FLUORIDE

Quarterly Journal of The International Society for Fluoride Research Inc.

Prospecting Low Fluoride Water for Drinking in Fluorotic Areas of Tanzania

Unique digital address (Digital object identifier [DOI] equivalent):
https://www.fluorideresearch.online/epub/files/287.pdf

Eli DAHI[1]

[1] Professor Eli Dahi
Defluoridation Technology Project
Regional Editor of *Fluoride* for Africa
Denmark

Paper presented at the XXXth International Conference for Fluoride Research, Szczecin, Poland, 2012 Sept 5-8.

Corresponding author:
Professor Eli Dahi
Defluoridation Technology Project
Regional Editor of *Fluoride* for Africa
Denmark
E-mail: elidahi@hotmail.com

Accepted: 2024 Sept 17
Published as e287: 2024 Sept 27.

ABSTRACT

The Defluoridation Technology Project was called upon to survey existing water resources by three different institutions lying in fluorotic Tanzania: 1) The Ngongongare Secondary School. 2) The St Constantine International School and 3) The Minjingu Church Project. In case 1), due to low affordability, an open dug well was proposed. In case 2) a defluoridation system was installed and could be used to estimate essential design parameters, as Operation Period (1 Year), Removal Efficiency (93 %) and Removal Capacity (3-4 mg/g of Bone Char). In case 3) the water was deadly toxic because of high fluoride concentrations, but, fortunately, unpalatable due to high contents of Alkalinity/Salinity. The salinity renders the defluoridation process useless. A system of combined rain water harvesting and defluoridation of brought water sources was proposed.

Key-words: *Defluoridation process, Tanzania, National Parks, Fluoride, Trona, Rainwater harvesting. Rift Valley, Alkaline water.*

INTRODUCTION

The Great Rift Valley, also called The Afro-Arabian Rift Valley, is the most extensive rift on the Earth's surface, 6,400 km in length and 60 km in average width (Figure 1).

It extends from Lebanon (Al-Biqaa Valley) through Jordan and Palestine (Jordan River, Dead Sea and Harava Valley to Gulf of Aqaba), Red Sea, Eretria-Djibouti, Rift Valley of Ethiopia, separating Eastern and Western Ethiopian Highlands and dotted by many small lakes, down to Kenyan Lake Rudolf. In East Africa the Rift forms a dual line. On the eastern part Kenyan Rift Valley is dotted by Lake Baringo, Lake Nakuru, Lake Naivasha and Lake Magadi. Here the dual line surrounds Lake Victoria.

The Tanzanian Rift is marked by Lake Natron, Lake Manyara and Lake Eyasi, down to Malawian and Mozambique Lake Nyasa. On the western part Zaire-Ugandan Lake Albert and Lake Edward and Ugandan Lake George. This Rift continues to Zaire-Rwandan Lake Kivu, Burundi-Zaire-Zambia-Tanzanian Lake Tanganyika, Tanzania Lake Rukwa and the mentioned Lake Nyasa. The Rift Valley ends with the Mozambique Basin and the Indian Ocean. The Great Rift Valley constitutes the most significant global fluoride belt on Earth.

Tanzania is one of the World's richest countries with respect to national parks. Mostly the parks lie within the Rift Valley, where fascinating wild life thrives prosperously. Through history the lands within and around have been sparsely populated by humans, probably because these lands have been considered marginal, without fresh water resources. Especially around the alkaline lakes the surface- as well as the groundwater resources contain unpalatable concentrations of Trona, locally called Magadi (from 500-20,000 mgTD/L), along with highly toxic concentrations of fluoride (from 2 up to 1,000 mg/L).

Population growth and intensive modern tourism has made such areas very popular and with that comes habitation of previously inhabitable land. Countless lodges and camps sites are established and supportive villages are proliferating. The hunt for fresh and safe water for human consumption is on-going and would probably be accelerating in near as well as far future.

The Defluoridation Technology project has its base near the Arusha National Park, thus centrally situated in the East African Rift Valley and the southern part of the Great Rift Valley. The Defluoridation Technology Project was called upon to survey existing water resources by three different institutions lying in fluorotic Tanzania.

