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# Fluoride, Total Dissolved Solid and Electrical Conductivity in Drinking Water Supplies Analyzed in EPHI from April 2017 to December 2018

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**Abstract:** This retrospective study is aim to examine the Fluoride, Total dissolved solid and Electrical conductivity in drinking water supplies of Ethiopia. The study used 345 water samples data that collected from seven regions plus two administrative cities of the country, which were tested in Environmental Public Health Chemistry Laboratory at Ethiopian Public Health Institute from April 2017 to December 2018 and from these 226, were from well water, 97 from piped and the remaining 22 were from spring water samples. The results of the water samples analysis indicate that the fluoride concentration, total dissolved solid and electrical conductivity in the water sample varied from 0.0 mg/L to 16.96mg/L, 0.25 mg/L to 3360mg/Land 2.04 µS/cm to 4430µS/cm respectively. Generally in analyzed data, 33.6% (n = 76), 55.8% (n=126) and 54.4% (n=123) of the well water samples, 60.8% (n = 59), 99% (n=96) and 99% (n=96) of the piped water samples and 68.2% (n=15), 91% (n=20) and 91% (n=20) of the spring water samples are below 0.5 mg/L, 500mg/l and 700 µS/cm of fluoride, total dissolved solid and electrical conductivity concentration respectively. on the other hand, 24% (n = 54), 9.3% (n=21) and 8.4% (n=19) of the well water samples, 7.2% (n = 7), 1% (n=1) and 1% (n=1) of the piped water samples and 4.6% (n = 1), 4.6% (n = 1) and 4.6% (n = 1) of the spring water samples had fluoride, total dissolved solid and electrical conductivity concentration higher than WHO and national standards maximum allowable concentration (i.e. 1.5mg/l, 1000mg/L and 1500µS/cm) respectively. According to the result obtained, the water sources require a sustainable corrective action in order to alleviate the effect of fluoride, total dissolved solid and electrical conductivity in human health. Hence, the result of this retrospective study will use as base to health authorities as well as other responsible body for the management of water supply regarding fluoride, total dissolved solid and electrical conductivity.

**Keywords:** Total Dissolved Solid, Electrical Conductivity, Fluoride, Piped Water, Well Water, Spring Water, Drinking Water and Ethiopia

## 1. Introduction

Fluoride, conductivity (EC) and total dissolved solids (TDS) are frequently used as water quality parameters, especially in the coastal area/lowland area. The most widely recognized fluoride bearing minerals, which constitute normal hotspot for fluoride in drinking water, are fluorspar (CaF2), rock phosphate, and voracity &phosphoreses. In many researches, it is mentioned that, the fluoride contamination in drinking water is responsible for 65% of endemic flourosis in the world [1, 2]. Total Dissolved Solids (TDS) correlates positively with conductivity and affects PH that means the higher the TDS, the higher the conductivity and the lower the pH, towards acidity. The presence of dissolved

solids in water may affect its taste [3]. Conductivity or electrical conductivity (EC) and total dissolved solids (TDS) are frequently used as water quality parameters, especially in the coastal area/lowland area. These two parameters are indicators of salinity level which make them very useful as one way in studying seawater intrusion [4–7]. The value of EC and TDS are correlated [8–10]. EC is the measure of liquid capacity to conduct an electric charge [9, 11]. Its ability depends on dissolved ion concentrations, ionic strength, and temperature of measurements [12]. The sources of material in TDS and EC can come from nature, i.e. geological condition and seawater, and from human activities, i.e. domestic and industrial waste and also agriculture [9, 13–15].

There are many standards that govern TDS and EC in water. For health reason, desirable limit for TDS is between 500 mg/L and 1,000 mg/L and for EC is no more than 1,500 µS/cm [16]. Other quality standards classify these parameters based on salt content or salinity level [17, 18]. One of the water resources dissolved ions is called fluoride. This ion may be come from artificial sources such as waste water discharges from a different of industries (e.g. glassware) or enter water form mineral deposits. When inadequate, it must be added artificially [19]. Other studies show when fluoride concentration in water is 0.1 mg/l, the concentration in saliva will be 0.3 mg/l, whereas an increase of water fluoride concentration to 1.2 mg/l will also increase fluoride concentration in saliva to 0.9 mg/l, since most system fluoride intake is from drinking water [20]. Hence, the direct relationship between water levels of fluoride and systemic absorption [21]. High exposure to Fluoride ion leads to flourosis in its dental and skeletal forms and is endemic in countries, including India, China, Mexico, Argentina, Brazil, Saudi Arabia, United States, Uganda, Tanzania, and Ethiopia. High-risk areas are mostly located in arid and semi-arid regions that are characterized by a rapid rate of chemical weathering of geological materials, in the center of East African rift, higher levels of salinity and fluoride are the most widely known. Fluoride ion problem is not only clinical, but also social problem too [22]. Ethiopia has surface and ground water resources potential, of which ground water hasalion-share. A suitability of ground water for water resource use in the central Ethiopian Rift is hampered by water quality limitations [23]. Over 40% of deep and shallow wells are contaminated with up to 36mg/l, sometimes 62mg/l of fluoride which is significantly higher than the (WHO) guide line of 1.5 mg/l. [24], that can give rise to a number of adverse effects. Natural ground water quality is mostly affected by total dissolved solids, gases and pollutants and is controlled by presence of soluble or reactive minerals in aquifers [25]. As rock chemistry and geological process like weathering of rocks, which promotes the availability of fluoride ions in the ground water [26] needs to be characterized in the study area. Existing methods for defluoridation of drinking water involve expensive and high technology or are slow, inefficient and unhygienic [22, 24]. Also, there is a gap concerning documentation of past experience, evaluating the existing performance of the spatial aquifer system chemical properties and introduction of quality improvement techniques study area.

