their survival. Water is also a raw material for photosynthesis and therefore, is important for crop production. Obviously, an optimum agricultural production depends on water and soil quality [1]. Safe drinking water is a basic need for good health, and it is also a basic right of humans. Fresh water is already a limiting resource in many parts of the world. In the next century, it will become even more limiting due to increased population, urbanization and climate change [2]. Drinking water quality is a relative term that relates the composition of water with effects of natural processes and human activities. Deterioration of drinking water quality arises from introduction of chemical compounds into the water supply system through leaks and cross connection [3].

The quality of water is affected by an increase in anthropogenic activities and any pollution either physical or chemical causes changes to the quality of the receiving water body [4].

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Chemical contaminants occur in drinking water throughout the world which could possibly threaten human health. In addition, most sources are found near gullies where open field defecation is common and flood-washed wastes affect the quality of water [5].

The sodium ion is ubiquitous in water. Most water supplies contain less than 20 mg of sodium per liter, but in some countries levels can exceed 250 mg/L. Saline intrusion, mineral deposits, seawater spray, sewage effluents and salt used in road de-icing can all contribute significant quantities of sodium to water. In addition, water-treatment chemicals, such as sodium fluoride, sodium bicarbonate and sodium hypochlorite, can together result in sodium levels as high as 30 mg/L. Domestic water softeners can give levels of over 300 mg/L, but much lower ones are usually found [6].

In a survey of 2100 water samples in the USA in 1963-1966, the sodium ion concentrations found were in the range 0.4-1900 mg/L; in 42% of the samples, the concentrations were in excess of 20 mg/L, but in 5% they were greater than 250 mg/L. In a later survey of 630 water-supply systems in the same country, the sodium ion concentrations found ranged from less than 1 to 402 mg/L, with similar distribution of values [7].

Sodium ion is ubiquitous in water, owing to the high solubility of its salts and the abundance of sodium-containing mineral deposits. Seawater contains about 30,000 mg of sodium chloride per liter (mg/L). Sodium chloride can also be found in many rivers and inland lakes and seas, in concentrations varying from 20 mg/L in the Mississippi River to 120,000 mg/L in the Great Salt Lake. Groundwater typically contains higher concentrations of minerals and salts than surface waters, especially in areas with an abundance of sodium mineral deposits or in areas with sea or estuarine water intrusions [8]. Sodium is a silver white metallic element and found in less quantity in water. Proper quantity of sodium in human body prevents many fatal diseases like kidney damages, hypertension, headache etc. In most of the countries, majority of water supply bears less than 20 mg/l, while in some countries the sodium quantity in water exceeded from 250 mg/L [9].

Potassium is alkali metal and the seventh most common element on earth [10]. It comprises 2.59% of the Earth's crust, is highly reactive and does not occur in nature as a free metal [11]. Potassium has a crystal structure, has high thermal and electrical conductivities [11] and is rapidly oxidized in moist air [10]. It has a melting point of 63.5°C, a boiling point of 759°C and a density of 0.89 g/cm3 at 20°C [12]. Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. It occurs widely in the environment, including all-natural waters. It can also occur in drinking-water as a consequence of the use of potassium permanganate as an oxidant in water treatment. In some countries, potassium chloride is being used in ion exchange for household water softening in place of, or mixed with, sodium chloride, so potassium ions would exchange with calcium and magnesium ions. Possible replacement or partial replacement of sodium salts with potassium salts for conditioning desalinated water has been suggested. The latter seems to be an unlikely development at this stage, in view of the cost difference. Potassium consumption of drinking water treated by water softeners using potassium chloride may significantly increase exposure to potassium. This is not a concern for the general population. However, increased exposure to potassium could result in significant health effects in people with kidney disease or other conditions, such as heart disease, coronary artery disease, hypertension, diabetes, and who are taking medication that interfere with normal body potassium handling.