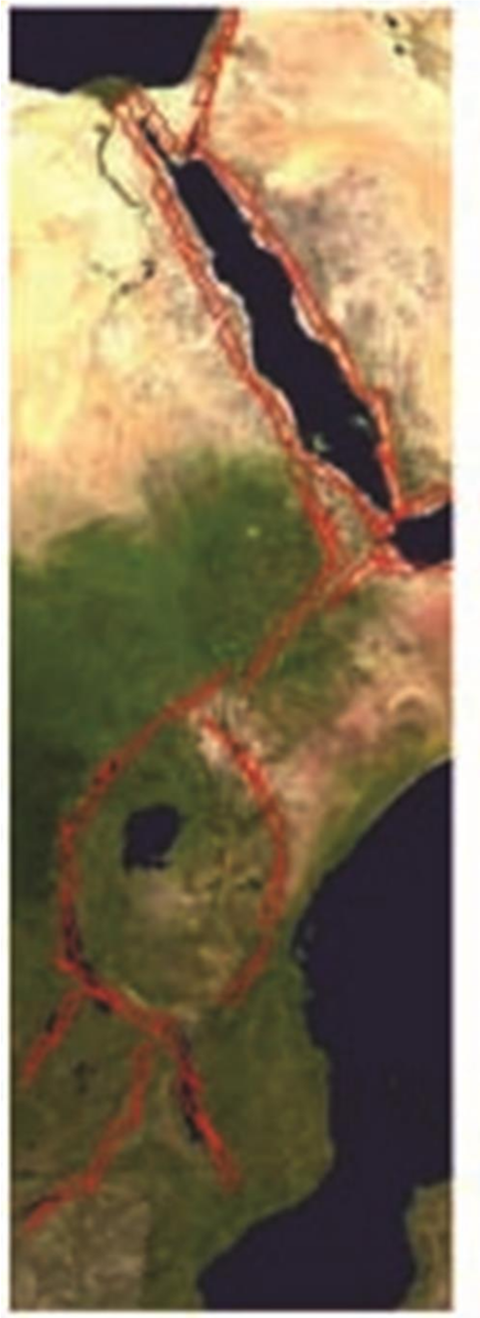

Figure 1. Rift Valley

CASE I: NGONGONGARE SECONDARY SCHOOL

Present Water Situation: Ngongo Secondary School (NSS) uses the village water supply line, comfortably coming down from the Arusha National Park and passing through the school area. A couple of years ago the water contained 8 mgF/L and this was known to the school. However, the present fluoride concentration in the water was not known, as were the fluoride associated risks. NSS had an old insufficient and faulty rainwater collection on one side of one of roofs. It also had a 5000 L rainwater collection tank. However, most of the year the tank was used to store the water from the Village Pipe Line at the time where the line was functioning during the short rainy season. Otherwise it was dry. The pupils were required to bring their own drinking water from their homes, which in some cases means from the Village Water Line.

Survey: NSS and the neighbouring area were surveyed, cf. Figure 2. It was found that all neighbours, especially on the belt between the Park and the school had their own open wells, with very fluctuating water depths. The wells however never went dry. While the first two private wells were in use, the well of the Simba Lodge was not in use, Like the borehole of Ailanga which was also not in use.[1]

All open wells had moderate fluoride concentrations, 1-2.5 mgF/L, as is normal for small catchment areas where the rain water does not infiltrate the ground for long distances/depths. On the contrary to this, the ground water from a school borehole nearby was 5.4 mgF/L. Most surprising was the water supply in the Village line. It contained 14.7 mgF/L.

From the slopes of the ground it was assumed that the ground water flows from the National Park South-East-wise toward the village. The school, though lying upstream of the Village in the water supply, experienced frequent water supply cuts, because the villagers downstream from the school withdraw water from the line by siphoning. This could be explained from the topography of the area, where the school area is relatively elevated compared to the entire village.

Proposal: The School, like most local schools, could not afford to maintain a defluoridation unit. Defluoridation was, therefore, not a feasible option.

