

A REVIEW OF THE DEFLUORIDATION PROGRAM OF DRINKING WATER SUPPLIES OF AN ETHIOPIAN ESTATE

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ABSTRACT: The Wonji Shoa Sugar Estate covers an area of 50 km² in central Ethiopia inhabited by 25,600 people. Dental and skeletal fluorosis were identified in the area in 1957 and 1972 respectively. Since then the Estate has been well known for its high fluoride levels in its water supplies. An evaluative study of the 35-year-old defluoridation program was conducted. Data were obtained from documentary sources and by making interviews, site visits and laboratory analyses. The community of the Estate has largely depended on a dual supply of well water - raw water and defluoridated water. The major problems noted were the lack of proper operation of the defluoridation plants, the lack of ready accessibility of the treated water supply and the lack of compliance by the community. The Estate's community is found to be quite aware of the fluorosis problems. Yet only 56.3 % of the community have access to defluoridated water and still there are high prevalence rates of fluorosis. The problems of the program are discussed and suggestions for improvement are made.

Key words: Ethiopia; Rift Valley; Fluorosis; Skeletal Fluorosis; Activated alumina; Defluoridation; Regeneration of media; Operation and maintenance.

INTRODUCTION

Ingestion of excessive amounts of fluoride has been known to be pathogenic to humans, particularly causing dental fluorosis in children and skeletal fluorosis in adults.¹ Communities depending on water supplies with fluoride levels in excess of 1.5 mg/L are at risk of fluorosis.² The safe level of fluoride in water supplies is lower in hot climates. In the East African Rift Valley there are high levels of fluoride both in ground water and in surface water due to the high fluoride content of the volcanic bedrock.³

The Wonji Shoa Sugar Estate. The Wonji Shoa Sugar Estate (WSSE) is a sugar producing estate (the official name of the company being Wonji Shoa Sugar Factory, WSSF) owned by the Ethiopian Government, and is located in central Ethiopia within the Rift Valley, 110 km south-east of Addis Ababa. At present the estate stretches over an area of 50 km². The altitude is 1540 m above sea level. The annual rainfall rarely exceeds 800 mm. During 1996, the mean maximum daily temperature was 27.4°C and the mean minimum daily temperature was 16.4°C. The estate presently has about 8000 employees. Its total population according to a census conducted in 1995 was 24,206, the present estimated population being 25,581. The community lives in two relatively large factory villages, namely Wonji and Shoa, and in 14 plantation villages scattered throughout the estate. The estate cultivates its own sugar cane plantation using irrigation water from the bordering Awash River. Water for domestic consumption is obtained from wells and is supplied through pipes. The provision of water supply to the residents of the estate is the responsibility of WSSF.

Historical background. The estate was established by a Dutch company and officially started work in 1954. The existence of "fluoride problem" in the estate was first recognised in 1957 when the children of the Dutch families had dental

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examination while holiday in Holland. In 1962, two defluoridation plants were installed in the two factory villages where the Dutch families lived. In 1972 the existence of skeletal fluorosis in the estate was discovered. Between 1974 and 1976, defluoridated water was made available to all villages of the estate. In 1975, the estate was visited by a Dutch dentist named Prof. Otto Backer-Dirks who had been involved in investigating the fluoride problem of the estate.

In 1976, the Ethiopian Government established a committee to examine the problem, but recommendations made by that committee were not implemented. Despite the launching of the defluoridation program it was noted the existence of fluorosis had continued. So, in 1984-1985 a feasibility study was conducted by an English company to provide low fluoride potable water to the estate's community.⁴ The study recommended the utilisation of water from Awash River as a single water supply to the entire community for all domestic purposes after conventional water treatment plus defluoridation of the entire supply at a single new plant. However, that alternative was not implemented due to cost hindrances.

Study objective. The community of the estate has largely depended on well water for domestic needs. At times Awash water is also used for domestic consumption in some villages. The defluoridation program of WSSE is the only one in Ethiopia and has now been going on for 35 years. The purpose of this review was to make an evaluation of the performance and outcomes of this program.

