CRITICAL SUSTAINABILITY PARAMETERS IN DEFLUORIDATION OF DRINKING WATER

H Bregnhøj*
Copenhagen, Denmark

SUMMARY: Experiences from household and community defluoridation projects have been collected. They are presented in the form of critical parameters that need to be considered for the success of household defluoridation projects. Parameters are classified in three groups. Motivation of households seems to be critical since fluorosis is not always considered as the main problem of concern and improvements are not always visible for a number of years. Appropriate and cheap technique is always a must in poor villages. Finally the organisation of supporting functions that may include quality control, technical and motivating support, as well as general educational initiatives.
Key words: Defluoridation; Water supply projects; Critical parameters; Appropriate technology; Sustainability criteria.

INTRODUCTION

Defluoridation of drinking water in third world countries has generally been unsuccessful in spite of many attempts to implement projects aiming at provision of safe drinking water in fluorotic areas. Furthermore, no defluoridation initiatives have been taken in many areas where fluorosis is prevalent, probably due to lack of knowledge of appropriate technologies or lack of means to provide all the project components associated with defluoridation. The difficulties to achieve sustainable results are illustrated by the fact that very few projects are actually practising defluoridation at present.

A review has been initiated by the Danish International Development Agency, Danida, in order to assess practical defluoridation experiences in selected areas and to identify critical parameters in defluoridation projects. This paper presents the preliminary findings by the reviewer, based on study visits to defluoridation projects in India, Sri Lanka and Tanzania, interviews with a number of researchers and practitioners in the field of defluoridation and experiences expressed in project reports and scientific papers.

It seems practical to classify the critical parameters into three groups, each of which is absolutely essential to consider in any defluoridation project:

- Motivation of users.
- Appropriate and economic technique.
- Proper organisational setup.

Basically, defluoridation can be introduced at two organisational levels; as *household defluoridation,* carried out by the single households for their own consumption, and as *community defluoridation,* carried out for the public in a village, town, sub-village etc. Experiences with other forms like institutional defluoridation (schools, health centres etc.) or private defluoridators shared by several households are presently limited. The specific parameters are in the following grouped in household defluoridation and community defluoridation.

* *EnDeCo, Thulevej 16, DK-2860 Søborg, Denmark, E-mail: endeco@image.dk*

HOUSEHOLD DEFLUORIDATION

Defluoridation of drinking water has been implemented in different numbers of households. The Nalgonda technique, i.e. flocculation with alum and lime, has been experienced in India and Tanzania. Adsorption in activated alumina columns has been experienced in India and in crushed brick columns in Sri Lanka. Adsorption in bone char columns has been experienced in Thailand, Sri Lanka and Tanzania.

Motivation. Motivation of users to actually procure and use an available defluoridation technique is absolutely essential in household defluoridation. Any of the selected techniques requires attendance and an extra workload and payment either daily in case of the Nalgonda technique or (as an example) tri-monthly in the case of the column adsorption methods. To carry out defluoridation on top of the other burdens often faced in the regarded countries requires that the "water manager" in the household, almost always the woman, is properly motivated to do so.

First of all it requires awareness about the advantages of defluoridation, i.e. the possibility of reducing the skeletal and non-skeletal fluorosis among the family members. Many villages have only been exposed to fluoride during few years and the examples of fluorosis are scarce. The awareness has been induced through an awareness camp, i.e. a public meeting in the village where fluoride's health hazards, sources of fluoride, the fluoride situation in the village and fluorosis prevention both through defluoridation and changes in dietary habits is introduced. Use of living examples of fluorosis victims in the village has been mentioned as effective in raising the understanding of the seriousness of the matter.

Awareness camps seem to be appropriate for teaching of fluorosis subjects to a large group in the first instance. It has however been mentioned that sometimes villagers tend to forget the knowledge with time.[1] A large number of villagers are often illiterate and more used to learn by experience than by teaching. Special attention has to be paid to the procurement of understandable handouts and perhaps also certain forms of reminder sessions or continuous information.

It is not always enough to be aware of the consequences to actually act accordingly. Like the smokers smoke, fully aware of the high risk of lung cancer, some people will not defluoridate the water even though they have means to do so and they have their own children as living examples of dental fluorosis victims. This irrational behaviour, whether attributed to lack of interest, ignorance or laziness, seems to be a general human character that must be realised.