Instead it was proposed that the school itself could dig an open well. Such a well could be protected and equipped to pump water automatically to a water reservoir near the kitchen, as the kitchen is already built on a hill. So far, this proposal was not adopted by the School Committee in fear of the well getting dry in the dry season. It has to be mentioned that the area, being a plateau, experiences significant fluctuations in ground water level, e.g. 2-4 m.

Further, it was proposed to improve and protract the present rain water collection to supply rainwater for drinking at least during a part of the year. This proposal was adopted and a Canadian Rotary Club agreed to sponsor the project. This project is on-going. .

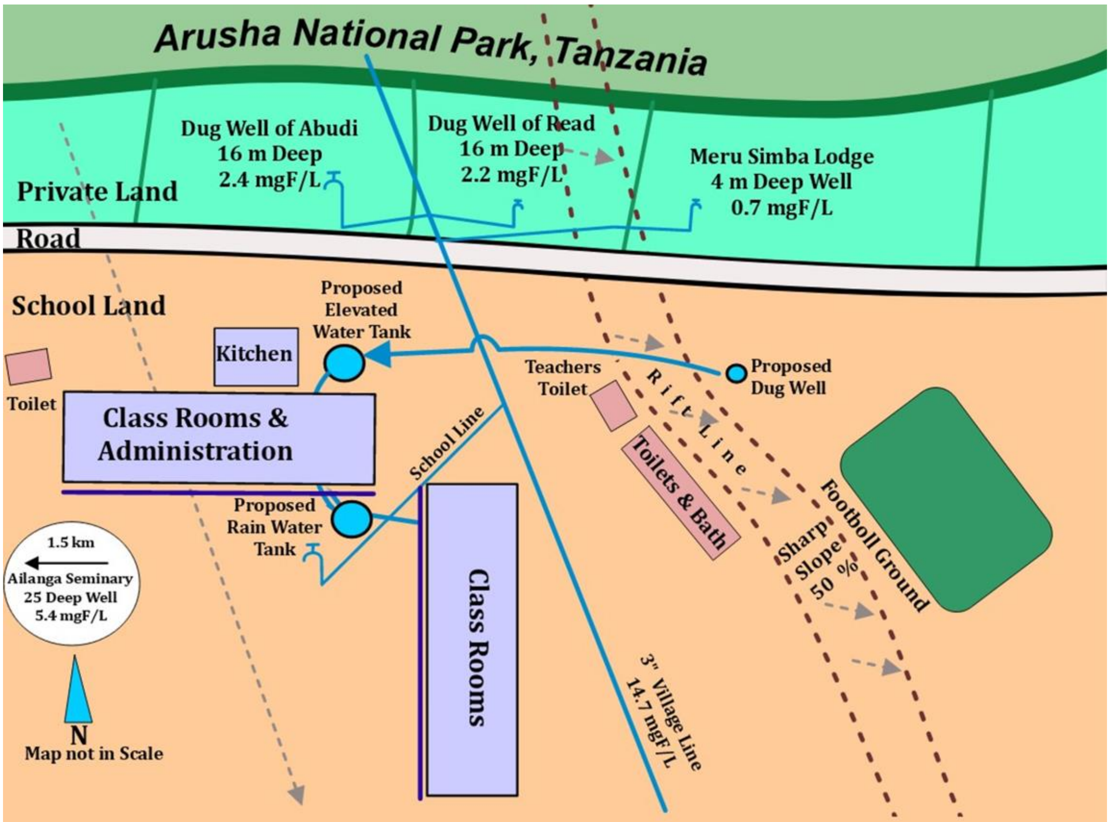

Figure 2. Map of the surveyed area of the Ngongongare Secondary School

CASE II: ST CONSTANTINE INTERNATIONAL SCHOOL

General information about the School: St Constantine international school (SCIS) is the largest International school in Arusha City. Although it has a large premise in the Eastern part of the city it does not have any municipal water supply. The school had its own water source from a nearby farm. The water contained 7.5 mgF/L and was not used for drinking. The drinking and cooking water were fetched daily from Arusha City, where the fluoride concentration is 4.5 mgF/L This was, surprisingly enough, in agreement with the Tanzania Temporary Standards. After installing the defluoridation water filters, the Cafeteria, the Kitchen and the Dormitories got piped safe water, on an average of 0.5 mgF/L (Figures 3 and 4).[2]

Figure 3. The St Constantine International School kitchen with the old manually transported drinking water.in the cafeteria and kitchen with 4.5 mg F/L.