MATERIALS AND METHODS

Data for the review were collected during the period July to October 1997. Historical data were obtained from records and files of WSSF. Contemporary data were obtained by interviewing program staff and by making site visits. Present levels of fluoride in water sources were determined at the laboratory of the hospital of WSSF (Wonji Hospital).

RESULTS

The present water supply. The domestic water supply involves a dual supply of raw well water for washing purposes and defluoridated well water for cooking and drinking purposes. At present there are 20 operational wells in the estate. The depth of the wells ranges from 12 m in village A (initially 50 m) to 64 m in village K (initially 110 m). Awash water is supplied to all neighbourhoods of both factory villages from standpipes for gardening purposes. The residents of the plantation villages have access to Awash water either directly from the river or from irrigation canals. In some of the plantation villages, Awash water is used for human consumption when tap water is not available. The level of fluoride in Awash water is 2-4 mg/L.⁴

Factory villages. There are 7 wells in Wonji village and 4 wells in Shoa village providing raw water through an interconnected piping system to each village. Here is a reservoir in each village. The supply is directly connected to certain houses and the factories, offices, etc. Other houses have one standpipe for 8-12 houses. The supply of raw water is almost always available in each village. There is one additional well in Wonji village solely used for the supply of defluoridated water. In Shoa village water to be defluoridated is obtained from one of the wells also supplying raw water to the

village. In each village the water is treated at a defluoridation plant, stored in a reservoir and supplied to the residents from standpipes, each standpipe being allocated to 50-60 houses. Some public buildings such as factories, offices, schools, hospital, bakery, recreational facilities, etc. have their own standpipes.

Plantation villages. There are 8 wells providing raw water to 13 plantation villages through separate piping systems. There are reservoirs and at each village raw water is supplied from standpipes and/or from a washing area. There is recurrent lack of raw water in the plantation villages due to interruption of electricity or to failure of pumps. During these periods the residents fetch water from nearby village or use Awash water. The 14th plantation village, village P, is supplied with raw water transported by a trailer from village E or Shoa.

Village Band E get the supply of defluoridated water from Wonji and Shoa defluoridation plants respectively. Each of these villages has a single standpipe for defluoridated water. There are ten defluoridation plants which were supposed to provide treated water to the remaining plantation villages. They get water from the wells also providing raw water to the villages. In each village there is a single standpipe for the supply of treated water (none in village P) connected directly to a defluoridation plant, without any reservoir involved.

TABLE 1. Levels of fluoride in raw water from various wells of the factory villages.

Date	Fluoride levels from wells (mg/L)	
	Wonji village	Shoa village
1973	5.6 - 13.5	3.3 - 18.7
Nov. 1976	2.9 - 19.2	3.4 - 13.0
Oct. 1984	2.7 - 18.8	3.3 - 11.2
Oct. 1997	1.4 - 18.8*	2.2 - 15.6*

*The individual levels of fluoride in Oct. 1997 were 1.4, 6.2, 14.0, 14.8, 15.6, 16.4 and 18.8 mg/L in Wonji and 2.2, 6.2, 10.0 and 15.6 mg/L in Shoa.

Requirements of the defluoridation program. The defluoridation of drinking water supplies has been necessary because the community of the estate has depended on well water, which has high levels of fluoride. At present all wells have fluoride levels above 0.8 mg/L which is the safe level for the estate taking into account the local climatic conditions (Table 1 and 2). So still the defluoridation program is requisite.

Defluoridation plants. There are 12 defluoridation plants in the estate. The two plants in the two factory villages were erected in 1962. Initially each plant had a single filtration tank but later a second tank was added. The media capacity of each tank is about 370 kg. There is a reservoir for treated water at each plant. Both plants are more or less in good condition at present. The ten plants in the plantation villages were installed in 1976. At present all of them are neglected and are heavily affected by rust. The defluoridation technique employed is adsorption by activated alumina, which in turn is regenerated by flushing with caustic soda. In the past bone char was also used.