Potassium is silver white alkali which is highly reactive with water. Potassium is necessary for living organism functioning hence found in all human and animal tissues particularly in plants cells. The total potassium amount in human body lies between 110 and 140 g. It is vital for human body functions like heart protection, regulation of blood pressure, protein dissolution, muscle contraction, nerve stimulus etc. Potassium is deficient in rare but may led to depression, muscle weakness, heart rhythm disorder etc. According to WHO standards the permissible limit of potassium is 12 mg/L.

Results show that the concentration of potassium in study areas ranges from 20.83 to 27.51 mg/L. All regions with an average value vary between 3.73 to 11.41 mg/L. Present investigation was similar with reports made by other researchers' study [13,14]. These results did not meet the WHO standards and may become diseases associated from potassium extreme surpassed. When we compare to this result, it is less than the report of these researchers.

METHODS & MATERIALS

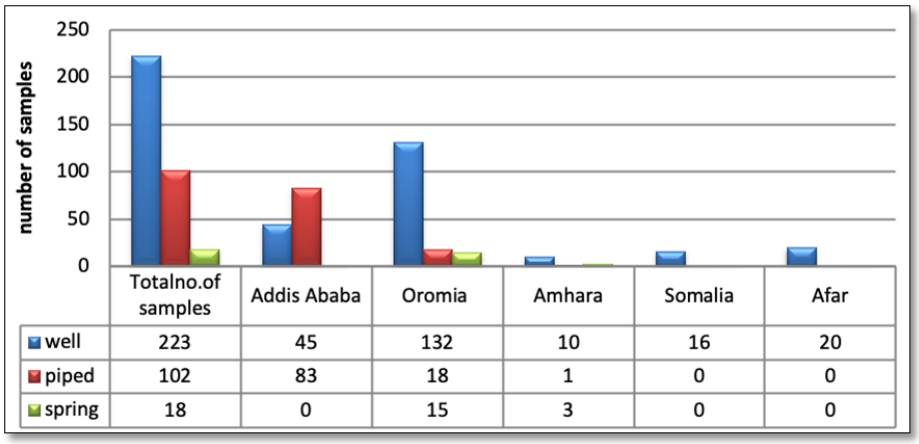
Country description

Ethiopia is found in the Horn of Africa and located between 33°E and 48°E longitudes and 3°N and 15°N of the equator. Ethiopia is a country with a great geographical variation. Its topography ranging from 4550 m above sea level to 110 m below and bordered by five countries: On the north and northeast by Eritrea, on the east by Djibouti and Somalia, on the south by Kenya and on the west and southwest by Sudan. Ethiopia is a Federal Democratic Republic composed of nine National Regional States namely: Tigray, Afar, Amhara, Oromia, Somali, Benshangul-Gumuz, Southern Nations, Nationalities and Peoples (SNNP), Gambella and Harari, plus two Administrative States (Addis Ababa and Dire Dawa City Administration) as indicated in **Figure 1**. The national regional states as well as the two city administrative councils are further divided in eight hundred woredas and around 15,000 Kebeles (5000 Urban and 10,000 Rural) [15].

Figure 1. Map of Ethiopian regional and administrative city.

Sample collection and analysis

In this retrospective study, 343 water samples data were used and tested in Environmental Public Health Chemistry Laboratory at Ethiopian Public Health Institute from April, 2017 to November, 2019. The samples data were collected from Amhara, Oromia, Somalia and Afar regions and Addis Ababa administrative city of the country and were classified based on the source type as spring, well, and piped water. This study used 223 well, 18 springs and 102 piped water samples collected across the country **(Figure 2)**. The tested physicochemical parameters are sodium (Na^+) and potassium (K^+) were investigated.



	Totalno.of samples	Addis Ababa	Oromia	Amhara	Somalia	Afar
well	223	45	132	10	16	20
piped	102	83	18	1	0	0
spring	18	0	15	3	0	0

Figure 2. Number of samples collected in four regions and one administrative city.

