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REACHING THE UNREACHED: CHALLENGES FOR THE 21ST CENTURY

Defluoridation using the Nalgonda Technique in Tanzania

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VARIOUS DEFLUORIDATION METHODS have been known to remove the excess of fluoride in drinking water in order to avoid endemic fluorosis, i.e. mottling of teeth, stiffness of joints and crippling. A comprehensive research programme has been carried out in the 60's and 70's at the National Environmental Engineering Research Institute (NEERI) in Nagpur, India, to develop appropriate methods for defluoridation of drinking water. As an important outcome of this programme it was concluded that the Nalgonda Technique is preferable at all levels because of the low price and ease of handling (Bulusu et al 1979). The Nalgonda Technique has been introduced in Indian villages and studied at pilot scale in e.g. Kenya, Senegal and Tanzania (Gitonga 1984, Lagaude et al. 1988, Gumbo 1987). This paper describes a modified design and an organisational setup of the Nalgonda Technique in household scale, as it has been introduced in Ngurdoto village in Tanzania by the Defluoridation Technology Project (a research collaboration between the University of Dar es Salaam, the Tanzanian Water Authorities and the Technical University of Denmark).

The Nalgonda technique

In the Nalgonda Technique two chemicals, alum (aluminium sulphate or kalium aluminium sulphate) and lime (calcium oxide) are added to and rapidly mixed with the fluoride contaminated water. Induced by a subsequent gentle stirring, "cotton wool"-like flocs develop (aluminium hydroxides) and are subject to removal by simple settling. The main contents of the fluoride is removed along with the flocs, probably due to a combination of sorption and ion exchange with some of the produced hydroxide groups. The removal process, which is still not fully understood, has by some authors been designated as a co-precipitation.

The Nalgonda Technique has been applied in India at different levels. On household scale it is introduced in buckets or drums and at community scale in fill and draw plants. For larger communities a waterworks-like flow system is developed, where the various processes of mixing, flocculation and sedimentation are separated in different compartments (NEERI 1987).

In the guidelines for household defluoridation published by NEERI in 1987, alum is to be added as a 10 per cent solution to a 40 litre bucket equipped with a tap. This was a modification of the previously described method, where alum was added as tablets (Bulusu et al 1979). The amount of chemicals required to reach 1 respectively 2 mg/l fluoride are presented as a function of the fluoride concentration and the alkalinity of the raw water in a dosage design table, originally published by Nawlakhe et al. (1975). Unfortunately, the experiences gained in Tanzania and Denmark have shown that the usability of these design guidelines has two serious limitations: Many water sources have fluoride/alkalinity limits outside the ranges presented in the table. Furthermore, the recommended addition of lime, as 5 per cent of the added alum, have shown to result in pH-values in the treated water which are significantly different from what is optimum for the fluoride removal (Lagaude et al. 1988, Dahi et al. 1995).

Defluoridation in the two bucket system

The designed defluoridator consists of two buckets equipped with taps and a sieve on which a cotton cloth is placed as illustrated in figure 1. Alum and lime are added simultaneously to the raw water bucket where it is dissolved/suspended by stirring with a wooden paddle. The villagers are trained to stir fast while counting to 60 (1 minute) and then slowly while counting to 300 (5 minutes). The flocs formed are left for settling for about one hour. The treated water is then tapped through the cloth into the treated water bucket from where it tapped as needed for drinking and cooking.

Our investigations have shown that at least some of the fluoride, which has been captured in the flocs, is released slowly back to the water. The use of two buckets should thus ensure that the treated water is separated from the fluoride containing sludge directly after the defluoridation. All physico-chemical processes are thus performed in the raw water bucket, while the treated water bucket is kept only for the storage of the defluoridated water.

Both containers are 20 litre plastic buckets, supplied with covers and equipped with one tap each, 5cm above the bottom to enable trapping of sludge. This type of bucket is produced in Tanzania, robust, cheap and very common, used by almost every family in Ngurdoto for fetching and storage of water.

The two small brass taps are imported from India at a low cost and can be installed by a local craftsman using a simple tool for punching the plastic.

The sieve acts as an extra safety device collecting any flocs which may escape through the tap in the raw water bucket. Normally, the water is completely clear, even more clear than the raw water, because the flocculation and sedimentation also remove water turbidity.

Distribution of chemicals

Alum and lime are sold to the consumers as powders in small sealed plastic bags. The bag contents equals the required dosage to defluoridate one bucket of the village water.

This chemical distribution system was selected in order ensure a skilled quality control, and a precise and reproducible dosage. The chemical bags are prepared at the Ngurdoto Defluoridation Research Station and wholesaled to the chairman of the village's women committee who arranges for a low profit sale to the villagers.

Alum is available in Tanzania in 50kg bags containing 5-15 cm bulky hard pieces, especially imported for water works practises. Alum is powdered manually in a stainless steel mortar. A sieving is required in order to ensure a uniform bulk density and a smooth handling of chemical. Lime is available locally in the markets, however in very different calcination qualities.

The bags are made from plastic film tube rolls, 4cm in width. The technology of distribution of materials in plastic rolls is locally well known and commonly used to pack spices and to produce home frozen juice ice cream. The chemicals are measured using a calibrated spoon, and put into a 4cm piece of the roll already sealed in the bottom, and then sealed on top by bending the plastic and heating it by passing it slowly over a flame of a small kerosene lamp. In order to avoid exchange of the two chemicals, lime is packed in black bags and alum in transparent ones. The two chemicals are always delivered together in equal numbers.