The East African Rift Valley, which cuts through Ethiopia, is geomorphologically still an active volcanic region. The volcanic rocks, particularly in the young basalt, contain high concentrations of fluoride and fluorapatite. Large fault systems in the Valley create conditions that allow very deep percolation of infiltrating surface water. The floor of the Rift Valley that is characterized by high hydrothermal activity accelerates the solubility of fluoride. The hot climate and high fluoride waterbed of the Rift Valley, therefore, favor the development of endemic fluorosis. The water supplies in the Ethiopian Rift Valley region come mainly from boreholes with depths from 10 to 100 meters [27].

## 2. Materials and Methods

*Country Description*

Ethiopia 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 country with a great geographical variation. its topography ranging from 4550 meters above sea level to 110 meters 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 Nationality and People Region (SNNPR), Gambella and Harari, plus two Administrative States (Addis Ababa and Dire Dawa City Administration). The national regional states as well as the two cities Administrative councils are further divided in eight hundred woredas and around 15,000 Kebeles (5,000 Urban and 10,000 Rural) [28].

In this retrospective study 345 water samples data were used and tested in Environmental Public Health Chemistry Laboratory at Ethiopian Public Health Institute from April 2017 to December 2018. The samples data were collected from seven regions plus two administrative cities of the country and were classified based on the source type as spring, well, and piped water. The fluoride concentration in the water sample were measured using the Colorimetric SPADNS Method, under acidic condition fluorides (HF) react with zirconium SPADNS solution and the lake (color of SPADNS reagent) gets bleaching due to formation of ZrF6. Since bleaching is a function of fluoride ions, it is directly proportional to the concentration of fluoride. It obeys Beers law in a reverse manner and calculated as mg F- /L present in the sample using standard curve, according to Standard Method of Water and Wastewater analysis [29]. Electrical conductivity and Total dissolved solid were determined by a portable Electrical conductivity and Total dissolved solid meter model (Model Sx713). An Electrical conductivity and Total dissolved solid were calibrated before measurement with an Electrical conductivity reference solution at 25°C according to the manufacturer's calibration procedure.


***Figure 1.*** *Map of Ethiopian regional and administrative city.*

## 3. Result and Discussion

Fluoride concentration in the water sample that collects from different regions of the country varied from 0.0 mg/L to 16.96mg/L.

The concentration of the sample classified into five groups based on WHO guidelines for fluoride in drinking water [30].

***Table 1.*** *Fluoride concentration in well water collected from different regions of Ethiopia.*

| Region | Total *N o | Concentration of fluoride (mg/l) | | | | | | | | | | Mean value | Max.Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <0.5 | | 0.5-1.5 | | 1.5-4 | | 4-10 | | >10 | | | |
| | | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | | |
| Addis Ababa | 42 | 25 | 59.5 | 16 | 38.1 | 1 | 2.3 | - | - | - | - | 0.49 | 2.81 |
| Oromia | 126 | 38 | 30.2 | 42 | 33.3 | 9 | 7.1 | 33 | 26.2 | 4 | 3.2 | 2.47 | 16.96 |
| Tigray | 6 | 4 | 66.7 | - | - | 1 | 16.7 | 1 | | - | - | 1.28 | 4.18 |
| Amhara | 7 | 4 | 57.1 | 3 | 42.9 | - | - | - | - | - | - | 0.42 | 1.12 |
| Somalia | 16 | 1 | 6.25 | 13 | 81.3 | 2 | 12.5 | - | - | - | - | 1.36 | 5.1 |
| Afar | 20 | 1 | 5 | 17 | 85 | 2 | 10 | - | - | - | - | 0.94 | 2.54 |
| SNNP | 5 | - | - | 4 | 80 | 1 | 20 | - | - | - | - | 0.92 | 1.72 |
| Harari | 2 | 1 | 50 | 1 | 50 | - | - | - | - | - | - | 0.5 | 0.63 |
| DireDawa | 2 | 2 | 100 | - | - | - | - | - | - | - | - | 0.36 | 0.4 |

Where *No stands for Number of Sample SNNPR- Southern Nation Nationality People Region

***Table 2.*** *Fluoride concentration in piped water collected from different regions of Ethiopia.*

| Region | Total *N o | Concentration of fluoride (mg/l) | | | | | | | | | | Mean value | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <0.5 | | 0.5-1.5 | | 1.5-4 | | 4-10 | | >10 | | | |
| | | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | | |
| Addis Ababa | 77 | 50 | 64.9 | 25 | 32.5 | 2 | 2.6 | - | - | - | - | 0.46 | 4.44 |
| Oromia | 19 | 8 | 42.1 | 6 | 31.6 | 4 | 21.1 | 1 | 5.2 | - | - | 1.4 | 7.75 |
| Tigray | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Amhara | 1 | 1 | 100 | - | - | - | - | - | - | - | - | 0.34 | 0.34 |
| Somalia | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Afar | - | - | - | - | - | - | - | - | - | - | - | - | - |
| SNNP | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Harari | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Dire Dawa | - | - | - | - | - | - | - | - | - | - | - | - | - |