A commitment to the investment done when the household has paid for the defluoridator has been mentioned as a driving force to carry out defluoridation. The feeling of ownership is generally considered as a positive factor in operation and maintenance.

One parameter that seems to hinder peoples motivation is the lack of viable results, since fluoride cannot be sensed and reduction in fluorosis prevalence are usually not seen the first many years. The Unicef supported project in Rajasthan has had success in making a health survey before introduction of defluoridation and a re-examination of fluorosis victims three months after defluoridation start. The victims felt a relief in both skeletal and non-skeletal symptoms. Furthermore an increase in the ability to make certain movements was measured.[2] The understanding of the positive benefits when the collective results were presented to the community has been judged to be

one of the most important motivating factor in the project. It may for this reason be much easier to motivate people to carry out household defluoridation in areas with high fluoride concentrations (≥4-5 mg/L) than in areas with lower fluoride concentrations (1.5-3 mg/L).

Factors that seem to enhance the motivation to some extent are other improvements in water quality, experiences like the brick defluoridation seems to cool the water and bone char may give a better taste. Among other factors that "motivates" is perhaps a continuous attention of the defluoridation project manager, combined with a commitment (like a signed contract) to carry out defluoridation for a number of years.

Appropriate and economic technique. Because of the difficulties in motivating people for defluoridation it is extremely important to choose a technique that is cheap and which requires only minor workload. At the same time it should be easy to learn and remember, even for illiterate people. Obviously it should not impart any adverse taste to the treated water and the maintenance and repair should be easy and affordable.

For the Nalgonda technique and other possible methods that need a daily operation it is important that the operation period is limited to a minimum. It has been experienced that it is very difficult for a housewife to find 15-20 undisturbed minutes every day to carry out defluoridation.[1] Probably 5 minutes for defluoridation should be considered as a maximum. This is also sufficient for the Nalgonda technique.[3]

For the column treatment methods the daily operation is normally negligible. The hurdle for the proper operation/maintenance is the regeneration or exchange of media, normally carried out every few months. This is either connected with a relatively heavy workload (crushing of bricks) or a relatively high investment in regeneration or new media. The cost may not seem high on a monthly basis, but when 3 months media has to be paid at one time it may seem overwhelming for a poor household thus pushing the payment till next month - and yet another month - etc. To reduce "irrational excuses" replacements and regeneration should be arranged as cheap and simple as possible.

All the mentioned defluoridation methods can be appropriate as such for household defluoridation, but proper designs and materials have to be selected. Users have expressed complaints of heavy manual workloads both in daily defluoridation practise and during exchange of media. This may, to a certain extent, hinder the success of the project. Simple procedures / easy operation and durable materials that are easy to maintain and repair, will be important if not crucial for the success of household defluoridation, especially where the motivation is not very high.

Safety of handling of chemicals for defluoridation and regeneration should be sought. Wrong dosage of e.g. alum in the Nalgonda technique may result in inappropriate pH in the treated water. Thereby fluoride removal will be less, but it is more crucial that the taste may become offensive and thereby demoralises people from using the method. Poor taste together with rumours about side effects of the treatment can be effective in discouraging people from drinking the water.[1] Variation in qualities of e.g. alum and lime may result in different fluoride removals and water qualities. Special attention has therefore to be paid to the fact that these chemicals are commercially available in different qualities.

There is at the moment not much experience with self-financing of defluoridation. The most obvious cost recovery method for household defluoridation would be self-payment of (at least) operation and maintenance costs. Obviously they should be kept at a level that people will pay. To meet the poor people's ability to pay, chemicals can be subsidised if there is economic basis to do so. That may also prevent people from buying commercial poor quality chemicals. The defluoridators should also be cheap enough for people to meet the costs. Otherwise there should be a public funding to provide or to subsidise the defluoridators.

It is experienced in various projects that defluoridators are in most cases too expensive to sell for the majority of the population. If no subsidies are available, an option like installation a tap in a bucket already at use in the household would in many cases be the only affordable solution. Moreover it has to be realised, that even methods which are known to be cheap, demand steady extra expenditure for water and the cost of chemicals, whether paid monthly or biannually, may be a significant factor of discouragement for many people to continue treating the water. More experience is needed with respect to people's willingness to pay, but there is a good reason to keep costs to a minimum.

