Partial Defluoridation of a Community Water Supply and Dental Fluorosis

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IN 1948, the Division of Dental Health, Public Health Service, installed a defluoridation plant in Britton, S. Dak., for the purpose of demonstrating a feasible means for removing excessive fluorides from a community water supply. At that time, the principal water supply for Britton, a community of approximately 1,500 persons, was derived from three deep wells with a combined average fluoride content of 6.7 parts per million (ppm).

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Ervin Bellack, Division of Water Hygiene, Office of Water Quality, Environmental Protection Agency, assisted with the engineering and fluoride surveillance aspects of the project. B. Jerald McClendon, Office of Technical Services, Division of Dental Health, Bethesda, Md., assisted in the statistical analysis of the data.

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Interim surveys to evaluate the procedure were conducted in 1960 and 1965. A report comparing findings from these surveys with the baseline has been published (*1*). This paper is a report of the final survey, conducted in 1970.

The Britton Defluoridation Plant

Description and operation. The design, construction, and operation of the defluoridation plant have been discussed in detail (*2–4*). Essentially, the plant was a pressure type in which the defluoridating medium was confined in a heavy steel tank designed to withstand the pressure of water maintained by elevated storage. As the untreated water percolated through the tank, fluorides were adsorbed by the medium. When the medium became saturated with fluorides, it had to be regenerated by chemical treatment.

A granular synthetic hydroxy apatite was the defluoridating medium when the plant began operation on November 20, 1948. This material was unsatisfactory, and its use was abandoned in November 1952. The average fluoride level achieved with the hydroxy apatite was 3.6 ppm, roughly half that of the natural water before treatment (6.7 ppm), but still well short of the target level of 1.5 ppm. The hydroxy apatite was replaced with bone char, and the plant resumed operation in January 1953.

The bone char was considerably more effective than the hydroxy apatite in removing fluorides from the water. Following a period of adjustment from January 1953 through August 1954, during which the average fluoride level achieved was 2.5 ppm, the fluoride readings were reduced to a point closely approaching the target level.

For the 15-year period from September 1954 through October 1969, there was a total of 792 cycles (the period between regenerations) during which the plant was functioning properly. The average duration of these cycles was about 5½ days. Approximately 1.1 million gallons of water were treated in each cycle.

Samples of water were analyzed daily to determine fluoride levels delivered throughout the period. The average fluoride level achieved per cycle was 1.56 ppm, only slightly above the target level of 1.5 ppm.

In the previously mentioned 15-year period, there were approximately 130 cycles, representing a cumulative time of almost 2 years, during which failures of equipment hindered operation of the plant. In approximately 100 of these cycles the plant did not function at all; it functioned only during part of the remaining cycles. When the plant was not working, natural water containing 6.7 ppm fluoride passed into the distribution system.

The gradual accumulation of sand in the three wells supplying the city with water resulted in progressively less water being available for regenerating the defluoridating medium. Even in winters when consumption was minimal, regeneration could be done only late at night; otherwise the city would be without water.

This critical lack of water prompted the city to authorize, in 1969, a bond issue that enabled the city to pipe its entire supply of water from a lake some 9 miles distant. The fluoride content of the lake water was negligible. Operation of the defluoridation plant was discontinued in November 1969. A new water system was put into use shortly thereafter.

Costs. The defluoridating medium (hydroxy apatite) and appurtenant equipment, including its installation in the Britton plant, cost the Federal Government $12,245 in 1947. The building that housed the equipment was financed by the city of Britton.

Today, the cost of installing a defluoridation plant similar in type and size to the Britton plant is estimated at $50,000. This figure includes the purchase and placement of bone char, which currently sells for 8.5 cents a pound. The cost of chemicals for regeneration at the Britton plant was about $28 per million gallons of water treated, according to recent figures.

The plant was operated by a laborer employed part time. Initially, he had no special technical training, but he received on-the-job instruction in the chemical and engineering aspects of defluoridation. He spent an average of about 8 hours a week operating the plant. For the last few years of the project, the total yearly operational cost, including labor, was approximately $5,600. The operational cost was borne by the Public Health Service from the start of the project until July 1965, when the city of Britton assumed this responsibility.