***Table 3.*** *Fluoride concentration in spring water collected from different regions of Ethiopia.*

| Region | Total *N o | Concentration of fluoride (mg/l) | | | | | | | | | | Mean value | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <0.5 | | 0.5-1.5 | | 1.5-4 | | 4-10 | | >10 | | | |
| | | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | | |
| **Addis Ababa** | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oromia | 11 | 10 | 90.9 | 1 | 9.1 | - | - | - | - | - | - | 0.23 | 0.58 |
| Tigray | 2 | 2 | 100 | - | - | - | - | - | - | - | - | 0.075 | 0.08 |
| Amhara | 4 | 2 | 50 | 2 | 50 | - | - | - | - | - | - | 0.66 | 1.09 |
| Somalia | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Afar | - | - | - | - | - | - | - | - | - | - | - | - | - |
| SNNP | 5 | 1 | 20 | 3 | 60 | - | - | - | - | 1 | 20 | 2.62 | 10.12 |
| Harari | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Dire Dawa | - | - | - | - | - | - | - | - | - | - | - | - | - |

Where *No stands for Number of Sample SNNPR- Southern Nation Nationality People Region

***Table 4.*** *Fluoride concentration in well, piped and spring water collected from different regions of Ethiopia that exceeded the WHO guideline (1.5 mg/L).*

| Region | Well Total *No | >1.5 mg/L | | Piped Total *No | >1.5 mg/L | | Spring Total *No | >1.5 mg/L | |
|---|---|---|---|---|---|---|---|---|---|
| | | Well *No | (%) | | Piped *No | (%) | | Spring *No | (%) |
| Addis Ababa | 42 | 1 | 2.4 | 77 | 2 | 2.6 | - | - | - |
| Oromia | 126 | 46 | 36.5 | 19 | 5 | 26.3 | 11 | - | - |
| Tigray | 6 | 2 | 33.3 | - | - | - | 2 | - | - |
| Amhara | 7 | - | - | 1 | - | - | 4 | - | - |
| Somalia | 16 | 2 | 12.5 | - | - | - | - | - | - |
| Afar | 20 | 2 | 10 | - | - | - | - | - | - |
| SNNP | 5 | 1 | 20 | - | - | - | 5 | 1 | 20 |
| Harari | 2 | - | - | - | - | - | - | - | - |
| Dire Dawa | 2 | - | - | - | - | - | - | - | - |

Where *No stands for Number of Sample SNNPR- Southern Nation Nationality People Region

***Table 5.*** *Fluoride concentrations that have 0.00 mg/L in their water source of the region of Ethiopia.*

| Region | Zone, wereda or another village | Source of Sample | Fluoride Concentration (mg/L) |
|---|---|---|---|
| Addis Ababa | Gulele sub city (woreda 9), Ethiopia pharmaceutical factory | Well | 0.0 |
| | Awash Wine Company, Gulele sub city (woreda 9) | piped | |
| Oromia | Dukem | Well | |

***Table 6.*** *Fluoride concentrations that have exceeded more from WHO guideline in their drinking water source.*

| Region | Zone, wereda or another village | Source of Sample | Fluoride Concentration (mg/L) |
|---|---|---|---|
| Add is Ababa | MCM Company | Well | 2.81 |
| | Gulele Sub city (woreda 9) | Piped | 3.99 |
| | | | 4.44 |
| Oromia | Lume (Qoqa) | Well | 16.96 |
| | | | 8.25 |
| | Merti | Well | 9.03 |
| | | | 8.64 |
| | Adama (Wonji) | Well | 7.67 |
| | Zeway | Well | 10.12 |
| | Adami tulu | Well | 10.58 |
| | | | 9.05 |
| | Zeway | Well | 9.84 |
| | | | 10.62 |
| | | | 9.72 |
| | East shoa (Batu) | Piped | 7.75 |
| Tigray | North west (Asegede Tsebela) | Well | 2.73 |
| | | | 4.18 |
| Somalia | D0lloo Galadi | Well | 4.21 |
| | Dolloo Warder | Well | 5.1 |
| Afar | Dulesa | Well | 2.54 |
| SNNP | Gurage (Agena) | Spring | 10.12 |

Total dissolved solid concentration in the water sample that collects from different regions of the country varied from 0.25 mg/L to 3360mg/L. The concentration of the sample classified into five groups based on WHO guidelines for total dissolved solid in drinking water [31, 16].

***Table 7.*** *Total dissolved solid concentration in well water collected from different regions of Ethiopia.*

| Region | Total *N o | Concentration of total dissolved solid (mg/l) | | | | | | | | | | Mean value | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <100 | | 100-500 | | 500-1000 | | 1000-1500 | | >1500 | | | |
| | | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | | |
| Addis Ababa | 42 | 3 | 7.2 | 36 | 85.6 | 3 | 7.2 | - | - | - | - | 301 | 579 |
| Oromia | 126 | 9 | 7.1 | 61 | 48.4 | 54 | 42.9 | 2 | 1.6 | - | - | 484.7 | 1190 |
| Tigray | 6 | - | - | 2 | 33.3 | 4 | 66.7 | - | - | - | - | 515.2 | 772 |
| Amhara | 7 | 2 | 28.6 | 5 | 71.4 | - | - | - | - | - | - | 208.3 | 433 |
| Somalia | 16 | - | - | - | - | 6 | 37.5 | 5 | 31.2 | 5 | 31.2 | 1246.3 | 2280 |
| Afar | 20 | - | - | 3 | 15 | 8 | 40 | 4 | 20 | 5 | 25 | 1196.1 | 3360 |
| SNNP | 5 | - | - | 5 | 100 | - | - | - | - | - | - | 195.8 | 257 |
| Harari | 2 | - | - | - | - | 2 | 100 | - | - | - | - | 747 | 931 |
| Dire Dawa | 2 | - | - | - | - | 2 | 100 | - | - | - | - | 709 | 758 |