Figure 4. The St Constantine International School with the new defluoridation water filter with safe water, 0.5 mg F/L, piped directly to the school cafeteria and kitchen.

Removal Efficiency:

The removal Efficiency, of the school water defluoridation filter can be calculated, from the relative difference between the inflowing and outflowing fluoride concentrations. As the outflowing fluoride concentration is changing by time, the removal efficiency is changing by time of use of filter before a recharge is done, from 100 % and downwards. If the Maximum Allowed Concentration in the treated water is selected to 1 mgF/L, corresponding to an Operation Period of 1 year, the average concentration , ($C_{o,av}$), within this operation period can be used,

e.g. $C_{o,av}$ = 0.5 mgF/L.

$$\varepsilon = \frac{C_i - C_o}{C_i}$$

$$\varepsilon = \frac{7.5 - 0.5}{7.5} * 100 = 93\ \%$$

Thus, the removal efficiency, during an operation period of one complete year, varies from 100 % to 87 %, where the effluent concentration is at Maximum Allowable, 1 mgF/L, and average removing efficiency, $\bar{\varepsilon}$, is 93 %.

This example illustrates, that a filter's Operation Period is a variable that decides the degree to which the effluent water is treated. The shorter the operation period, the better is the average removal efficiency. The Defluoridation Technology Project designs its filters for a one-year operation period and average drinking water fluoride of 0.5 mgF/L

Figure 5 shows how the drinking water use increased drastically, after installation of the defluoridation system, probably in part because teachers and other school workers and watchmen took some defluoridated water home to their families.

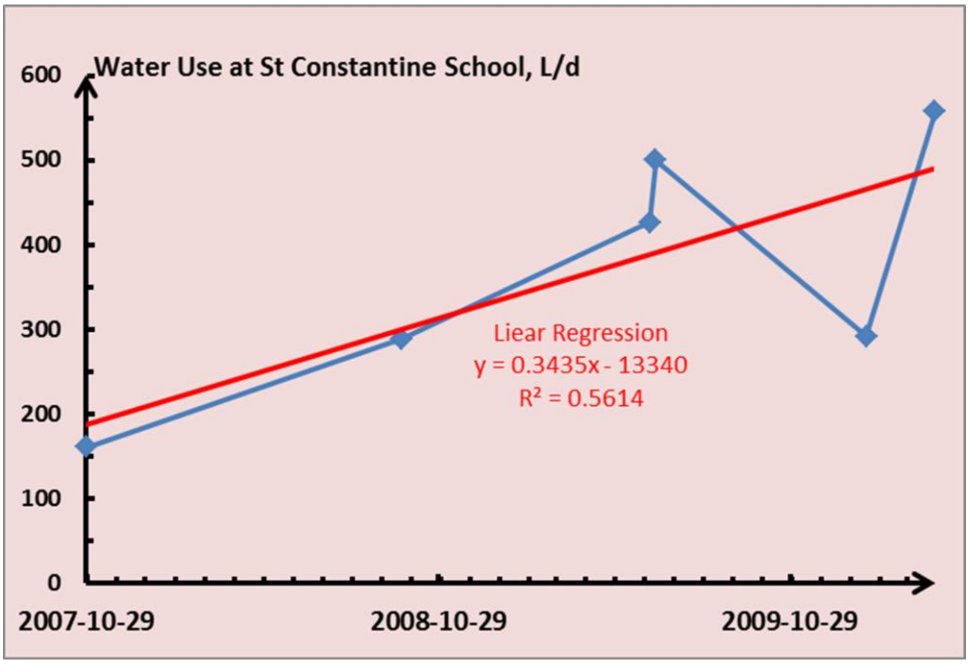

Figure 5. Observed increase in daily drinking water use after defluoridation installation at the SCIS.

