WATER DEFLUORIDATION FOR RURAL FLUORIDE AFFECTED COMMUNITIES IN TANZANIA

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Summary: Fluoride is present in high concentrations in drinking water from a large number of boreholes and wells in many districts in Tanzania. This create major fluorosis problems, and a lack of appropriate alternative water sources. The Ministry of Water, Energy and Minerals has constructed a pilot scale defluoridation plant. The plant allowed for investigations of the efficiency of the Nalgonda technique and the magnesite technique to remove fluoride from drinking water. The Nalgonda technique involves addition of high concentrations of alum and lime, while the Magnesite technique involves contact with magnesia (MgO), obtained by calcination of Magnesite ($MgCO_3$). Addition of 800 mg/l alum and 80 mg/l lime could reduce fluoride concentration in the water from 22 mg-F/l to 3.5 mg-F/l. By filtering the treated water through a filterbed filled with calcinated magnesite the fluoride concentration could be reduced further by approximately 1 mg-F/l. However the pH of the water which has passed the magnesite filterbed, has raised to around 10, and require further treatment.

Key words: Defluoridation; aluminium sulphate; lime; magnesite.

INTRODUCTION

Excessive consumption of fluoride by man and animals is known to cause adverse affects on calcified tissues. The effects associated with regular and prolonged consumption of water containing high concentrations of fluoride have been studied and documented by various researchers. It has now been generally accepted that while drinking water with the optimum amount of fluoride, significantly reduces dental carries, excess fluoride will produce adverse effects that range from mild dental fluorosis to crippling skeletal fluorosis.

Fluorosis is a major public health problem in some parts of Tanzania. Endemic fluorosis is a well defined clinical entity characterised by dental mottling and skeletal manifestations. Ever since the first fluoride surveys were made by MacQuillan, 1944[1] in the Northern part of Tanzania a number of scientific papers on the problem have been written and tremendous interest has been shown over the past few years. Several investigators have studied different aspects of the problem in Tanzania such as the clinical, epidemiological and biochemical nature of the disease. Grech et.al. 1964[2] and Latham M.C. 1967[3] studied the extent of the problem in Kilimanjaro and Arusha regions. Their studies highlighted the areas in which fluorosis exists in the endemic form, and elucidated the extent of the problem and the factors underlying the cause of the disease.

Apart from the health effects associated with high fluoride uptake by man, fluorosis also has socio-economic implications. In Tanzania, for instance, there has been a decline in the implementation of water supply programmes in the fluoride regions of

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Kilimanjaro, Arusha, Shinyanga, Mwanza and Mara. The fluoride regions are semiarid and depend most on groundwater as sources of water, which unfortunately has high levels of fluoride resulting in many shallow and deep boreholes, costing millions of shillings to drill, being abandoned.

Researchers in many countries of the World have, since the early 1930's, been trying to develop a suitable defluoridation method to reduce fluoride concentrations in water. While several methods have achieved some degree of success, no universally acceptable method has been developed so far.

This paper reviews the defluoridation work carried out by the Ministry of Water, Energy and Minerals (MAJI) in Tanzania. The defluoridation work concentrated on improving existing defluoridation technologies which have been tried elsewhere. The technologies should preferable use raw materials which are easily available at affordable prices in Tanzania. The objective of the work was to search for a possibility to apply the technology to the rural communities in the fluoride affected regions.

FLUORIDE AND FLUOROSIS IN TANZANIA

In Tanzania the issue of excessive fluoride levels in drinking water in some parts of the country is well known to experts from the water, health, nutrition and agricultural sectors. Studies by various researchers have indicated that most people from Kilimanjaro, Arusha, Singida, Shinyanga, Mwanza and Mara regions drink water with fluoride levels well above the WHO drinking water quality guideline value of 1.5 mg-F/l. As a result, some people have developed fluorosis problems ranging from mottled teeth to crippling fluorosis. It has also been observed that the diet of the people from the fluoride regions add to the total fluoride uptake from drinking water. Kitefu village in Arusha region for instance, received water from Maji ya Chai River until 1966, which has a fluoride content of 22 mg-F/l; at the same time people from the village used salt crusts (magadi) whose fluoride concentration varied from 2,000 to 14,000 µg-F/g-magadi for cooking purposes[4]. Mungure J.S. 1987[4] also verified that 34 % of the people in Kitefu village were suffering from skeletal fluorosis and 77% from dental fluorosis.

TABLE 1 Fluoride concentrations in selected water sources of Arusha, Singida and Shinyanga regions.

