# SIGNIFICANCE OF ELEVATION ON FLUORIDE BINDING CAPACITY OF ETHIOPIAN SOILS

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**SUMMARY: The present study tests the hypothesis that elevation might be a factor to be considered in the search for the soil best fit for fluoride removal in high-F waters. Fifteen soil samples (mostly reddish ferruginous laterite) were collected from surface soil in the Ethiopian Rift Valley area above Addis Ababa, at elevations between 2000 and 3,000 m. The samples were heated at 500°C for three hours, whereupon the fluoride binding capacity was tested by immersing aliquots of 10 g fired soil in 100 ml NaF solution. The residual F-concentrations were checked versus time. Soils from the lower areas of the Rift Valley were fluoride-rich, and tended to release fluoride, even to 40 mg F/L solutions. At initial concentration of 5 mg/L, addition of 100 mg soil to 1 litre of the water could almost double the initial fluoride concentration, i.e. "removal" efficiency of –78 %. On the other hand, soil samples from elevated areas could remove fluoride from the aqueous NaF solutions. On an average, the removal efficiencies were of the same magnitude, 67 and 68 % from waters containing respectively 5 and 40 mg/L. This corresponds to removal capacities of respectively 0.03 and 0.3 mg/g. It is discussed that soils from the Ethiopian Highland may be used for inexpensive moderate removal of excessive fluoride from the drinking water.**

**Key words:** Fluoride; Defluoridation; Lateritic soils; Elevation; Ethiopia; Rift Valley.

## INTRODUCTION

The volcanic base-rock in the African Rift system is predominantly alkaline, and rich in e.g. sodium and fluoride. The soil produced by the weathering of these rocks is similarly rich in fluoride. After precipitation, however, rainwater leaches fluoride from soils as well as from crystalline rocks.[1] The surface waters of East Africa, therefore, usually have high fluoride concentrations.[2] Furthermore, since the hydro-chemistry of aquifers is strongly influenced by the surrounding lithology, the fluoride content of ground water of Rift Valley is high, frequently to the extent that the waters are rendered unfit for human consumption.[3,4]

In discussing the occurrence of fluoride in the environment, a WHO expert committee (1994) concluded that «Waters with high fluoride content are usually found at the foot of high mountains» and, conversely, «In high mountains, the fluoride content of the soil is usually low».[5] The experts offered no explanation for these facts. However, over the millennia, fluoride may have been washed out of the topsoil in high places. Rivers and creeks have transported the element to the low lands, where it, due to evaporation, has enriched soil and local groundwaters. This might particularly be the case in the African Rift Valley, where low precipitation and high temperature often drain the mountain-rivers before they reach the ocean.

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High fluoride drinking water is a serious health problem in the Rift Valley as well as in other arid and semi-arid areas in Africa and elsewhere. Simple, low-cost defluoridation methods are urgently needed. Consequently, we decided to test the following hypotheses:

Fluoride-depleted topsoil may be able to reabsorb $F^-$, and, thereby, remove excessive fluoride from high-fluoride water.

The fluoride binding capacity of the soil may depend on e.g. the relative elevation of the sites from where the soils were sampled.

**TABLE 1.** Location of sampled soils, according to elevation.

| Relative elevation | Area |
|---|---|
| 1. | Lake Shala |
| 2. | Lake Langano |
| 3. | Lake Ziway |
| 4. | Wonji |
| 5. | Mojo |
| 6. | Debre Zeyt |
| 6. | Akaki |
| 7. | Borago River |
| 8. | Borago Mountain (1) |
| 8. | Borago Mountain (2) |
| 9. | Kotebe Kara |
| 10 | Lambaret |

## MATERIAL AND METHODS

**Soil samples.** A series of 15 soil samples were collected for the study. The sampling sites were chosen based on their relative elevation: Starting at Lake Shala, at the “bottom” of the Rift Valley, 2,000 m above seal level, soil samples were collected from sites of increasing elevation, up to an altitude of approximately 3,000 m, in the mountains around Addis Ababa. As exact data for the altitude of some of the sites are not known, elevation was indicated according to an increasing, relative scale, 1-10 (Table 1). The distance between the lowest and the highest point was around 200 km.

The samples were taken from the surface layers of the soil. Most samples were reddish ferruginous laterite; i.e. soils formed in tropical regions by decomposition of under-laying rocks. In some sites the laterite was covered by a layer of black, humus-like earth. The soil samples were collected in plastic bags, labelled, and brought to Bergen, Norway, for further processing. The soils were heated at 500°C for three hours, and aliquots of 10 g soil were prepared from each sample.