***Table 8.*** *Total dissolved solid concentration in piped water collected from different regions of Ethiopia.*

| Region | Total *N o | Concentration of total dissolved solid (mg/l) | | | | | | | | | | Mean value | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <100 | | 100-500 | | 500-1000 | | 1000-1500 | | >1500 | | | |
| | | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | | |
| Addis Ababa | 77 | 23 | 29.9 | 54 | 70.1 | - | - | - | - | - | - | 201.1 | 448 |
| Oromia | 19 | 4 | 21.1 | 14 | 73.7 | - | - | 1 | 5.2 | - | - | 305.3 | 1170 |
| Tigray | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Amhara | 1 | - | - | 1 | 100 | - | - | - | - | - | - | 165 | 165 |
| Somalia | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Afar | - | - | - | - | - | - | - | - | - | - | - | - | - |
| SNNP | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Harari | - | - | - | - | - | - | - | - | - | - | - | - | - |
| DireDawa | - | - | - | - | - | - | - | - | - | - | - | - | - |

Where *No stands for Number of Sample SNNPR- Southern Nation Nationality People Region

***Table 9.*** *Total dissolved solid concentration in spring water collected from different regions of Ethiopia.*

| Region | Total *N o | Concentration of total dissolved solid (mg/l) | | | | | | | | | | Mean value | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <100 | | 100-500 | | 500-1000 | | 1000-1500 | | >1500 | | | |
| | | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | | |
| **Addis Ababa** | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oromia | 11 | 8 | 72.7 | 3 | 27.3 | - | - | - | - | - | - | 81.7 | 180 |
| Tigray | 2 | - | - | 2 | 100 | - | - | - | - | - | - | 207 | 226 |
| Amhara | 4 | - | - | 3 | 75 | - | - | - | - | 1 | 25 | 982.5 | 3280 |
| Somalia | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Afar | - | - | - | - | - | - | - | - | - | - | - | - | - |
| SNNP | 5 | 3 | 60 | 1 | 20 | 1 | 20 | - | - | - | - | 238.5 | 773 |
| Harari | - | - | - | - | - | - | - | - | - | - | - | - | - |
| DireDawa | - | - | - | - | - | - | - | - | - | - | - | - | - |

***Table 10.*** *Total dissolved solid concentration in well, piped and spring water collected from different regions of Ethiopia that exceeded the WHO guideline (1000 mg/L).*

| Region | Well Total *No | >1000mg/L | | Piped Total *No | >1000mg/L | | Spring Total *No | >1000mg/L | |
|---|---|---|---|---|---|---|---|---|---|
| | | Well *No | (%) | | Piped *No | (%) | | Spring *No | (%) |
| Addis Ababa | 42 | - | - | 77 | - | - | - | - | - |
| Oromia | 126 | 2 | 1.6 | 19 | 1 | 5.3 | 11 | - | - |
| Tigray | 6 | - | - | - | - | - | 2 | - | - |
| Amhara | 7 | - | - | 1 | - | - | 4 | 1 | 25 |
| Somalia | 16 | 10 | 62.5 | - | - | - | - | - | - |
| Afar | 20 | 9 | 45 | - | - | - | - | - | - |
| SNNP | 5 | - | - | - | - | - | 5 | - | - |
| Harari | 2 | - | - | - | - | - | - | - | - |
| Dire Dawa | 2 | - | - | - | - | - | - | - | - |

Where *No stands for Number of Sample SNNPR- Southern Nation Nationality People Region

Electrical conductivity in the water sample that collects from different regions of the country varied from2.04 µS/cm to 4430µS/cm. The concentration of the sample classified into five groups based on [18, 16] guidelines for Electrical conductivity in drinking water.

***Table 11.*** *Electrical conductivity in well water collected from different regions of Ethiopia.*

| Region | Total *N o | Concentration of electrical conductivity (µS/cm) | | | | | | | | | | Mean value | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <700 | | 700-1500 | | 1500-10000 | | 10000-45000 | | >45000 | | | |
| | | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | | |
| Addis Ababa | 42 | 39 | 92.8 | 3 | 7.2 | - | - | - | - | - | - | 444.5 | 843 |
| Oromia | 126 | 69 | 54.8 | 56 | 44.4 | 1 | 0.8 | - | - | - | - | 703.5 | 1666 |
| Tigray | 6 | 2 | 33.3 | 4 | 66.7 | - | - | - | - | - | - | 755.3 | 1107 |
| Amhara | 7 | 7 | 100 | - | - | - | - | - | - | - | - | 308.8 | 636 |
| Somalia | 16 | - | - | 6 | 37.5 | 10 | 62.5 | - | - | - | - | 1723.6 | 3030 |
| Afar | 20 | 1 | 5 | 11 | 55 | 8 | 40 | - | - | - | - | 1647.9 | 4430 |
| SNNP | 5 | 5 | 100 | - | - | - | - | - | - | - | - | 291.8 | 383 |
| Harari | 2 | - | - | 2 | 100 | - | - | - | - | - | - | 1072 | 1325 |
| DireDawa | 2 | - | - | 2 | 100 | - | - | - | - | - | - | 1022 | 1090 |