Quality assurance and quality control were checked for Sodium and Potassium parameters. We determined the sodium and potassium calibration with each batch analysis of the samples (0, 5, 10 and 15ppm solution for each parameter) and calculating ion balances (cation and anion). All the analytical procedures used in the physicochemical analysis of the water samples were executed according to standard method of water and wastewater analysis [16]. The concentration of sodium (Na^+) and potassium (K^+) were measured by the flame photometric method (model JANWAY PFP7).

RESULTS AND DISCUSSION

To summarize the results for sodium and potassium parameters from spring, well, and piped water samples are shown in **Tables 1, 2 and 3** as mean, maximum, the mean value of sodium and potassium parameter compared with the

values and % of number of sample that greater than the standards that set by the Ethiopian drinking water standards.

Table 1. Mean, maximum value and Ethiopia standard of selected sodium (Na^+) and potassium (K^+) parameters of **well** water samples.

Region	Total No. sample	Ethiopia standards (ES)		Max		Mean		No. sample >ES		No. sample >ES (%)	
		Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+
Addis Ababa	45	200	1.5	65	13	31.61	5.19	0	41	0	91.1
Oromia	132	200	1.5	640	32	125.4	8.54	46	121	34.8	91.7
Amhara	10	200	1.5	95	19	25.07	4.75	0	8	0	80
Somalia	16	200	1.5	267.5	28	152.6	11.41	3	13	18.8	81.3
Afar	20	200	1.5	1000	13.3	325	6.29	11	20	55	100

Table 2. Mean, maximum value and Ethiopia standard of selected sodium (Na^+) and potassium (K^+) parameters of **piped** water samples.

Region	Total No. Sample	Ethiopia standards (ES)		Max		Mean		No. sample >ES		No. sample >ES (%)	
		Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+
Addis Ababa	83	200	1.5	62	11	25	4.5	0	68	0	81.9
Oromia	18	200	1.5	89	17	44.1	7.5	0	14	0	77.7
Amhara	1	200	1.5	28	5.8	28	5.8	0	1	0	100
Somalia	-	200	1.5	-	-	-	-	-	-	-	-
Afar	-	200	1.5	-	-	-	-	-	-	-	-

ES=Ethiopia standards

Table 3. Mean, maximum value and Ethiopia standard of selected sodium (Na^+) and potassium (K^+) parameters of **spring** water samples.

Region	Total No. Sample	Ethiopia standards (ES)		Max		Mean		No. sample >ES		No. sample >ES (%)	
		Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+
Addis Ababa	-	200	1.5	-	-	-	-	-	-	-	-
Oromia	15	200	1.5	40	9.9	13	3.64	0	11	0	73.3
Amhara	3	200	1.5	30	6.6	23.1	3.73	0	2	0	66.7
Somalia	-	200	1.5	-	-	-	-	-	-	-	-
Afar	-	200	1.5	-	-	-	-	-	-	-	-

A standard value for sodium and potassium in drinking water set by the Ethiopian standard is 200 mg/L and 1.5 mg/l [17] respectively. In well water the sodium concentration is higher than the piped and spring water samples.

From well water samples, the average concentration and number of sample (in %) greater than ES of sodium concentration were higher in Afar region. Whereas, the average concentration of potassium was higher in Somalia region. When we come to number of sample (in %) greater than ES the potassium content was higher in Afar region as compared to other regions. Average concentration of sodium and potassium were higher in Oromia region. The number of sample (in %) greater than ES was 0 for sodium in all regions, for potassium concentration were 100,81.9 and 77.7 in Amhara, Addis Ababa and Oromia regions respectively for piped water samples.

From spring water samples, average concentration of sodium and potassium in Amhara region was higher than Oromia, when we come to the number of samples (in %) greater than ES was reversed.

A very high sodium and potassium concentration in spring water sources are 40 mg/Land 9.9mg/l, in piped water sources, 89mg/l and 17mg/l from Oromia and well water sources, 1000 mg/L from Afar and 32 mg/l from Oromia respectively **(Figures 3 and 4)**. In generally, all average concentration of sodium was found below 200mg/l in all regions and water type sources except Afar region in well water type source, whereas, all average concentration of potassium was found above 1.5 mg/l of drinking water standard of Ethiopia in all regions and water type sources.