Fluoride, Epub 2024 Sept 27: e287

Figure 6 shows the observed fluoride breakthrough as a function of time when the school defluoridation filter is used.

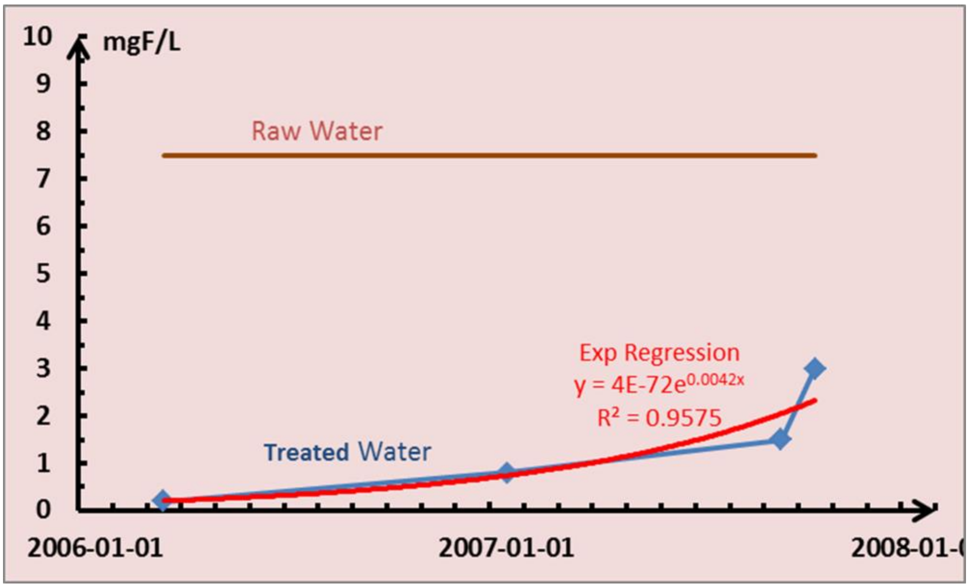

Figure 6. Observed fluoride breakthrough as a function of time where the school defluoridation filter is used.

The totally removed fluoride, $P*Q*(F_i-F_o)$ in mg, divided by the amount bone char in the filter, M, in kg, is the Removal Capacity of the filter, under these operation conditions.

$$\kappa = \frac{P * Q * (F_i - F_o)}{M}$$

$$\kappa = \frac{12\ m * 30\ d/m * 250\ L/d * (F_i - F_o)\ mg/L}{210\ kg * 1000\ g/kg} = 3\ mg/g$$

The Removal Capacity, κ, was calculated to 3 mg/g. The Defluoridation Technology Project worked out different designs and the Removal Capacity could be improved to 4 mgF/g bone char (BC). It is seen that this estimation of κ is quite burdensome, expensive and time-consuming. That is why efforts have been made to develop a rapid batch test to estimate the defluoridation capacity.[3,4].

The Removal Capacity is valid for a certain quality of Bone Char and operation parameters of the filtration. It is most useful in the process of design of new filters.

CASE III: MINJINGU CHURCH PROJECT

The Minjingu Church Project called upon DTP to advice about providing safe drinking water. Minjingu is a town lying close to Lake Manyara and the Lake Manyara

National Park, known as an alkaline lake in a highly fluorotic area.

DTP surveyed the area and worked out a map, showing the location of the Church and surrounding water source sites 2–10, (Figure 7).[5]