***Table 12.*** *Electrical conductivity in piped water collected from different regions of Ethiopia.*

| Region | Total *N o | Concentration of electrical conductivity (µS/cm) | | | | | | | | | | Mean value | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <700 | | 700-1500 | | 1500-10000 | | 10000-45000 | | >45000 | | | |
| | | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | | |
| Addis Ababa | 77 | 77 | 100 | - | - | - | - | - | - | - | - | 301 | 658 |
| Oromia | 19 | 18 | 94.7 | - | - | 1 | 5.3 | - | - | - | - | 447.9 | 1638 |
| Tigray | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Amhara | 1 | 1 | 100 | - | - | - | - | - | - | - | - | 247 | 247 |
| Somalia | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Afar | - | - | - | - | - | - | - | - | - | - | - | - | - |
| SNNP | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Harari | - | - | - | - | - | - | - | - | - | - | - | - | - |
| DireDawa | - | - | - | - | - | - | - | - | - | - | - | - | - |

***Table 13.*** *Electrical conductivity in spring water collected from different regions of Ethiopia.*

| Region | Total *N o | Concentration of electrical conductivity (µS/cm) | | | | | | | | | | Mean value | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <700 | | 700-1500 | | 1500-10000 | | 10000-45000 | | >45000 | | | |
| | | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | *N o | (%) | | |
| **Addis Ababa** | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oromia | 11 | 11 | 100 | - | - | - | - | - | - | - | - | 124.1 | 270 |
| Tigray | 2 | 2 | 100 | - | - | - | - | - | - | - | - | 309.5 | 337 |
| Amhara | 4 | 3 | 75 | - | - | 1 | 25 | - | - | - | - | 1316 | 4300 |
| Somalia | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Afar | - | - | - | - | - | - | - | - | - | - | - | - | - |
| SNNP | 5 | 4 | 80 | 1 | 20 | - | - | - | - | - | - | 348.7 | 1113 |
| Harari | - | - | - | - | - | - | - | - | - | - | - | - | - |
| DireDawa | - | - | - | - | - | - | - | - | - | - | - | - | - |

***Table 14.*** *Electrical conductivity in well, piped and spring water collected from different regions of Ethiopia that exceeded the WHO guideline (1500 µS/cm).*

| Region | Well Total *No | >1500 µS/cm | | Piped Total *No | >1500 µS/cm | | Spring Total *No | >1500 µS/cm | |
|---|---|---|---|---|---|---|---|---|---|
| | | Well *No | (%) | | Piped *No | (%) | | Spring *No | (%) |
| Addis Ababa | 42 | - | - | 77 | - | - | - | - | - |
| Oromia | 126 | 1 | 0.8 | 19 | 1 | 5.3 | 11 | - | - |
| Tigray | 6 | - | - | - | - | - | 2 | - | - |
| Amhara | 7 | - | - | 1 | - | - | 4 | 1 | 25 |
| Somalia | 16 | 10 | 62.5 | - | - | - | - | - | - |
| Afar | 20 | 8 | 40 | - | - | - | - | - | - |
| SNNP | 5 | - | - | - | - | - | 5 | - | - |
| Harari | 2 | - | - | - | - | - | - | - | - |
| Dire Dawa | 2 | - | - | - | - | - | - | - | - |

Where *No stands for Number of Sample SNNPR- Southern Nation Nationality People Region

***Table 15.*** *Electrical conductivity and Total dissolved solid Concentration that have exceeded more from WHO guideline in their drinking water source.*

| Region | Zone, wereda or another village | Source of Sample | Total dissolved solid Concentration (mg/L) | Electrical conductivity (µS/cm) |
|---|---|---|---|---|
| Oromia | Sululta | Well | 1190 | 1666 |
| | East Shoa (Batu) | Piped | 1170 | 1638 |
| Amhara | Chagni | Spring | 3280 | 4300 |
| Somalia | Dolloo | Well | 2280 | 3030 |
| | Dolloo (Wardher) | Well | 1950 | 2640 |

| Region | Zone, wereda or another village | Source of Sample | Total dissolved solid Concentration (mg/L) | Electrical conductivity (µS/cm) |
|---|---|---|---|---|
| | Dolloo (Danod) | Well | 1540 | 2110 |
| | Dolloo (Danod) | Well | 2000 | 2680 |
| | Dolloo (Danod) | Well | 1730 | 2350 |
| | Addiar Foun | Well | 1660 | 2270 |
| | WakeAdaar | Well | 1560 | 2130 |
| | Mesgidadar Adaar | Well | 3360 | 4430 |
| Afar | Daridaba Adaar | Well | 2330 | 3100 |
| | Talalak (Wata) | Well | 3220 | 4230 |
| | Halbehawaletelalak | Well | 1360 | 1887 |
| | Yorengira Talalak | Well | 1470 | 2020 |