Dental Fluorosis Study

Method. In October 1948, immediately before initiation of partial defluoridation, a baseline survey was conducted on Britton's elementary and high school children to determine the prevailing extent of dental fluorosis. Only children who had resided in Britton continuously from birth, with absences from the city totaling no more than 90 days in any one year until they were 8 years of age, were included in that survey.

The age span of birth to 8 years was specified in the requirements for residence because calcification of enamel on all permanent teeth except third molars is completed during this period (*5*). Once enamel is calcified, it is no longer susceptible to fluorosis (*6*). For all children in the survey, the town's water supply was their major source of drinking water and of water used in preparing their food.

On the two interim examinations and also on the final examination, the requirements in regard to residence and source of water were the same as those used in the baseline survey. In the final survey, however, nearly 200 children who did not meet the residential requirements were examined along with the children in the study. The examiners were not aware of which children were actually in the study.

All examinations for the four surveys were made by Public Health Service dentists. On the interim and final surveys, the examiners assigned a fluorosis score to each permanent tooth according to standards described by Dean (*7*).

The examiner in 1948, while basically using Dean's classification system, introduced two additional intermediate rating categories. When examining children with teeth in which he perceived fluorosis to be between mild and moderate or between moderate and severe, the examiner chose not to make a decision that placed the tooth into one or the other of these categories. Instead, he classified the tooth as either "mild to moderate" or "moderate to severe."

The fluorosis index, developed by Dean and McKay (*8*), is computed by assigning a definite weight to each of the various degrees of clinical fluorosis as shown in the list.

Variable	*Weight*
Normal	0
Questionable	0.5
Very mild	1
Mild	2
Moderate	3
Severe	4

For the two intermediate categories used on the baseline survey, intermediate weights of 2.5 for the mild-to-moderate category and 3.5 for the moderate-to-severe category were given. The individual scores were averaged to derive a mean index for the children examined.

The fluorosis index permits a comparison of one group or population with another on the basis of average severity of fluorosis. For all four surveys, classification of an individual child's teeth was based on the condition of the two teeth showing the most severe form of fluorosis.

Findings. The table shows the number of eligible children examined and the fluorosis index for each of the four surveys. The 71 children examined in 1948, prior to the initiation of partial defluoridation, had a fluorosis index of 2.63. The index decreased to 1.37 for the examinees in 1960, 12 years after the procedure began and only 6 years after the use of bone char had become standardized. By 1965 the index had fallen to 0.99, and by 1970 an index of 0.81 was recorded. By 1970 all study participants except eight 17- and 18-year-olds had been born after August 1954.

Percentage distributions of the children according to their fluorosis classification at each of the examinations are also shown in the table. The data have been grouped to show the proportion of children with positive signs of fluorosis as opposed to those with no fluorosis or those with borderline signs, classified as questionable.

One of the most conspicuous features of the data is that all the children examined in 1948, before partial defluoridation was started, had definite fluorosis. In contrast, scores of normal or of questionable fluorosis were assigned to 42 percent of those examined in 1960, 58 percent in 1965, and 54 percent in 1970. With regard to the degree of severity of fluorosis, 42 percent of all children examined in 1948 had at least moderate fluorosis. Corresponding figures were reduced to 25 percent in 1960 and 13 percent in 1965. Still greater improvement was achieved by 1970, when not a single examinee had severe fluorosis, and only 3 percent (five children) had moderate fluorosis.

Discussion. The findings clearly show that the prevalence of objectionable fluorosis has been reduced considerably among school children born and reared in Britton. The measured benefits were progressively greater on each followup examination as more children who had consumed the partially defluoridated water continuously since birth were available. Although a slightly higher proportion of children had measurable fluorosis in 1970 than in 1965, the 1970 examinees showed fewer signs of moderate and severe fluorosis.

Despite the progress in reducing fluorosis shown in this study, the results of the 1970 survey suggest that still further improvements would have been desirable. Dean has reported that fluorosis

Fluorosis index and percentage distribution of children according to fluorosis classification for baseline, interim, and final surveys, Britton, S. Dak.