Raw estimation of required dosage

A preliminary estimate is made on the amounts of alum needed using the reundlich based formula developed by Dahi et al. 1995:

$$A = \frac{(F_r - F_t) \cdot V}{[\text{illegible}] \cdot F_t^{1/[\text{illegible}]}}$$

Where:

A is the amount of alum required, g.
F_r is the fluoride concentration in the raw water, mg/l.
F_t is the residual fluoride concentration in the treated water, mg/l.
V is the volume of water to be treated in batch, l.
[illegible] is the sorption capacity constant, $l^{(1-1/[\text{illegible}])}\ mg^{2/[\text{illegible}]} g^{-1}$
[illegible] is the sorption intensity constant, -

Our results have shown that, for pH = 6.7 and required residual fluoride between 1 and 1.5 mg/l, [illegible] = 6 and [illegible] = 1.33. The amount of lime required is far more difficult to estimate theoretically as it depends on the quality of lime, the alkalinity and pH of the raw water and the fluoride removal itself. Our experience have however shown that lime addition may be 20-50 per cent of the alum dosage.

Jar test determination of dosage

The appropriate dosage of alum and lime are determined experimentally through a Jar Test on each raw water source. The amount A is calculated for defluoridation of the water to 1 mg/l fluoride. Six different combinations of alum and lime are selected and tested. The chemicals are added simultaneously and jars are stirred for about 20 seconds at 100 RPM. Then for 5 minutes at 25 RPM before leaving to settle for ½ hour.

A series of jar tests were performed on raw water containing 12.5± 0.9 mg/l. Figure 2 illustrates the residual fluoride concentrations and corresponding pH obtained where different dosages of alum and lime were applied. The results demonstrate the importance of ensuring a pH of 6-7 in order to obtain an optimised fluoride removal (Dahi et al. 1995). Thus an optimum fluoride removal is obtained in the same pH range which is known to be optimum in usual waterworks flocculation.

Our experiences have shown that other factors like f. ex. the initial mixing time and intensity, the slow stirring time and intensity, if any of the two chemicals is added first and the shape of container are of minor importance for the removal compared to the dosage of alum at the right pH.

Alternatively, the Jar Test may be carried out in village buckets.

Experiences from village treatment

So far the defluoridation in Ngurdoto has been carried out for 1½ year including 76 families. Some of the main findings may be summarised as follows:

- The concentration of fluoride in the raw water, which is pipe schemed spring water, has been subject to both seasonal as well as non-seasonal variations, between 12.5 and 8.8 mg/l.
- The adopted dosages of 12.8g alum and 6.4g lime has been reducing the fluoride concentration to 2.1± 0.7mg/l in the villagers buckets.
- The villagers, have been capable of understanding and reproducing the treatment process.
- the price for 50kg of alum and 50kg of lime in Tanzania is 17 and 2 US$ respectively, and the total cost of one pair of chemical bags is estimated to be 0.02 US$.
- The villagers seem to be motivated and willing to pay 0.025 US$/pair of chemical bags, as they have been carrying out the treatment daily, at least in the non-rain season.

Obviously, the sat up system has its built-in limitations. It is not possible to reach lower fluoride concentrations unless excessive amounts of alum are applied. Hence the use of a small bone char column instead of the cotton cloth filter is under testing. Similarly the organisational setup of the distribution of chemicals is still dependent of the project. Its sustainability in a market oriented situation is still to be proven.

Figure 1.
The two bucket Nalgonda defluoridation setup.

Figure 2.
The effect of pH on defluoridation using 700-900 mg/l alum and 75-350 mg/l lime. Initial fluoride concentration was 12.5±0.9 mg/l.

References

Bulusu, K.R., Sundaresan, B.B., Pathak, B.N., Nawlakhe, W.G. et al. Fluorides in Water, Defluoridation Methods and Their Limitations. *Journal of the Institution of Engineers (India), vol. 60, p. 1-25, 1979.*

Dahi, E., Orio, L., Bregnhj, H. Sorption Isotherms of Fluoride on Flocculated Alumina. *In Proceedings of the 4th Workshop on Fluorosis and Defluoridation of Water, Ngurdoto, Tanzania, October 18-22 1995 (in Press).*

Gitonga, J.N. Partial Defluoridation of Borehole Water. *In: Flurosis Research Strategies, (ed Likimani, S.), Department of Dental Surgery, University of Nairobi, 1984.*

Gumbo, F.J. Partial Defluoridation of Drinking Water in Tanzania. *In: Proceedings of the Second Workshop on Domestic Water Health Standards with Emphasis on Flurode, Arusha, Tanzania, 1987.*

Lagaude, A., Kirsche, C., Travi, Y. Défluoruration des Eaux Souterraines au Sénégal Travaux Préliminaires sur L'eau du Forage de Fatick. (Eng Defluoridation of ground waters in Senegal preliminary work in the case of Fatick waters).*Techniques Sciénces Methodes (in French), vol. 83:9, p.449-452, 1988.*

Nawlakhe, W.G., Kulkarni, D.N., Pathak, B.N., Bulusu, K.R. Defluoridation of Water by Nalgonda Technique *Indian Journal of Environmental Health, vol. 17.1, p. 26-65, 1975.*

NEERI. Defluoridation. Technology mission on drinking water in villages and related water management. *National Environment Engineering Research Institute. Nagpur 440020, India. 1987.*

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