Proper organisational set-up. Any defluoridation method would sooner or later need supply of chemicals for dosage or for regeneration of media and a reliable supply of spare parts and spare media. It is obvious that these needs can be covered either through arrangement with the private retailers or through the water authorities. The system of choice will depend on the local conditions. It is also obvious in case activated alumina or bone char is used, certain arrangements have to be made in order to ensure proper regeneration/supply of media.

It has been experienced that when introducing a technique utilising breakable parts, it is necessary to set up units to carry out minor repair of the households defluoridators.[1] That is because the households neither have the skills nor the simple tools to carry out the repair on their own. In some cases, the households do not give priority to buy even cheap spare parts or to spend the necessary time to do the repair. Easy access to technical support (both as adviser and manual support), e.g. a man in every village that has got specific training, may be needed to keep as many defluoridators as possible in operation.

In this connection it has also been experienced that people, after some time of operation, tend to forget procedures and/or to loose interest in the defluoridation. It may be necessary to ensure a continuous follow up of awareness or motivation among the households for an extended period of time. Collaboration with community development NGO's has been suggested and is being tried out in some projects. In the project using crushed bricks in Sri Lanka it has been decided to follow the implementation for at least five years. Such a follow up may be required in order for people to observe better oral health among children and to ensure the sustainability of the implementations. Organisation of the provision of qualitative test kits for fluoride measurements based on the alizarin method may be useful for the households to gain assurance about the efficiency of treatment (motivation).[5] However still this method needs more documentation about its usability in practise as an on/off method.

The preceding applies for the local organisation necessary for maintaining household defluoridation. The superior water authority needs to play an active role in at least the control and monitoring functions.

A certain control of, ultimately, the quality of the treated water in the households is necessary. Frequent sampling of treated water for analysis can be used to point out problems in operation. The water authorities should carry this out. Other kinds of water quality assurance will include control of quality of chemicals and control that these are actually used by the households. Finally the responsible authorities should control the procedures and guidelines given for defluoridation. The Nalgonda technique represents a special problem that should be addressed, because the quality of the alum and lime is critical and so is the dosage of chemicals, that ultimately needs to be determined for every single water source (at different times of the year) and every single bucket size.

It may be crucial for a large scale implementation that some functionaries at all levels of the water supply and health authorities are aware of the fluorosis problem and the possible means to solve it. Higher levels of administration will only be able to advice the lower executing levels about the strategies if they themselves are aware of the fluoride problem and its implications. This would require a general educational program in the administration.

Finally the water authorities should be the institution that collects the experiences gained in the particular geographical and cultural environment since no technique will be applicable the same way in all environments. Together with the health authorities they have an important role to play in surveying the health (fluorosis) status as a result of defluoridation programmes.

COMMUNITY PLANT DEFLUORIDATION

Many practitioners as an intermediate solution see household defluoridation until a more permanent low-fluoride water supply has been established. In fluorotic areas the permanent water supply may well be based on defluoridation of water in a community water treatment plant. The reason why community plants are not always introduced in the first place is higher costs of construction, higher costs of chemicals, especially if all domestic water should be treated and distributed. Moreover because of problems in maintaining and paying the O & M costs of a public water treatment plant in areas where the public management is poor. The following is partly based on village defluoridation experiences gained in India..[4]

Motivation. It is presumably easier to motivate people to walk a little longer to fetch their drinking water than to do the additional work connected with household defluoridation. They will however need to be informed about fluorosis and the installed defluoridator. Information meetings by the time of implementation are therefore necessary. Plants should also be marked clearly with a message like "water fit for drinking and cooking".

It is rather de-motivating for people if the plant is not functioning as expected. The plant can be non-functioning in periods because of power cuts or operational problems (technical breakdowns or lack of chemicals). It can also deliver water of poor aesthetic quality e.g. because of erroneous dosage of chemicals. Both cases can lead to rejection by the users and by-pass of the treatment plant.

If the water treatment is functioning, affordable and not too distant, lack of motivation should not be a problem. There are probably no experiences so far with payment for defluoridated water and how it effects the users' willingness to use defluoridated water. Payment will probably lead to a higher demand of service.

Appropriate and economic technique. In relation to community operated plants, appropriate mainly means that it should be feasible to operate by someone in the village and not too difficult to procure breakable spare parts. Obviously it should not be situated too far away from the users, but it needs not be the easiest accessible source. If consumption is not controlled, people living close to the plant may use the treated water for their entire needs, leaving too little water for other households.