The ratio of sodium to total cations is important in human pathology and agriculture. But, persons affect by certain diseases with low sodium concentration. The idea state of Florida Department of Environmental Protection (FDEP) has set the drinking water standard for sodium at 160 mg/L to control individuals that are simply attract to sodium sensitive hypertension or diseases that cause difficulty in regulating body fluid volume [18].

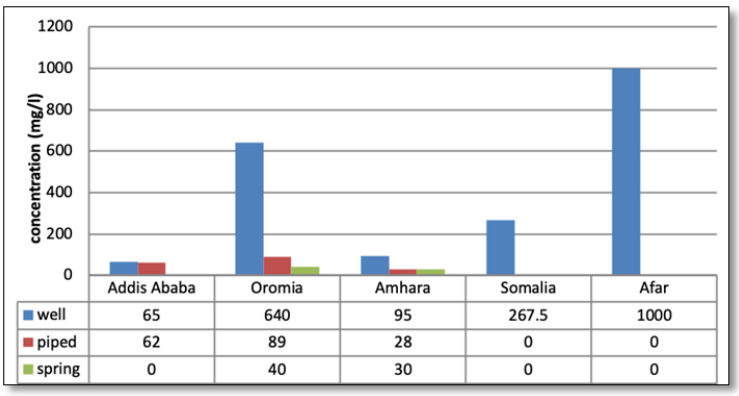


Figure 3. Maximum value of sodium.

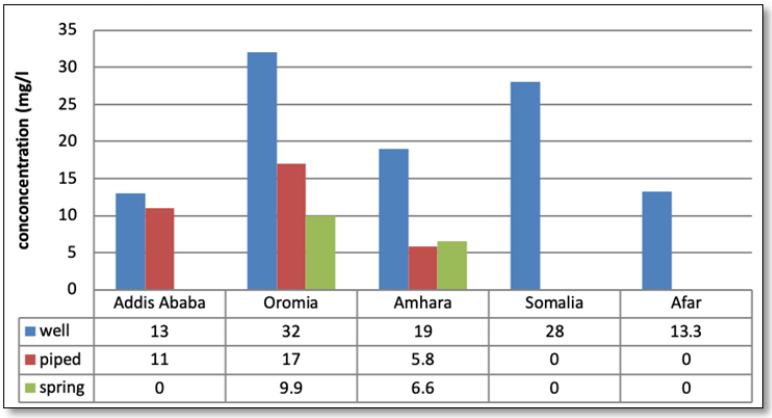


Figure 4. Maximum value of potassium.

The concentrations in excess of 200 mg/L may give rise to unacceptable taste [19,17], no health-based guideline value is proposed for sodium in drinking water. While, the reports of this finding reducing salt intake lowers blood pressure and cardiovascular diseases [20]. Similarly, for all water

resources with extremely high in sodium concentration may rise cardiovascular diseases and increase the mortality rate.

Sodium is mostly found in natural waters, whereas, the potassium content of natural water is usually less than that of sodium. Concentrations of potassium more than 10mg/l were decided unusual except in water having dissolved solids concentration /hot spring. Potassium is not a major component in public /industrials water supplies [21].

CONCLUSION

In this retrospective study the sodium and potassium concentration in the water sample varied from 0.2 mg/L to 1000 mg/L and 0.0 mg/L to 32mg/L respectively. We can conclude that, all average concentration of sodium was found below 200mg/L (drinking water standard of Ethiopia) in Addis Ababa, Oromia, Amhara and Somalia for well, piped and spring water samples except Afar region in well water samples. Whereas, all average concentration of potassium was found above 1.5 mg/L of drinking water standard of Ethiopia in all regions and water samples type sources.

When we compare with standards, the drinking water analysis cause serious health problem because the results are not conforming to national standard this result in public health problem in long time exposure. Therefore, the Ethiopia water authority shall work focus on water quality assessment and controlling mechanism. component in public /industrials water supplies [21].

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