Materials. In the past there was problem of availability of the medium. At present there is no shortage of the supply of the activated alumina but sometimes poor quality water, containing coarse grains of alumina, is supplied. Also there is no shortage of caustic soda either. At times there is lack of necessary spare parts for the maintenance of the defluoridation plants.

Personnel. The formation of personnel consists of two operators and a driver. At present all positions are filled but the driver is not in the defluoridation team. The operators appear to be satisfactory skilled.

Transportation. There is one vehicle in the budget formation but at present the vehicle is assigned to other tasks and is not available for defluoridation activities. Similar shortage of transportation hindering regeneration and maintenance activities was present also in the past.

Organisation. In the past the water supply service of the estate was divided and was organised under three departments. But since 1976 the whole domestic water supply (both the supply of raw water and the supply of treated water) has been organised under one department (Shoa Factory Mechanical Workshop).

Laboratory. The laboratory of Wonji Hospital performs fluoride analysis of water samples and is responsible for quality control of the program. It uses OIRION Research Model 701 digital pH-meter purchased in 1974. The necessary materials are available at present but in the past there was a problem of the supply of electrodes.

Performance of activities.

Media renewal. The frequency of media renewal was to be based on the results of fluoride analyses of treated water samples. At the Shoa plant media renewal is done every 1½-3 months. At the Wonji plant this is done every 9-12 months. During the activated alumina renewal caking of the medium has been a major problem. At the plantation villages, media renewal was carried out at irregular intervals. For instance at one village the medium was renewed after 18 years. The renewal activities have been totally abandoned at the plantation villages for the last two years due to lack of transportation.

Regeneration. At each of the two present operational plants, regeneration is carried out for each of the two tanks after having served for 24 hours. The two tanks at each plant serve on a 24 hour shift. The steps of the regeneration procedure appear to be well known by the operators but there is no supervision. The operators have problems during regeneration because of not having proper protective devices. After introduction of caustic soda solution, flushing is done with raw hard water as a result of which calcium carbonate scales form on the activated alumina granules reducing the adsorption capacity. In the past carbon dioxide injection was used to reduce regeneration time. Regeneration activities were carried out at irregular intervals at the plantation villages in the past due to shortage of transportation and have been totally abandoned as of the end of 1995.

Monitoring. Weekly analyses of water samples from Wonji and Shoa defluoridation plants was started in 1969 and from the plantation villages in 1976. However, frequently water samples are not collected from several plantation villages due to lack of transport. Analytical results are delivered to the responsible department after a delay of 5-7 days. The results were to be used to evaluate the regeneration activities

TABLE 2. Levels of fluoride in raw water from the various wells of the plantation villages.

Village	Dec. 1971	Oct. 1997
A	3.0	1.8
B	8.0	3.6
C	7.5	12.0
D	4.0	5.0
E	7.5	12.0
K	7.5	17.5
L	7.5	4.5*
M	3.0	3.1

* Average of measurements made during various occasions from January to October 1997.

and to decide whether or not to change the media. Regular monitoring of prevalence rates of fluorosis has not been done.

Availability of treated water. Before 1962 only raw water was available to the entire community of the estate. Between 1962 and 1974 defluoridated water was available to certain families in the two factory villages. In 1974 the supply of defluoridated water was extended to all families of the two factory villages and of plantation village B and E. In 1976, defluoridated water was made available to the remaining 12 plantation villages. This was going on until the end of 1995.

At present, defluoridated water is available only to the two factory villages and the two nearby plantation villages B and E. The resident of the remaining 12 plantation villages utilises raw well water (either from the standpipes of treated water assuming that it is defluoridated, or from the standpipes of raw water) and sometimes Awash water for domestic purposes - cooking, drinking and washing.