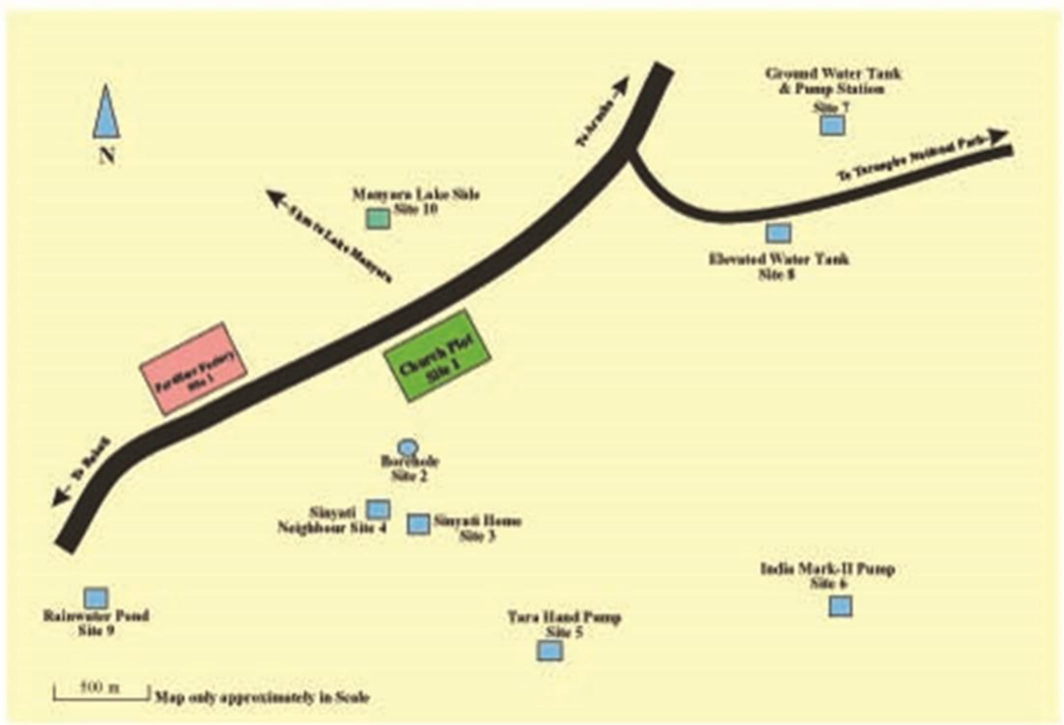

Figure 7. Map of the Minjingu Church plot and surrounding potential drinking water sources.

Figure 8 is a close-up map of the Minjingu Church plot and nearby area.

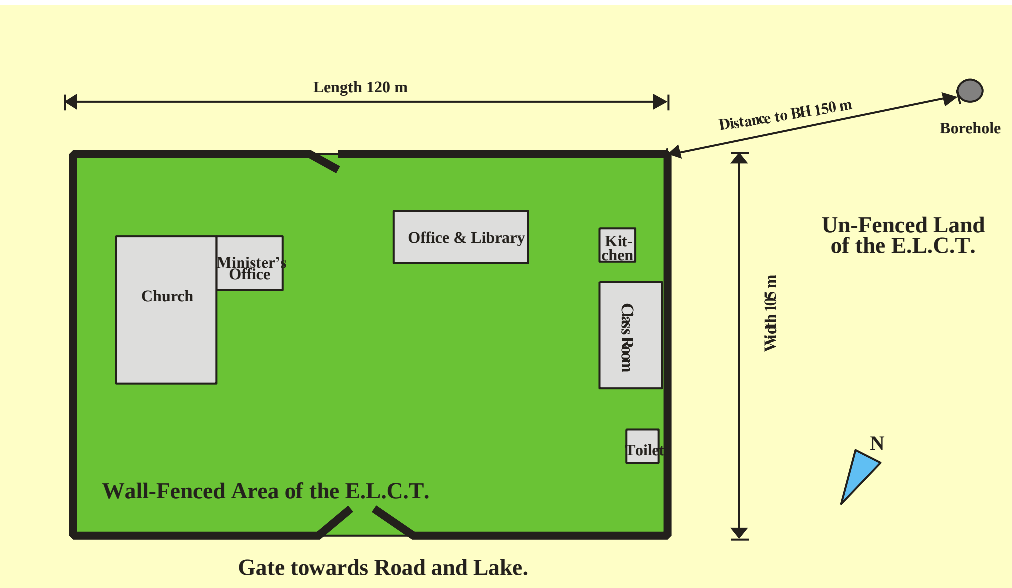

Figure 8. Close map of the Minjingu Church plot and the nearby area.