The dimensioning of the plant requires selection between three options:

Treatment of all water for domestic use including shower, cloth-washing etc. There will be no confusion about selection between different water sources, but both construction and running costs will be many times as high as required for drinking purposes.

Treatment of only required amount of water, e.g. 4-5 lpcd. This is the cheapest and most rational option. If all households shall be able to have their share of water it will require careful control of how much water every household gets, e.g. by payment for every single bucket.

Treatment of more water, e.g. 7-10 lpcd. This may be a pragmatic solution in order to ensure that everyone covers own need and still pays for it.

As any other water supply in third world villages, materials for construction should be locally available so it is possible to repair. The experience with many types of water treatment systems in small societies is that if they are not repaired/rehabilitated easily, they will soon be bypassed. In areas with frequent power cuts (or no electric power), operation should preferably be possible without electricity. Raw water for column systems should be supplied by gravity from a gravity scheme, a high level reservoir or even a hand-operated pump in the case of smaller plants. Batch systems like Nalgonda technique may in the simplest form be mixed by the power of the in-flowing water, alternatively by manually operated paddles. Paddles and gearboxes are often corroding and breaking down.

Daily routine check of treated water quality on site should be ensured. It is important for the motivation that the taste and visible appearance are not offensive. In the case of adsorption in columns, where the effluent fluoride concentration increases with time, the test parameter will be the fluoride concentration, which should be measured frequently around the expected time of regeneration or exchange of media. This may be simply measured e.g. by the use of the zirconium-alizarin method[5]. In systems where fluoride is removed by dosage of chemicals other parameters may be more important. E.g. for the Nalgonda technique pH is the control parameter to be tested at every batch treated, using pH-paper strips.

When water is treated centrally in the village, the waste is also concentrated more than in household treatment. Care should be taken that waste medium, sludge or regeneration wastes are treated safely for the environment and the people and animals around the plant.

Proper organisational set-up. As for the household defluoridation some organisational issues specific for the single techniques (procurement of bone char, regeneration of activated alumina) have to be considered separately and will not be mentioned here.

Operation and maintenance is often problematic, not only because of technical constraints. Special training of a local caretaker is very critical, but when the caretaker leaves the village the knowledge of operation may get lost. Employing at least two trained caretakers alternating in operating the plant may prevent this. A full and detailed operation and maintenance manual should be available with the responsible body and the caretakers. It should also contain a detailed list of where to find all breakable parts.

The local caretaker performs the day to day operation and control of treated water quality. A control and supervision infrastructure should be established with the water authorities. This includes regular water sampling, bringing samples from the plants to the laboratory, processing of data, and regular evaluation of performance. Action should be taken to rectify poor performance of the plants. It will in most cases also involve training of employed in the water authorities.

Many problems can arise if responsibilities are not clear and attended from the planning phase. The local body in charge of defluoridation should be able to take over responsibility of operation and maintenance in terms of trained caretakers and operational funds (cost recovery system). Engineers who erect the plants should be made responsible for the proper functioning of the plants and provision of manuals. Water supply departments should approve the plant and be able to assist when larger operational problems occur.

Like for household defluoridation, higher levels of co-ordination will be necessary for the creation of institutional memory and development of area-specific knowledge. Engineering departments, health departments and other local organisations should work together in connection with erection of plants to maximise the effect and use of defluoridated water. Since defluoridation has still not proved to be sustainable in third world rural areas, building of co-ordinated institutional memory within the country will be determining for the country's possibilities to develop and sustain defluoridation in future.

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REFERENCES

1. de Groot CPM, Vasudev BH. *Household defluoridation in Peddur and Kondamvaripalli villages in Bagepalli Taluk, Kolar District.* Danida-assisted Integrated Rural Sanitation and Water Supply Project, Karnataka, November 1996.
2. Bhatnagar R, Sharma S. *Fluorosis. Health and epidemiological survey of some high fluoride villages of Dungarpur district.* Unicef, Rajasthan, 1997
3. Dahi E, Mtalo F, Njau B, Bregnhøj H. Defluoridation using the Nalgonda technique in Tanzania. *Proceedings of the 22nd WEDC Conference, New Delhi* 1996.
4. *Evaluation of the activities of the sub-mission "Control of fluorosis" and fluorosis control cell (Draft).* Harcharan Singh Committee Report, 1995.
5. Fluoride. In: *Standard Methods for the examination of water and wastewater*, 16 edition, APHA, AWWA, WPCF, 1985 (not later versions)