Afluoride, total dissolved solid and electrical conductivityin drinking water in the low class indicates samples with no risk for human health. However, water samples higher than the maximum allowable fluoride, total dissolved solid and electrical conductivityadversely affects the public health due to excessive consumption of fluoride, total dissolved solid and electrical conductivity. Generally in the country, 24% (n = 54), 9.3% (n=21) and 8.4% (n=19) of the well water samples, 7.2% (n = 7), 1% (n=1) and 1% (n=1) of the piped water samples and 4.6% (n = 1), 4.6% (n = 1) and 4.6% (n = 1) of the spring water samples had fluoride, total dissolved solid and electrical conductivity concentration higher than the maximum allowable concentration (i.e. 1.5mg/l, 1000mg/L and 1500µS/cm) respectively and 42.5% (n = 96), 35% (n=79) and 37.2% (n=84) of the well water samples, 32% (n = 31), 0% (n=0) and 0% (n=0) of the piped water samples and 27.3% (n = 6), 4.6% (n=1) and 4.6% (n=1) of the spring water samples had fluoride, total dissolved solid and electrical conductivity concentration between 0.5 mg/L, 500mg/l, 700 µS/cm and the WHO recommendation guideline value (i.e. 1.5 mg/L, 1000mg/l, 1500 µS/cm) respectively. In addition to this 33.6% (n = 76), 55.8% (n=126) and 54.4% (n=123) of the well water samples, 60.8% (n = 59), 99% (n=96) and 99% (n=96) of the piped water samples and 68.2% (n = 15), 91% (n=20) and 91% (n=20) of the spring water samples are below 0.5 mg/L, 500mg/l and 700 µS/cm of fluoride, total dissolved solid and electrical conductivity concentration respectively.

In the country, fluoride, total dissolved solid and electrical conductivity content analyzed in the well water sample in the regions had mean value of fluoride, total dissolved solid and electrical conductivity concentration less than the WHO maximum allowable standard of fluoride, total dissolved solid and electrical conductivity (1.5 mg/L, 1000mg/L and 1500 µS/cm) respectively except the average fluoride concentration of Oromia region (2.47mg/L) and total dissolved solid and electrical conductivity in the region Somalia (1246.3 mg/L and 1723.6 µS/cm) and Afar (1196.1 mg/L and 1647.9 µS/cm) respectively as indicated in (Table 1, Table 7 and Table 11). Furthermore, as groundwater passes through the earth and comes into contact with fluoride containing minerals, fluoride is dissolved and enters the water. The deeper the water flows through the earth, the more fluoride-containing minerals, and the greater fluoride concentration in the water.

High exposure to Fluoride ion leads to flourosis in its dental and skeletal forms and is endemic in countries, including India, China, Mexico, Argentina, Brazil, Saudi Arabia, United States, Uganda, Tanzania, and Ethiopia. High-risk areas are mostly located in arid and semi-arid regions that are characterized by a rapid rate of chemical weathering of geological materials, in the center of East African rift, higher levels of salinity and fluoride are the most widely known. Fluoride ion problem is not only clinical, but also social problem too [22]. Ethiopia has surface and ground water resources potential, of which ground water hasalion-share. Several studies conducted in the Rift valley have shown that groundwater contains excess fluoride contents where it adversely affects the health of the surrounding community. Fluoride concentration higher than the WHO guideline value 1.5 mg/L causes dental fluorosis or mottling of teeth. Few studies of dental fluorosis prior to 1985 in Ethiopia reported high prevalence rates in several communities in the central part of the Rift Valley [32, 33].

The fluoride, total dissolved solid and electrical conductivity content analyzed in the Piped water sample in the regions had mean value of fluoride, total dissolved solid and electrical conductivity concentration less than the WHO maximum allowable standard of fluoride, total dissolved solid and electrical conductivity (1.5 mg/L, 1000mg/L and 1500 µS/cm) respectively (Table 2, Table 8 and Table 12).

The fluoride, total dissolved solid and electrical conductivity content analyzed in the spring water sample in the regions had mean value of fluoride, total dissolved solid and electrical conductivity concentration less than the WHO maximum allowable standard of fluoride, total dissolved solid and electrical conductivity (1.5 mg/L, 1000mg/L and 1500 µS/cm) respectively except the average fluoride concentration of Southern Nation Nationality People Region (2.62mg/L) as indicated in (Table 3, Table 9 and Table 13). On the other hand, in the Amhara region of Ethiopia recorded fairly low average content of fluoride, total dissolved solid and electrical conductivity in all the well, piped and spring water samples was below the WHO maximum allowable standard of fluoride (1.5 mg/L, 1000mg/L and 1500 µS/cm) respectively as indicate in (Table (1, 2, 3), Table (7, 8, 9) and Table (11, 12, 13)).

A suitability of ground water for water resource use in the central Ethiopian Rift is hampered by water quality limitations [23]. Over 40% of deep and shallow wells are contaminated with up to 36mg/l, sometimes 62mg/l of fluoride which is significantly higher than the (WHO) guide line of 1.5 mg/l. [24], that can give rise to a number of adverse effects. Natural ground water quality is mostly

affected by total dissolved solids, gases and pollutants and is controlled by presence of soluble or reactive minerals in aquifers [25]. As rock chemistry and geological process like weathering of rocks, which promotes the availability of fluoride ions in the ground water [26] needs to be characterized in the study area. Existing methods for defluoridation of drinking water involve expensive and high technology or are slow, inefficient and unhygienic [22, 24]. Also, there is a gap concerning documentation of past experience, evaluating the existing performance of the spatial aquifer system chemical properties and introduction of quality improvement techniques study area. People in several areas of the Ethiopian Rift Valley are consuming water with up to 33 mg/l of fluoride [34]. So it is required to implement appropriate water treatment procedures using local resources that are accessible to the rural community with technically simple, cost wise feasible and easily transferable technology.

