Correlation of Fluoride and Iron Concentrations in Rift Valley Aquifer of Jimma, Ethiopia

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SUMMARY: Three test wells were drilled in Jimma town as part of water source identification for the town water supply project. Water quality parameters and the lithologic profiles were determined for depth specific samples taken during drilling. Furthermore, depth integrated samples at subsequent pumping test operations were analysed in details.
The Examination of the integrated samples indicates a reciprocal relationship between the contents of iron and contents of fluoride. From the wells lithology it appears that the fluoride to iron concentration ratio in the attached water is significantly lower in the clay based depths; 0.6 towards 1.4 in non-clay based depths.
Ion balance considerations on the integrated depth samples show that the groundwater is sodium-bicarbonate water type, as typically found in the Rift Valley basin.

Key words: Fluoride, iron, correlation, Rift Valley, Ethiopia, drilling logs, lithology.

INTRODUCTION

Fluorine accounts for about 0.3 g/kg of earth crust [7]. According to Arnold et al [1] fluoride concentration of approximately 1.0 mg/L in drinking water reduces dental caries without harmful effects on health. However, excessive fluoride in groundwater is the most serious water quality problem in Ethiopia and many people are being affected by both dental and skeletal fluorosis [6]. Therefore, water supply development projects in Ethiopia usually include close examinations and verifications of fluoride contents of the available water source potentials.

Iron is one of the most abundant metals in the earth crust. It is an essential element in human nutrition [5]. Some ground waters may contain considerable concentrations of iron. Because groundwater is often anoxic, any soluble iron in ground water is usually in ferrous state Fe^{2+} and its concentration is controlled by the carbonate concentration. A bittersweet astringent taste is detectable by some persons at levels above 1 mg/L [1].

Because of the frequent need for iron removal and aesthetic and technical water quality, the determination of iron concentration in drinking water is very important.

With the increased demand for drinking water and with the intensification of water utilisation for different purposes, the quality problems become the limiting factor in the development of water resources. During water resources identification for Jimma

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town, the possibilities of excessive fluoride and iron concentrations in the groundwater were investigated. As water flows through aquifer it assumes a diagnostic chemical composition as a result of interaction with the lithologic framework [4].

Jimina is located in the upper part of the Ghibe-Omo river basin, which drains into Lake Rudolf (Lake Turkana) on the Ethiopia-Kenya border. Its geographical coordinates are approximately 70415 N latitude 360505 E longitude. The general elevation of the town is about 1720 meters above sea level.

It lies on a low hill to the north of the wide alluvial plain of the river Gilgel Gibe. The average annual rainfall of the town is 1482 mm. Maximum temperature are around 30°C and a minimum 4°C. According to the geologic map of Ethiopia, the Jimma area is underlain by volcanic rocks of tertiary age [2].

TABLE 1. Iron and fluoride concentrations at different depths of test wells 1-3.

Well no	Depth, m	Fe^{++}, mg/L	F^- , mg/L	pH
1	22	0.4	1.15	7.75
	42	0.4	0.74	7.5
	50	0.6	0.72	7.5
2	54	1.2	2.05	7
	62	0.6	1.89	7.5
	67	1.5	1.25	7.5
	94	2.5	1.30	7.5
3	24	0.3	2.2	7.6
	34	0.4	1.7	7.4
	36	1.3	1.4	7.5
	43	1.4	1.5	7.6
	53.5	1.2	1.55	7.8
	60	0.5	1.5	7.8
	83	1.7	1.2	7.8
	105	1.2	1.1	7.8
	119	1.5	1.1	7.7
	160	1.2	1.2	7.8

METHODS

Two kinds of samples were taken; depth integrated and depth specific samples. The depth-integrated samples were aimed at identifying regional patterns in groundwater composition and its rock types. In many cases groundwater compositions show major variations even on a small case. Therefore depth specific sampling was used in order to study chemical composition as much in detail as possible.

The geological logs of three test bore-holes were referred to relate the lithology profile of the test bore-holes to the results of the chemical analyses of the specific samples.

RESULTS

The results of depth specific sample analyses are shown in Tables 1. The lithologic logs of the same test wells are shown in Table 2. Table 3 shows the results of comprehensive analyses of depth integrated samples from the three test wells.

TABLE 2. Geological logs of test wells 1-3.

Well no	Depth, m	Geological log
1	22 – 23	Dark grey rock, softer, ash
	30 – 43	Grey-green and tan tuff, some basalt pieces
	47 – 58	Dark grey to black basalt, fresh and hard
2		
	26 – 41	Dark grey tuff
	50 – 54	Grey tuff
	61 - 69.5	Very hard basalt
	69.5 – 94	Dark brown compact clay
	At 94	Basalt
3		
	21 – 24	Dark to light grey tuff
	33 – 34	Dark green and grey tuff
	34 – 35	Dark green dark brown tuff
	35 – 36	Dark brown tuff
	36 – 37	Dark brown and green tuff
	42 – 43	Dark grey and light grey tuff
	49 – 68	Basalt, quite hard
	68 – 98	Tuff various colour
	103 – 105	Blue grey and brown tuff
	105 – 106	Hard shell-like clay
	112 – 119	Clay with hard lenses
	119 – 122	Hard, crumbly clay
	159 – 161	Grey clay
	161 – 167	Shell-like clay

According to the geological log of the test well no 2, the first 17.5 meters of the hole is dominated by different types of clay; 2 meters of heavy clay top soil, and 12.5 sticky clay which have brown, black, and greenish-grey colours.