Variable	1948 (N=71)	1960 (N=97)	1965 (N=114)	1970 (N=154)
Fluorosis index	*2.63*	*1.37*	*0.99*	*0.81*
No fluorosis	0	42.3	57.9	53.9
Normal	0	22.7	19.3	20.8
Questionable	0	19.6	38.6	33.1
With fluorosis	100.0	57.7	42.1	46.1
Very mild	7.0	17.5	20.2	31.2
Mild	16.9	15.5	8.8	11.7
Mild to moderate	33.8	....	....	....
Moderate	26.8	20.6	10.5	3.2
Moderate to severe	9.9	....	....	....
Severe	5.6	4.1	2.6	0

is not a public health problem in communities having a fluorosis index of 0.4 or less (*7*). However, when the index rises above 0.6, Dean states, it constitutes a problem warranting increasing consideration. Thus, the fluorosis index of 0.81 found during the 1970 survey indicates that the problem of fluorosis was not eliminated completely in Britton.

According to fluoride concentrations recommended by the Public Health Service (*9*), the optimum fluoride concentration for Britton, according to its mean maximum daily temperature, should be 1.1 ppm, with an upper control limit of 1.5 ppm. The target level in Britton was set at the upper control limit rather than at a level closer to the optimum because of technical and economic factors. However, an acceptable level of fluorosis was expected as long as the upper control limit for the community was not exceeded.

When the defluoridation plant in Britton was operating in a normal manner, the average fluoride level (1.56 ppm) slightly exceeded the upper control limit. Another likely reason that the fluorosis index in Britton was not lower than 0.81 relates to problems in the operation of the plant.

As previously mentioned, between September 1954 and November 1969 there were approximately 100 cycles (representing almost 1½ years) when the plant did not function at all. Although not all of these cycles were consecutive, the cumulative effect of consuming 6.7 ppm fluoride during these periods undoubtedly had an adverse effect on the prevalence of fluorosis. There were an additional 30 cycles when the plant malfunctioned during a part of the cycle, resulting in higher average fluoride levels than expected for normal operating conditions.

Because Britton had no regular water treatment plant and, thus, no full-time personnel to operate the defluoridation unit, the plant was unattended between regenerations. Mechanical failures were not usually detected while they were developing nor were repairs always made promptly. It is likely that with better maintenance and closer surveillance most of the lapses in proper operation of the defluoridation plant could have been avoided.

Conclusion

It has been estimated that approximately 4.2 million people live in more than 1,100 communities in the United States served by public water supplies that exceed the upper control limits for fluoride recommended in "Public Health Service Drinking Water Standards" (*1*). In 712 of these communities, having a combined population of 1.8 million, the fluoride levels are at least twice the optimum, which constitutes grounds for rejection of the water supply.

For these communities the decision of choice generally would be to change to a new water supply and, if necessary, to fluoridate the new supply to optimum levels.

If this approach is not feasible, an alternative, the chemical removal of excessive fluorides from the existing supply, has been proved effective in reducing fluorosis and reasonably economical. The results in Britton with bone char and, in Bartlett, Tex., with activated alumina (*10*) offer justification for the adoption of partial defluoridation as a public health measure.

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In 1948, a defluoridation plant was installed in Britton, S. Dak., where the water supply averaged 6.7 ppm of fluoride. Synthetic hydroxy apatite, used initially as the defluoridating medium, was unsatisfactory; it was replaced with bone char in 1953. The average fluoride level achieved with the bone char was 1.56 ppm, only slightly above the target level of 1.50 ppm.

The Britton plant cost $12,245 in 1947. Today, the cost of installing a similar plant is estimated at $50,000.

A baseline survey using Dean's fluorosis index was conducted in 1948 on children in grades 1–12; the final followup survey was made in 1970. Data were analyzed only for children who had lived in Britton from birth to 8 years of age and who had used the city's water supply exclusively during that period. Results showed that 100 percent of the 71 children examined in 1948 had fluorosis, whereas of the 154 children examined in 1970, only 46 percent had fluorosis. Moderate to severe forms of fluorosis decreased from 42 percent in 1948 to 3 percent (five children) in 1970. The fluorosis index for baseline examinees was 2.63. Although the fluorosis index declined to 0.81 by 1970, it still exceeded 0.6, the point above which fluorosis is an esthetic problem from a public health standpoint.

The most probable reasons that the fluorosis index was not lower related to operational problems of the plant and to the relatively high target level. Results in Britton offer justification for the adoption of partial defluoridation as a public health measure by other communities having water sources containing excessive fluorides.