Region	Source & Location	Conc. mg-F/l
Arusha	Maji ya Chai, Arumeru District	20.0
	Lemongo spring	10.5
	Kikati B/H 113/79	11.0
	Masai Furrow-Tingatinga	32.0
	B/H 186/81 - Hanang	46.0
Singida	S/W 8/78 - Ngorongoro	11.6
	Senene	10.5
	Well camp Doromoni	21.3
	Fish camp Migilango village	12.5
	S/W 5H2 Doromoni	10.0
	Hot spring - Manyoni	10.5
Shinyanga	S/W Mkokolo	17.0

Source: Water Qwality Laboratory in Arusha

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The fluorosis situation in Arusha region is not different from the other fluoride stricken regions. Table 1 shows examples of water sources, some of which are boreholes with fluoride levels well above the WHO guideline value of 1.5 mg-F/l.

The prevalence of high concentrations of fluoride in water supply schemes has greatly affected the implementation of the water supply programme in the fluoride hit regions of Arusha, Kilimanjaro, Singida, Shinyanga, Mwanza and Mara regions. Large sums of money have been lost in the fluoride regions as most of the developed water supply schemes especially boreholes had to be abandoned due high levels of fluoride. Table 2 shows the percentage of water supply schemes mostly boreholes which should be abandoned due to high levels of fluoride when observing the WHO fluoride guideline value and the Tanzanian temporary fluoride standard.

TABLE 2. Percentage of water supply schemes which should be abandoned due to high concentrations of fluoride.

Region	Above WHO Guideline value of 1.5 mg-F/l.	Above Tanzanian Temporary Drinking Water Quality Standard of 8.0 mg-F/l.
´Arusha	55	18.0
Kilimanjaro	29	5.5
Singida	72	24.0
Shinyanga	61	12.0
Mwanza	59	10.0
Mara	49	3.5

Source: Proceeding of the Workshop on Domestic Water Health Standards with emphasis on fluoride - Arusha 21 - 23 June, 1982.

Various researchers including Horowitz, H.S and Heifez, S.B, 1972[5] have proved that by providing a community with defluoridated water, the prevalence and severity of fluorosis is reduced. These conclusions were drawn in Texas, USA where in 1952 a defluoridation plant reduced the fluoride level of the water source of Bartlett from 8 mg-F/l to an average of 1.08 mg-F/l. Studies carried out in 1954 and fifteen years later gave the different degrees of fluorosis as presented in Table 3.

TABLE 3. Percentage Distribution of children in Bartlett by fluorosis classification in the years 1954 and 1969.

Year	Normal	Questionable	Very Mild	Mild	Moderate	Severe
1954	2.3	1.5	3.0	43.9	34.9	14.4
1969	49.0	32.5	12.1	5.7	0.6	0.0

DEFLUORIDATION TECHNOLOGIES STUDIED

Various water defluoridation techniques has been studied by scientists around the World. After reviewing, it was decided in 1985 that the Nalgonda technique and the Magnesite technique were the cheapest, the easiest to operate and that both could be carried out by using locally available materials. A pilot plant for experiments was constructed and completed 1990.

Nalgonda Technique. Developed in India, the Nalgonda technique involves flush mixing of alum and lime solutions with the raw water, flocculation, sedimentation, and filtration in a way similar to what is practised in conventional water treatment. To be effective the method requires careful control of the alkalinity of the water.

TABLE 4. Jar tests on alum dosage and fluoride removal capacity. Raw water quality are the average over a 10 month period.

E.C.:Electrical Conductivity. TDS: Total Dissolved Solids.

Alum (mg/l)	pH	E.C. µS/cm	TDS mg/l	Fluoride (mg-F/l)
0	8.7	892	448	21.10
100	7.5	850	430	19.95
200	7.2	850	440	15.64
300	6.9	900	450	13.30
400	6.7	930	460	11.30
500	6.5	950	470	10.23
600	6.3	970	490	9.12
700	6.0	1,010	510	8.55
800	5.8	1,030	520	8.55
900	5.6	1,060	530	10.00
1000	5.1	1,080	540	10.20
1100	4.8	1,130	570	11.30
1200	4.7	1,150	580	11.30
1300	4.6	1,170	590	11.30
1400	4.4	1,240	620	10.85
1500	4.3	1,290	650	10.42

TABLE 5. Jar test experiment indicating the fluoride removal capacity of Alum and lime on raw water supplied to the pilot plant. Alkalinity of the raw water was 367 mg/l.