In Amhara region, 7 well water, 1 piped water and 4 spring water samples were analyzed. The average and maximum value of fluoride, total dissolved solid and electrical conductivity concentration detected were (0.42 mg/L, 208.3 mg/L and 308.8 µS/cm) and (1.12 mg/L, 433 mg/L and 636 µS/cm); (0.34 mg/L, 165 mg/L and 247 µS/cm) and (0.34 mg/L, 165mg/L and 247 µS/cm); (0.66 mg/L, 982.5 mg/L and 1316.8 µS/cm) and (1.09 mg/L, 3280 mg/L and 4300 µS/cm) for well water, piped water and spring water source samples respectively (Table (1, 2, 3), Table (7, 8, 9) and Table (11, 12, 13). Water samples from 1 of those springs (25%) had total dissolved solid and electrical conductivity concentration above the WHO maximum allowable value of the total dissolved solid and electrical conductivity concentration (Table 10 and 14)).

In Oromia region, 126 well water, 19 piped water and 11 spring water samples were collected and analyzed. The average and maximum value of fluoride, total dissolved solid and electrical conductivity concentration were (2.47 mg/L, 484.7 mg/L and 703.5 µS/cm) and (16.96 mg/L, 1190 mg/L and 1666 µS/cm); (1.4 mg/L, 305.3 mg/L and 447.9 µS/cm) and (7.75 mg/L, 1170mg/L and 1638 µS/cm); (0.23mg/L, 81.7 mg/L and 124.1 µS/cm) and (0.58 mg/L, 180 mg/L and 270 µS/cm) for well water, piped water and spring water source samples (Table (1, 2, 3), Table (7, 8, 9) and Table (11, 12, 13)). Fluoride, total dissolved solid and electrical conductivity concentration above the WHO standard value were detected in 36.5%, 1.6% and 0.8% of the well water samples (n = 46, n=2 and n=1), 26.3%, 5.3% and 5.3% of the piped water samples (n = 5, n=1 and n=1), and 0% of the spring water (n = 0) as indicated in (Table 4, 10 and14).

Fluoride, total dissolved solid and electrical conductivity above the WHO standard was detected in some area of the Oromia region (Table 6 and 15). In Lume (Qoqa), Zeway and Adamitulu for fluoride and Sululta for total dissolved solid and electrical conductivity samples from well water, East Shoa(Batu) from piped water had fluoride, total dissolved solid and electrical conductivity concentration which exceeded (1.5 mg/L, 1000mg/L and 1500 µS/cm). Several cases of fluorosis have been reported from this area. High-risk areas are mostly located in arid and semi-arid regions that are characterized by a rapid rate of chemical weathering of geological materials, in the center of East African rift, higher levels of salinity and fluoride are the most widely known. Fluoride ion problem is not only clinical, but also social problem too [22]. Ethiopia has surface and ground water resources potential, of which ground water hasalion-share. Concentrations of fluoride greater than the WHO guideline value of1.5 mg/l have been found in ground waters from several parts of Ethiopia, but are recognized to be highest in the Rift Valley zone [34]. According to [35], in the Ziway–Shala basin in particular, wells had high fluoride levels (mean: 9.4 ±10.5 mg/L; range: 1.1 to 68 mg/L), with 48 of 50 exceeding the WHO drinking water guideline limit of 1.5 mg/L.

In Addis Ababa, 42 well water and 77 piped water samples were collected from all parts of the city. The average concentration fluoride, total dissolved solid and electrical conductivity in well water, piped water and spring water samples were very low than WHO standard value (1.5 mg/L, 1000mg/L and 1500 µS/cm). The mean and maximum value of fluoride, total dissolved solid and electrical conductivity concentration detected were (0.49 mg/L, 301mg/L and 444.5 µS/cm) and (2.81 mg/L, 579 mg/L and 843 µS/cm); and (0.46mg/L, 201.1 mg/L and 301 µS/cm) and (4.44 mg/L, 448 mg/L and 658µS/cm) for well water and piped water samples respectively as indicated in the (Table (1, 2, 3), Table (7, 8, 9) and Table (11, 12, 13)). Two and two well water samples were analyzed from Harari and Dire Dawa regions respectively. The average and maximum value of fluoride, total dissolved solid and electrical conductivity concentration detected were lower than the WHO maximum allowable standard value as indicated in (Table (1, 2, 3), Table (7, 8, 9) and Table (11, 12, 13)).

The Tigray region, 6 well water and 2 spring water samples were analyzed. The average and maximum value of fluoride, total dissolved solid and electrical conductivity concentration detected were (1.28 mg/L, 515.2mg/L and 755.3 µS/cm) and (4.18 mg/L, 772mg/L and 1107 µS/cm); and (0.075mg/L, 207 mg/L and 309.5 µS/cm) and (0.08 mg/L, 226mg/L and 337µS/cm) for well water and spring water samples respectively as depicted at (Table (1, 2, 3), Table (7, 8, 9) and Table (11, 12, 13)).. Two from well water (33.3%) had fluoride concentration above the maximum allowed levels for drinking water (Table 4). Unacceptable or moderately high concentrations have also been found in ground waters from volcanic rocks in the highlands. Concentrations in ground waters from the ancient basement rocks are typically low for instance in Mekele area [36].