**Fluoride binding capacity.** The fluoride binding capacity of the various soils was assessed by immersing the 10 g soil samples into aliquots of 100 ml NaF, which had been prepared to contain 5, 10, 20 and 40 mg F/L.

The test samples (100 ml NaF solutions with 10 g soil) were kept unstirred at room temperature in lidded plastic vials. After 1, 2, 6, 12 and 24 hours, 5 ml liquid was taken from each of the (sixty) vials, and analyses were made by the use of a fluoride selective electrode (ORION comb. fluoride electrode 960900), according to standard methods.[6]

The results were entered in an SPSS-statistical programme.

## RESULTS

Figure 1 and 2 demonstrate the results of fluoride analyses over a 24 h period in solutions of, respectively, 5 and 40 mg F/L, after the immersion of soil from the three lowest, respectively, highest sites. The immersion of soil in all cases caused changes in fluoride concentration of the NaF solutions. In most cases the fluoride concentration was decreasing.

However, soil samples from the lake areas, i.e. the lowest parts of the Rift Valley, tended to release fluoride into the solution, thereby increasing the concentration of fluoride. This was particularly notable in the solutions with lower concentrations of fluoride, i.e. 5-10 mg F/L, Figure 1.

Based on the results at 24 h, the reduction of fluoride, expressed in mg/L, was plotted against the relative elevation of the soil sites. Similar patterns were found in all the tested solutions: Soil from higher altitudes absorbed more fluoride than did soils from the areas at a lower elevation. There seemed to be no systematic difference in fluoride absorbing capacity between black and red soils.

## DISCUSSION

The fact that clay and clay-ware as well as various soils may be used for defluoridation of water is well known.[7-9] In most cases, however, investigators have concluded that the $F^-$ binding capacity of these materials is - for practical purposes - too low.[10] The reason for the negative conclusion may be that the defluoridation agents are made from high-fluoride clay/ pottery. The defluoridating agent may, consequently, have started out more or less saturated with fluoride. The average fluoride binding capacities observed in this study are shown in table 1.

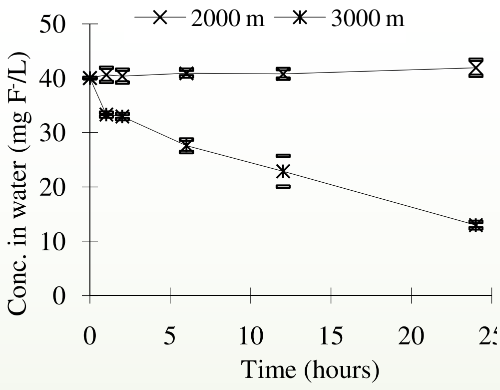


**FIGURE 1.** Fluoride concentration in water vs. time, after exposure to soils collected at mountains areas and low parts of the Ethiopian Rift Valley, respectively. (Mean of three samples and standard deviation)

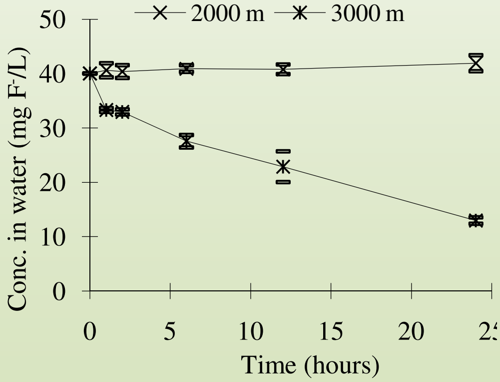


**FIGURE 2.** Fluoride concentration in water vs. time, after exposure to soils collected at mountain areas and low parts of the Ethiopian Rift Valley, respectively. (Mean of three samples and standard deviation)

**TABLE 1.** Average data of fluoride removal as calculated for three replica samples from Ethiopian soil at different altitude. Negative removal means that the soil is leaching fluoride to the fluoride water. Dosage is 100 g soil/L.

| Relative height in m | 2000 | | 3000 | |
|---|---|---|---|---|
| Initial F-conc., mg/L | 40 | 5 | 40 | 5 |
| F-conc. after 24 contact time | 41.9 | 9.4 | 13.0 | 1.6 |
| F-removal efficiency in % | -5 | -87 | 68 | 67 |
| Soil removal capacity | -0.02 | -0.04 | 0.27 | 0.03 |

It should be emphasised that there is a wide variation in the fluoride binding capacity also of high-altitude soils. In fact, the altitude per se is probably irrelevant. The crucial point might seem to be whether precipitation and surface water have depleted or enriched the soil as to fluoride.

The *best* defluoridating agent may not yet have been found through this study, but, according to the present findings, black and red soils from the Ethiopian Highland may be used for inexpensive moderate removal of excessive fluoride from the drinking water.

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