Jar No.	Alum mg/l	Lime mg/l	pH	Conc. mg-F/l
1	800	80	6.5	3.39
2	800	85	6.8	4.52
3	800	90	6.9	4.62
4	800	95	7.0	4.78
5	800	100	7.1	5.12
6	800	105	7.3	5.43
Raw water	0	0	8.8	23.3

Magnesite Defluoridation. Raw magnesite from Chambogo in Same, was collected and burned at different temperatures. Portions of magnisite burned at 900 ^{o}C were crushed and sieved to the size of 0.5 to 1 mm and packed in plastic buckets. Treated water from the sedimentation tank water was passed through and the efficiency of the magnesite in further removing fluoride was recorded (Table 6).

Determination of dosages of alum and lime. In order to optimise the pilot plant, jar test experiments were carried out using the standard laboratory jar test apparatus with

six stirrers and one litre beakers. The stirrers were rotated at 150 revolutions per minute for 1 minute for flush mixing and at 40 revolutions per minute for 15 minutes for flocculation. The water was allowed to stand for 1 hour and supernatant sampled for analysis. results of experiments with different alum additions are presented in Table 4, while results of experiment with alum addition fixed at 800 mg/l and lime addition varying from 80 to 105 mg/l are presented in Table 5.

DISCUSSION

The Nalgonda technique was able to reduce fluoride concentrations in water from 22.1 mg-F/l to an average of 3.5 mg-F/l. Lower levels of fluoride would have been reached if dosages of more than 800 mg/l alum were applied. With addition of 800 mg/l alum, residual sulphate was found to be below 600 mg/l.. In a pH range of 6.0 - 8.0, where pH 6.5 is the optimum residual aluminium was found to be below 0.2 mg-Al/l.

Water defluoridated by the Nalgonda technique was passed through a filter bed consisting calcined magnesite granules, fluoride was adsorbed by the magnesite granules thus reducing further the fluoride concentration in the treated water, however rise in pH to above 10.0 in the finished water created a need of adjustment. Although magnesite reduces fluoride, it needs to be regenerated regularly, a situation which would not be easy in the rural areas.

TABLE 6. Efficiency of Fluoride removal from pilot plant sedimentation tank when passed through a magnesite filterbed. TAL:Total Alkalinity

	Before Magnesite filter bed					After Magnesite filter bed				
Day	Time	pH	TAL mg/l	Hardness mg/l	F^- mg/l	Time	pH	TAL mg/l	Hardness mg/l	F^- mg/l
1	13.20	7.8	123	74	3.6	13.20	8.9	287	176	2.9
	14.20	7.9	130	76	3.5	14.20	9.9	346	177	1.4
	15.20	7.8	123	73	3.5	15.20	10.2	257	137	1.5
	16.20	7.9	128	78	3.6	16.20	10.0	207	121	1.4
	17.20	7.9	128	76	3.5	17.20	10.2	190	104	1.6
	18.20	8.1	129	74	3.5	18.20	9.9	177	98	1.7
2	12.35	7.9	134	70	3.4	12.35	10.1	158	79	2.1
	13.35	7.8	134	72	3.6	13.35	10.0	146	76	2.2
	14.35	7.6	136	72	3.6	14.35	10.0	158	79	2.3
	15.35	7.8	133	71	3.7	15.35	10.0	147	74	2.5
	16.35	-	-	-	-	16.35	10.0	152	73	2.5
	17.35	7.7	136	67	4.1	17.35	10.0	167	86	2.8
	18.35	7.7	131	75	4.0	18.35	10.0	148	78	2.8

CONCLUSIONS AND RECOMMENDATIONS

The raw water which had been used in the defluoridation experiments has a high fluoride level (22.1 mg-F/l). The data in Table 6 clearly indicates that defluoridation by the Nalgonda Technique is possible. However, the technology is at present expensive since aluminium sulphate is not produced locally. Once the plant is constructed, operation and maintenance costs are affordable especially when the water from the source flows by gravity. For other types of schemes costs could be a bit higher. For the pilot plant already constructed which can serve a village of about 2,000 people, the capital construction costs was estimated at TSh.15 mill. and monthly operational costs at about TSh.10,000/=.

Now that it has been proved that defluoridation is possible, immediate action is needed to disseminate the technology to fluoride affected rural communities in Arusha, Kilimanjaro, Singida, Shinyanga and Mara regions. External financial support is vital in order to ensure the success of the exercise.

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