In Somalia region, 16 well water samples were analyzed. The average and maximum value of fluoride, total dissolved solid and electrical conductivity concentration detected were (1.36mg/L, 1246.3mg/L and 1723.6 µS/cm) and (5.1 mg/L, 2280mg/L and 3030 µS/cm) for well water samples respectively as depicted at (Table1, Table7 and Table 11). Fluoride, total dissolved solid and electrical conductivity concentration above the WHO standard value were detected in 12.5%, 62.5% and

62.5% of the well water samples (n = 2, n=10 and n=10) respectively as indicated in (Table 4, 10 and 14).

The number of well water samples collected and analyzed from different parts of the Afar regions was 20. The average and maximum value of fluoride, total dissolved solid and electrical conductivity concentration detected were (0.94mg/L, 1196.1mg/L and 1647.9 µS/cm) and (2.54 mg/L, 3360mg/L and 4430 µS/cm) for well water samples respectively in the (Table 1, Table 7 and Table 11). Fluoride, total dissolved solid and electrical conductivity concentration above the WHO standard value were detected in 10%, 45% and 40% of the well water samples (n = 2, n=9 and n=8) respectively as indicated in (Table 4, 10 and 14). In Dulesa for fluoride and Addiar foun, Wake Adaar, Mesgidadar Adaar, Daridaba Adaar, Talalak (Wata), Halbehawaletelalak and Yorengira Telalak for total dissolved solid and electrical conductivity samples from well water had fluoride, total dissolved solid and electrical conductivity concentration which exceeded (1.5 mg/L, 1000mg/L and 1500 µS/cm) in (Table 6 and 15) respectively. The problematic fluoride concentrations were derived from hot springs (high temperature) and by weathering of the volcanic bedrocks [37]. Water sources with Fluoride content above 5.0mg/L in the Rift Valley were found mostly in hot spring (100% of all sources), lakes (78%), shallow wells (54%) and boreholes (35%) and the lowest concentrations less than 1.5 mg/L observed in springs and rivers [38].

The Southern Nation Nationality People Region is another region where the fluoride, total dissolved solid and electrical conductivity problem is prevalent. 5 well water and 5 spring water samples were collected and analyzed. In this region, drinking water sources with fluoride contents exceeding 1.5 mg/L were recorded in 20% (n = 1) and 20% (n = 1) for well water and spring water samples respectively as showed in Table 4. Both dental and skeletal fluorosis is prevalent in the Rift Valley region of Ethiopia because of high fluoride waters that originate from springs and boreholes.

## 4. Conclusion

The result of this retrospective study indicated that fluoride, total dissolved solid and electrical conductivity concentration in the water sample varied from 0.0 mg/Lto 16.96 mg/L, 0.25mg/L to 3360mg/L and2.04 µS/cm to 4430 µS/cm respectively. Generally in water samples that was brought to the environmental health laboratory of EPHI in the year between April 2017 to December 2018, 24% (n = 54), 9.3%(n=21) and 8.4%(n=19) of the well water samples, 7.2% (n = 7), 1%(n=1) and 1%(n=1) of the piped water samples and 4.6% (n = 1), 4.6% (n = 1) and4.6% (n = 1) of the spring water samples had fluoride, total dissolved solid and electrical conductivity concentration higher than the maximum allowable concentration (i.e. 1.5mg/l, 1000mg/L and 1500µS/cm) respectively and 42.5% (n = 96), 35%(n=79) and 37.2%(n=84) of the well water samples, 32% (n = 31), 0%(n=0) and0%(n=0) of the piped water samples and 27.3% (n = 6), 4.6%(n=1) and4.6%(n=1) of the spring water samples had fluoride, total dissolved solid and electrical conductivity concentration between 0.5 mg/L, 500mg/l, 700 µS/cm and the WHO recommendation guideline value (i.e. 1.5 mg/L, 1000mg/l, 1500 µS/cm) respectively. In addition to this 33.6% (n = 76), 55.8%(n=126) and 54.4%(n=123) of the well water samples, 60.8% (n = 59), 99%(n=96) and 99%(n=96) of the piped water samples and 68.2% (n = 15), 91%(n=20) and91%(n=20) of the spring water samples are below 0.5 mg/L, 500mg/l and 700 µS/cm of fluoride, total dissolved solid and electrical conductivity concentration respectively. A concentration of fluoride, total dissolved solid and electrical conductivity below 0.5, 500 and 700 were recorded in 63%, 97.5% and97.5%; 75%, 50% and 50%; and 58.3%, 91.7% and 91.7% of samples collected from Addis Ababa, Tigray and Amhara regional states respectively. Therefore, to decide the importance of fluoride and fluoridation in the prevention of Dental Caries or Tooth decay for water sources with fluoride concentration of 0.0 mg/L or below 0.5 mg/L is needed more research. However, water fluoridation is still opposed by some scholars; reasons for opposition include concerns about possible long-term harmful effects such as a high risk of Osteoporosis. Rift Valley areas of Afar, SNNPR and Oromia are characterized with a highest concentration of fluoride. The concentration below 1.5mg/L carry an increasing risk of dental fluorosis, and higher concentrations lead to skeletal fluorosis especially to the Rift Valley area. Therefore, the result of this retrospective study will use as a base to health authorities as well as other responsible body for the management of water supply regarding fluoride.

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