In case of test well no 2, the first 21 meters of the hole is characterised by different clay which have different features; grey sticky clay, red clay, dark clay, brown clay and greenish clay. Test well no 3 has almost the same profile as test well no 2; the first 21 meters of the hole is characterised by different clay which have different features.

TABLE 3: Chemical analyses results of the three boreholes, depth integrated samples.

Water Quality Parameters	Unit	Test well 1	Test well 2	Test well 3
Turbidity	NTU	0	8	28
Total Dissolved Solids	mg/L	408	548	320
Electrical Conductivity	µS/cm	460	816	397
PH	-	8.40	8.00	7.30
NH_4^+	mg/L	0.00	0.30	0.58
Sodium	mg/L	146.3	200.6	85
Potassium	mg/L	8.10	7.00	5.30
Calcium	mg/L	7.00	8.00	9.60
Magnesium	mg/L	1.80	2.90	3.40
Total Iron	**mg/L**	**0.17**	**1.8**	**1.7**
Manganese	mg/L	0	0	0.30
Fluoride	**mg/L**	**2.82**	**2.30**	**2.20**
Chloride	mg/L	8.90	9.90	7.10
Nitrate	mg/L	3.10	0.90	0.90
Nitrite	mg/L	0.01	0.03	0.06
Bicarbonate	mg/L	230	512	268
Carbonate	mg/L	90	24	0
Sulphate	mg/L	0	1.00	2.00
Phosphate	mg/L	0.14	0	0
Silica	mg/L	39	25	56
Total Alkalinity, as $CaCO_3$	mg/L	365	492	258
Total Hardness, as $CaCO_3$	Mg/L	25	32	38

DISCUSSION

Comparing the specific sample analyses results of the three test wells as shown in table 1 with the respective geological logs as shown in Table 2, the concentrations of fluoride in all three cases seem relatively low specially at the depths of clay based profile. Furthermore, at the same depths, the concentrations of iron seem relatively high, cf. Figure 1. It implies that the clay-based minerals have considerably high contents of iron. Close examinations of the test results clearly indicate that there is some sort of relation between iron and fluoride, which was observed at different depths.

As can be seen from the chemical analyses results of integrated sample of the three test bore-holes, Table 3, the concentrations of iron and fluoride have shown some sort of relationships; when the concentration of iron is relatively low, the relative concentration of fluoride is low. On the other hand, when the concentration iron is relatively high, the concentration of fluoride is relatively low. Figure 2 shows that the fluoride to iron concentration ratio in the attached water is significantly lower in the clay based depths; 0.6 towards 1.4 in the non-clay based depths. This phenomenon is probably due to adsorption of fluoride on iron rich minerals. The aquifers, i.e. the water bearing strata of the three test wells are of are in the same regime.

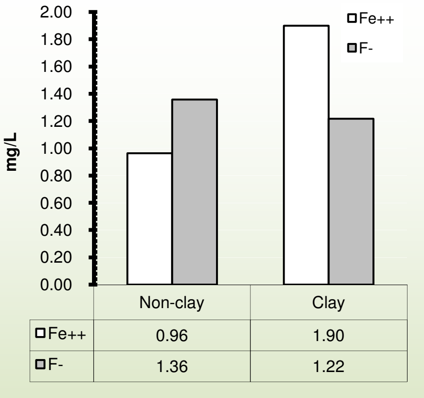

FIGURE 1 Average Fe2+ and F- concentrations in mg/L in the depth specific logs without and with clay.

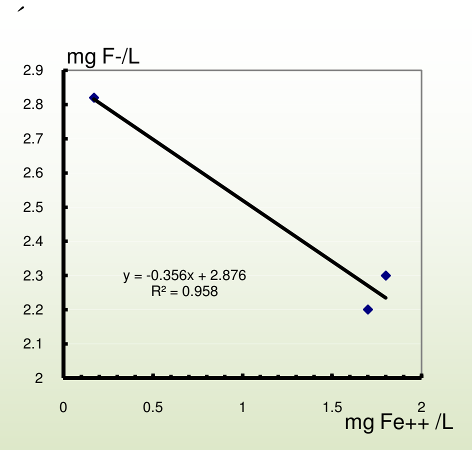

FIGURE 2. Conc. of Fe^{2+} and F^- in the integrated samples of the three test wells. Trendline and equation indicated.

The results of the chemical analyses given in Table 3 show the major cations and anions contents in the integrated samples. It is seen from the data that the groundwater of this specific aquifer is exclusively categorised as sodium-bicarbonate type water. The data illustrate that the rock composition of the well field is almost uniform.

CONCLUSION

The examination of the groundwater quality of Jirnma area indicates a relationship between the contents of iron and fluoride in this specific aquifer. A correlation is established tentatively, subject to confirmation upon further testing. From the study of the lithology of the test well, it appears that iron rich clay based minerals are attached to lower fluoride concentrations in the groundwater. Ion balance considerations on the integrated depth samples show that the groundwater is sodium-bicarbonate water type, as typically found in the Ethiopian Rift Valley basin.

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