So, out of the estimated present population of the estate of 25581, only 14396 or 56.3 % has access to defluoridated water. There is some waiting at the standpipes as has also been the case in the past.⁴ The waiting is greater at Shoa village because residents from the surrounding areas also share the service. At Wonji village at times there is total lack of treated water but this does not happen at Shoa.

Degree of utilisation.

The community is well aware of the fluoride problem, both of dental fluorosis and of skeletal fluorosis. The standpipes supplying treated water are well identified but are not very readily accessible as each one is supposed to serve a large number of people.

It is a common observation that still children and also adults consume considerable amounts the more readily accessible raw water even in the villages which have the supply of treated water. At times, the limited supply of treated water is abused for washing purposes.

Outcome evaluation.

Fluoride levels in drinking and cooking water. Fluoride levels in water from the 12 defluoridation plants are given in Table 3. The levels of fluoride in treated water from the two presently operational defluoridation plants before and after regeneration are given in Table 4.

Prevalence rates of fluorosis. In 1975 mottling of the permanent teeth was found in 100% of 8 to 10 year-old-children examined in Wonji and Shoa villages (personal communication, Prof. O Backer-Dirks). A survey conducted in 1977 showed 87% mouth prevalence of dental fluorosis among children 5-10 years old and 31% prevalence among individuals 16-25 years old.⁵

Surveys conducted in 1985 gave the following results.⁴ In one of the surveys involving examination of the permanent anterior teeth, mouth prevalence rates of dental fluorosis ranging between 34 % and 75 % were found among 8-year-old children residing in the various villages of the estate and a 77 % mouth prevalence of dental fluorosis was found among adults aged 20-25 years. In the other survey involving examination of the prevalence posterior teeth mouth prevalence rates of dental fluorosis of 39% and 54% were found among children aged 12-15 years in the two villages; a 74 % prevalence rate was found among adults 20-25 years old. A survey done in 1997 in children aged 8-12 years showed mouth prevalence rates of

dental fluorosis ranging between 71.4 % and 95.7% in the various villages; excluding the very mild cases the rates ranged from 27.1 % to 86.1 % (personal communication, Fantaye et al.).

In 1975 there were 60 bone fluorosis patients identified in the estate, most of them having only restriction of movement, but five had neurological complications. A survey conducted in 1979-1980 by Wonji Hospital involving 530 estate workers aged 45-55 years, found radiologically evident skeletal fluorosis in 46 % of them. In 1990, a survey showed that 63 % of the individuals who had resided in the estate for more than 20 years had physical impairments indicative of skeletal fluorosis.⁶ A survey done in 1997 and involving the X-rays of 263 retiring employees of the estate showed radiographical signs of spinal fluorosis in 70.3 of the individuals (personal communication, Shifera et al.).

TABLE 3. Fluoride levels in treated water from the various defluoridation plants of Wonji Shoa Sugar Estate.

Plant	76.11.27	79.10.04	88.04.21	88.08.12	89.02.02	89.10.09	94.09.29	95.10.06	97.10.31
Wonji	0.36	0.45	0.40	0.23	1.30	0.28	<0.10	0.70	0.92
Shoa	0.21	0.45	0.32	0.82	1.30	0.66	0.45	1.50	0.90
A	-	0.20	0.34	0.25	0.50	0.62	0.15	0.95	*
C	0.40	-	2.80	6.01	4.00	7.7	2.90	4.20	*
D	0.11	0.18	1.61	6.01	2.80	2.5	0.75	1.80	*
F	0.20	0.18	1.00	6.01	-	-	0.45	1.50	*
H	0.28	0.57	2.80	6.01	4.60	6.1	9.50	6.80	*
K	0.15	0.34	7.10	4.56	4.30	2.2	-	3.50	*
L	0.11	-	1.30	4.56	0.61	5.2	3.00	-	*
M	-	0.26	1.40	0.48	1.00	2.0	0.17	-	*
O	-	0.30	0.25	0.52	1.30	1.3	-	-	*
Y	-	-	3.34	2.40	6.10	-	-	7.00	*

* Water samples not analysed because there was no treatment at the plant.

