Journal of Hydrology: Regional Studies 19 (2018) 240–249

Contents lists available at ScienceDirect

Journal of Hydrology: Regional Studies

journal homepage: www.elsevier.com/locate/ejrh

Fluoride ion and total dissolved solid distribution in Ethiopian Rift valley: The case of Hawassa city aquifer

Shemsu Gulta Abdurahman[a,*], Moltot Zewdie[b]

[a] Water Resources Engineering and Management (Thesis: Aquifer Characterization) Hawassa University, Institute Of Technology, Water Supply And Environmental Engineering Department, Ethiopia

[b] Water Resources and Hydraulic Engineering (Thesis: Model For Water Quality Management In A Tidal River) (Hawassa University), Hawassa University, Institute Of Technology, Water Resources And Irrigation Engineering Department, Ethiopia

ARTICLE INFO

Keywords:
Aquifer
Fluoride ion
Geochemistry
Hawassa catchment
Drinking water
Rift valley

ABSTRACT

Study region: The Main Ethiopian Rift valley (MER) region, where millions rely on fluoride contaminated drinking water that is by far higher than the WHO standard resulting skeletal and tooth decay.

Study focus: Pumping test and drilling lithology data of the already drilled and productive 25 wells (25 m–200 m depth) to characterize the aquifer. Particular emphasis is given to the spatial distribution of fluoride ion (F-) and Total dissolved solids (TDS) applying SPSS (Statistical Package for the Social Scientists) statistical tool.

New hydrological insights for the region: The major water bearing formation is of weathered and fractured geologic formation having high porosity and permeability, which resulted in risk of shallow groundwater surface contamination. The concentration of fluoride ion, ranging from 0.65mg/l to 11mg/l is under significance influence by the geochemistry. Higher temperature at the shallow aquifer along with geological process like weathering of rocks and dissolution of CaF_2 promotes the concentrated availability of fluoride ions. The deeper the strata along with igneous formation dominated by pumice, the lower the concentration showing strong inverse correlation with depth for both F- and TDS with $R^2 = 0.78$ and $R^2 = 0.68$ respectively at $\alpha < 0.001$. Either drilling wells beyond such formations (=60m) or blinding the poor quality strata is recommended to minimize the effect of high fluoride and TDS concentration in drinking water for Hawassa city aquifer.

1. Background and purposes

The world's fluoride stores in the ground are assessed to 85 million tons. The most widely recognized fluoride-bearing minerals, which constitute normal hotspot for fluoride in drinking water, are fluorspar (CaF2), rock phosphate, and voracity & phosphoresces. In many researches, it is mentioned that, the fluoride contamination in drinking water is responsible for 65% of endemic flourosis in the world (Patil et al., 2017; Rango, 2012). 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 (Yadav et al., 2008). Ethiopia has surface and ground water resources

* Corresponding author.
E-mail addresses: shemsugt@yahoo.com (S. Gulta Abdurahman), tambek72@yahoo.com (M. Zewdie).

https://doi.org/10.1016/j.ejrh.2018.09.003
Received 24 January 2018; Received in revised form 17 September 2018; Accepted 18 September 2018

potential, of which groundwater has a lion-share. The preliminary estimated amount of yearly groundwater recharge of the country is about 28,000Mm (Brook Abate and MikhailovichDeganovsky, 2008) (MOWE, 2011). However, suitability of groundwater for water resource use in the central Ethiopian Rift is hampered by water quality limitations (Kebede et al., 2014). Over 40% of deep and shallow wells are contaminated with up to 36 mg/l, sometimes 62 mg/l of fluoride which is significantly higher than the (WHO) guideline of 1.5 mg/l. (Rango et al., 2014), that can give rise to a number of adverse effects. Natural groundwater quality is mostly affected by total dissolved solids, gases and pollutants and is controlled by presence of soluble or reactive minerals in aquifers (EWTC, 2008). Increased exploitation of groundwater reserves coupled with a lack of information on declining water quality, water tables level, extraction estimates, and aquifer properties is of great concern from a sustainability standpoint. As rock chemistry and geological process like weathering of rocks, which promotes the availability of fluoride ions in the groundwater (Rafique et al., 2008) 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 (Yadav et al., 2008; Rango et al., 2014). 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. Therefore, this study is aimed to identify the major water bearing geological formations of the Hawassa city, the spatial variation and distribution of fluoride ion and TDS in the aquifer system of the city and the related geochemistry of the aquifer in the area. It is relevant for the prevention of flourosis through management of drinking water, which is a difficult task, requires favorable conditions, combining knowledge, motivation, prioritization, discipline and technical and organizational support.

2. Study area

Lake Hawassa catchment is part of the main Ethiopian Rift containing Lake Hawassa, 1680 m above sea level (m.a.s.l). The lake catchment lies between latitude 6°48′45″-7°14′ 49″ N, and longitude38°16′34″-38°43′26″E. Hawassa city is found in the catchment adjacent to the lake where the lake got its name. The average altitude of the city is 1697 m.a.s.l. The city is one of the fast growing in the country with the development of basic infrastructure and different industries (ceramics, brewery, textile and garment).There are nine sub-cities within the administrative area of the city, where Tulahewela sub city has the largest areal coverage. However, there were only seven well points located within this sub-city.

The rift system is one of the largest structural features of the earth's crust, extending for a distance of 6000 km from Mozambique to Syria, equivalent to 1/6th of the earth's circumference. In Ethiopia, the rift system extends over 1000 km in the NE direction. It covers 150,000km2 and it can be divided into two broad units: The Main Ethiopian Rift (MER) 50–90 N and 37030′–400E and the Afar depression (Table 1).

3. Materials and methods

3.1. Data collection and organization

The main data used for the assessment of hydraulic properties of formations were well pump test data, well drilling completion reports, borehole depth data, water quality data, location and geologic map of the formations. Well location data collected during fieldwork. Location information and GPS coordinates (Northing and Easting) of all wells are collected in order to crosscheck with the existing design-pumping test data. Pumping test data of the wells with constant pumping rate for the whole 24 h is recorded for

Table 1
Fluoride ion and TDS values of the selected shallow wells.

Well Name	Bore hole depth (m)	Selected Parameters		Major Aquifer
		Fluoride ion (mg/l)	TDS (mg/l)	Shallow (25 m–58 m)
South Star Int.Hot.	52.00	2.54	498.00	Sand & Fractured scoria
Hawassa Flour Factory	50.00	11.00	700.00	Pumice & fractured Scoria and Basalt
Zewd Village	25.00	8.90	725.00	Weathered Rhyolite and Basalt
ZinabuAbera	41.50	5.00	500.00	Fractured &volcanic Basalt & Pumice
Dashen Bank	36.00	4.80	670.00	Fractured basalt
HU(ACA)	40.00	6.58	337.00	Highly weathered Ignimbrite
Midroc Construction	52.00	4.45	470.00	Pumice & Rhyolite
AbebeWendmu	41.50	8.61	284.00	Basalt & Rhyolite
South Road Auth.	37.00	5.80	460.00	Trachyte
Hawassa University 2	50.00	4.85	498.00	Basalt & Rhyolite
Hawassa University 3	58.00	1.64	462.00	Sand & red Scoria
Hawassa University 4	50.00	2.90	497.00	Pumice & Rhyolite
Hawassa University 5	46.00	4.94	363.00	Basalt & Rhyolite
HU(health sc.c)	41.00	8.00	460.00	Fractured Basalt
HU Condominium	51.00	8.71	445.00	Weathered Basalt
Police garage	52.00	5.95	714.00	Fractured Scoria