The water sources of the area near the Church Project were analysed for fluoride and Total Dissolved Solids (TDS). The results are shown in Figure 9 which shows that: The Minjingu area is ecologically a part of the Lake Manyara National Park, and that the water is unfit for human habitation, because of high fluoride as well as TDS, both in the ground and the subsurface waters.

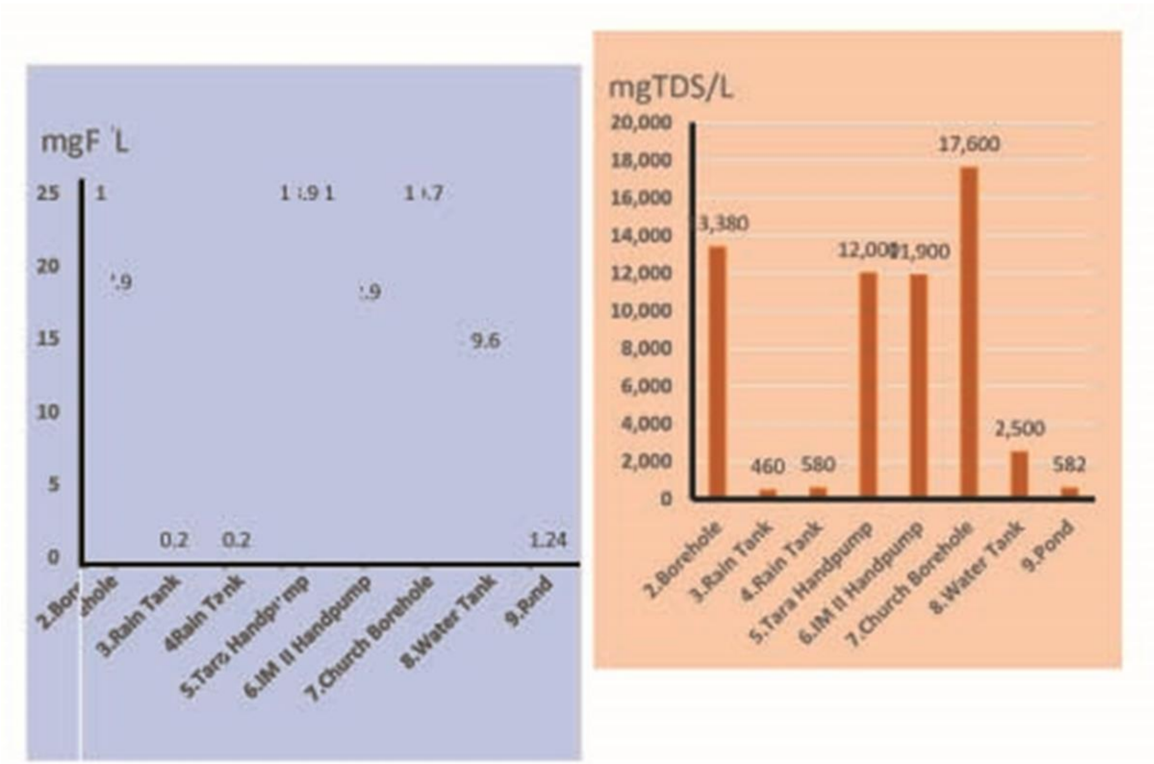

Figure 9. Fluoride(L) and Total Dissolved Solid (R) concentrations as measured in water resources near the Church Project. The site numbers indicated refers to the Map, Figure 7.

- The rain water tanks (Sites 3 & 4) are fine for drinking, but only available for the tank households.
- The pond (Site 9), dug by the Masai for their cattle drinking, is safe from fluoride as well as salinity points of view, but unfit for drinking of humans, because of repulsive suspended solids and general microbial pollution.
- The borehole drilled outside the Church Plot (Site7), which was meant to provide safe water to the Church and its neighbours, is totally non-useful for drinking of both humans and animals. It was recommended blocked for good, to avoid potential misuse.
- The system proposed for the Minjingu Church Project includes rain water harvesting, utilising the large roof of the church, in combination with a defluoridation system for treatment of brought from far low fluoride water, as sown in Figure 10