TABLE 4. Fluoride levels from defluoridation plants of the two factory villages on Wonji Shoa Sugar Estate, October 1997.

Defluoridation plant	Fluoride levels (mg/L) in		
	Inlet	Outlet before regeneration	Outlet after regeneration
Wonji	1.4	1.2	0.92
Shoa	2.2	1.8	0.90

DISCUSSION

The domestic water supply of WSSE involves a dual supply of tap water from wells - a readily accessible supply of raw water and a very less readily accessible supply of defluoridated water. In certain plantation villages there is, in addition, access to a third source of water - Awash River water. There is a wide variation in the level of fluoride among the various wells, ranging from 1.4 to 18.8 mg/L, all exceeding the estate's safe level of 0.8 mg/L. Nineteen of the twenty presently operational wells (95 %) have fluoride levels greater than 1.5 mg/L and eleven wells (55 % of the total) have fluoride levels greater or equal to 10 mg/L. Therefore the defluoridation program is still necessary if the estate's community is going to continue depending on well water.

It seems that the number of available treatment plants is sufficient to provide drinking and cooking water for the estate's community except in one of the factory villages. The main problem rather is the lack of transport, which has resulted in the total shut down of media renewal and regeneration activities at ten of the twelve (83.3 %) defluoridation plants for the last two years. Therefore it is necessary that a vehicle be assigned solely for water supply activities as it was in the past. The quality of the activated alumina supplied is sometimes poor and measures have to be taken by WSSF to ensure that good quality activated alumina is consistency supplied. It has to be emphasised that the defluoridation plants, which had demanded a lot of efforts, dialogue and investment to be installed, be given due maintenance and care.

It is necessary that the frequency of media renewal and generation be strictly geared to the levels of fluoride in treated water. For this purpose regular weekly and random samples of water have to be collected from all defluoridation plants. Laboratory analytical equipment has to be updated and results have to be reported overnight to the responsible department. Proper protective devices need to be provided to the operators and supervision of the regeneration activities also has to be exercised. Possible mechanisms to reduce calcium carbonate scale formation during regeneration have to be investigated. To increase the adsorption capacity and service period of the media acidification has to be practised.

At present only 4 of 16 villages of the estate or 56.3 % of the total population has access to defluoridated water. The residents in several plantation villages are using water with very high fluoride levels (> 10 mg/L in four villages) for cooking and drinking purposes. This situation has to be urgently changed and all villages have to have access to defluoridated water. On the other hand it has to be known that due to the better accessibility of raw water in relation to treated water, significant quantities of raw water appear to be consumed particularly by children in the villages where defluoridated water is also available. So measures have to be taken to educate parents and children to alter this behaviour or to make treated water more readily accessible. The water supply department has also to make sure that there is a continuous supply of tap water in all the villages so that residents will not be forced to consume less hygienic water from Awash River or from irrigation canals.

The defluoridation program was launched in the two factory villages 35 years ago and was extended to all villages of the estate 21 years ago. But still there are high levels of fluoride in the water available to a large part of the community and the prevalence rates of dental fluorosis and skeletal fluorosis are also high. The reason for the failure of the program does not seem to be the deficiency of the defluoridation technique employed. Rather the reasons for the failure of the program in producing the final desired outcome i.e. the prevention of the new occurrence of dental and skeletal fluorosis are:

- The lack of proper operation of the existing defluoridation plants.
- The absence of easy accessibility of the treated water supply.
- The lack of compliance as to water ingestion behaviour by the community.

It is suggested that the concerned act without delay to revive the defluoridation program using the same or other more convenient technique and to modify the behaviour of the community so that the disfiguring and the disabling problems of fluorosis are eliminated. Or WSSF has to be ready to re-examine the excellent

feasibility study conducted earlier which had connected resorting from well water to river water.⁴

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