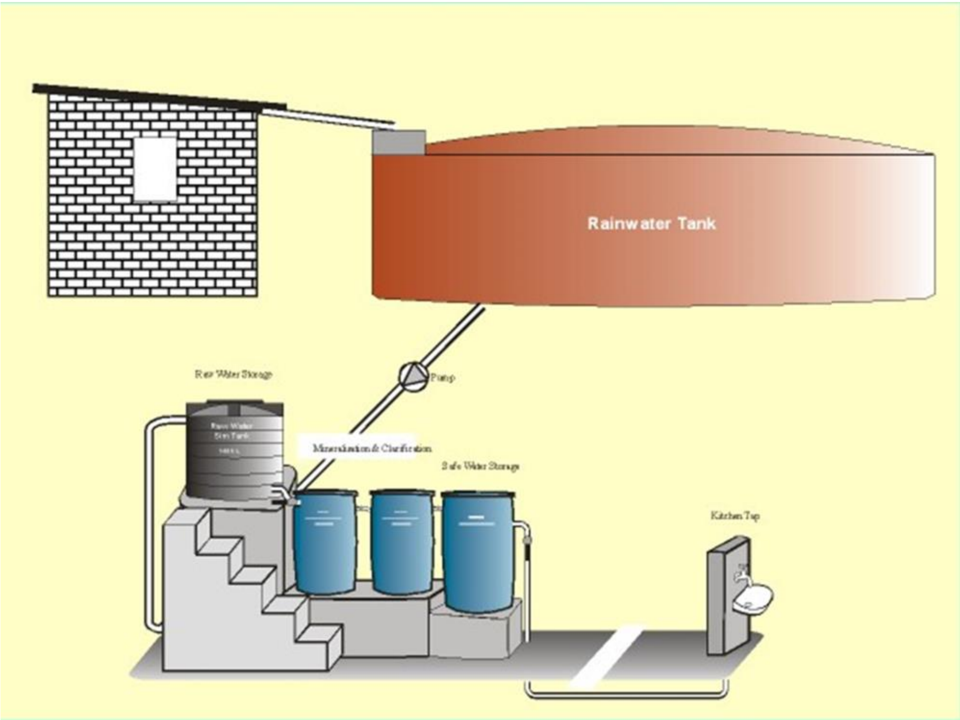

Figure 10. A proposed combined rain water harvesting and supplementary fluoride water transport and treatment.

CONCLUSIONS

In an International School in Arusha, where the fluoride concentration in water is 7.5 mgF/L, a defluoridation system could remove the fluoride for 1 complete year, at an average Removal Efficiency of 93 %, and a removal Capacity of 3-4 mgF/gBone Char.

In moderately fluorotic areas of Tanzania, safe water can be provided through prospecting of low fluoride water resources e.g. in shallow dug wells or even shallow depth boreholes, alone or in combination with rain water harvesting.

In the marginal lands of Tanzania, the fluoride concentration in the ground and even subsurface waters is so high, that the water is deadly toxic for both humans and animals. When acute fluoride poisoning does not occur, it is because of the attached unpalatable alkalinity/salinity in the water.

The same alkalinity/salinity turns the defluoridation by means of bone char useless as a water treatment, as it may remove the fluoride but not the salinity.

A water supply system is proposed combining rain water harvesting and defluoridation of brought water resources.

REFERENCES

[1] Defluoridation Technology Project. Personal Communication to the Ailanga Stirring Committee. 2017 01 17.

[2] Defluoridation Technology Project. Performance of the Defluoridation Plant & Survey of Leakage and Wastage of Defluoridated Water at SCIS, 2015. pp 5.

[3] Dahi E. A simple procedure for the routine determination of the standard defluoridation capacity of media. Fluoride 2015;48(1):2-28 .

[4] Spittle B. A standard defluoridation capacity test. [editorial]. Fluoride 2015; 48(1):19-21.

[5] Defluoridation Technology Project. Consultation Report on Safe Water Supply to ELCT Church, Ndori Parish, Minjingu, Babati District, Manyara District. 2012.