Effect of School Water Fluoridation on Dental Caries, St. Thomas, V.I.

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BECAUSE the major benefits of fluoridation accrue to children whose teeth are in the process of formation, public health agencies have begun to seek ways to bring the benefits of water fluoridation to children residing in areas without central water systems. One method, investigated by the Division of Dental Public Health and Resources, Public Health Service, is the fluoridation of elementary school water supplies, which appears to offer a means whereby a sizable number of children may be benefited with minimal demands on personnel, equipment, and funds. Approximately 44 million persons, or 23 percent of the U.S. population, live in areas without central water supply systems, according to the Community Fluoridation Section, Division of Dental Public Health and Resources.

Schools not served by central water systems usually have private wells, from which the water can be easily fluoridated. Nearly all children 6 years old or over spend between 20 and 25 percent of their total waking hours during a year in school. Probably a similar proportion of the total water consumed by children is drawn from the school's water supply.

The most apparent disadvantage of school-water fluoridation is that children are at least 5 years old, and possibly 6, before they begin attending school and consuming the water, whereas maximum benefits accrue when fluoridated water is consumed from birth. Data from communities that have instituted controlled fluoridation, however, indicate that children who were 6 years old or older at the time fluoridation was initiated do derive dental benefits from the procedure (*1–4*). For example, 13-year-old children in Evanston, Ill., 7 years after fluoridation was started, had about a 25 percent lower decayed, missing, and filled (DMF) tooth rate per 100 children than did 13-year-old children examined just before fluoridation was started (*4*). These findings are not surprising since at the age of 6 years there is still a significant amount of calcification to occur in the later erupting permanent teeth (*5*). In addition, it has been demonstrated that a fluoride uptake of notable extent occurs between the completion of permanent tooth calcification and eruption (*6*, *7*). Strong evidence also indicates a caries-inhibitory effect from the topical action of fluoridated water (*8*, *9*).

Another disadvantage of school-water fluoridation is that children receive only intermittent exposure to fluorides. There are usually about 180 class-days during a school year, and only 6 to 7 hours are spent in school on these days. To compensate for this part-time ex-

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Franz J. Maier, chief, Engineering and Chemistry Section, Division of Dental Public Health and Resources, supervised and gave consultation on the engineering aspects of the study. Mary B. Thompson, chief of the Statistical Unit, Research and Development Section, provided statistical consultation.

posure, it appears that, for school fluoridation, the fluoride concentration must be considerably higher than that recommended for community fluoridation in the same geographic area.

To determine the efficacy and practicality of fluoridating school-water supplies, the division has undertaken three studies. The first was started in 1954 in the Washington and Lincoln Elementary Schools of Charlotte Amalie, St. Thomas, V.I. Both schools contain grades 1 through 6. The other investigations are continuing, one in Pennsylvania and one in Kentucky, where the schools contain grades 1 through 12. These studies will be described in subsequent reports.

Background

In 1960 Charlotte Amalie, the largest city on St. Thomas, had a population of 12,880, predominantly Negro (*10*). It has been reported that children in Charlotte Amalie have a relatively high prevalence of dental caries and that their level of dental care is lower than that of children of comparable ages in most other areas of the United States (*11*).

Drinking water in the city is available from more than one source. The largest quantity comes from rainwater, obtained from individual home cisterns and from numerous catchments built in the hills surrounding the city. Some potable water is also available from wells; however, that water tends toward brackishness, and the rainwater is generally preferred. Recently, a seawater conversion plant was put into operation on an experimental basis, but only limited quantities of drinking water are available to date from this source. None of the drinking-water sources in Charlotte Amalie contains more than a trace amount of fluoride. In times of drought, drinking water is shipped to the islands by barge, usually from Puerto Rico. This water probably is fluoridated because nearly all of that island's cities have instituted water fluoridation in recent years (*12*).

The division installed the necessary fluoridation equipment at the Washington and Lincoln Schools and started fluoridating the water at both schools in the fall of 1954. Because the mean maximum daily temperature in Charlotte Amalie is 84.7° F. (*13*), the optimum concentration of fluorides for community fluoridation should be 0.7 ppm (*14*). However, since the children would be of school age when initially exposed to the water at school and would drink it only intermittently, it was decided that fluorides would be added to the school-water supplies in the ratio of 2.3 ppm, slightly more than three times the optimum fluoridation level for community water supplies in that temperature zone. This concentration was thought to be well below that which would result in any significant mottling of tooth enamel in these age groups.

Direct servicing of the fluoridation equipment was the responsibility of personnel in the Bureau of Environmental Sanitation, Virgin Islands Department of Health. General supervision and consultation were provided by the Engineering and Chemistry Section of the Division of Dental Public Health and Resources. The fluoridators at both schools had to be shut down frequently because of technical difficulties and equipment failures. Replacement parts were not readily available, and adequate maintenance by local personnel was lacking; therefore, delays of several weeks often occurred before faulty equipment was repaired.

Because the Washington School was altered and enlarged during the study, the fluoridator in the school had to be disconnected for a lengthy period, and when the unit subsequently broke down it was felt that the Washington School children no longer provided a suitable test group. However, the study was continued at the Lincoln School because it had an acceptable record of controlled fluoridation.

From the fall of 1954 to June 1962, 96 water samples were taken at the Lincoln School and analyzed for fluoride content. The average fluoride levels, by school year, are listed in the following tabulation:

School year	*Average ppm*
1954–55	2.20
1955–56	2.38
1956–57	2.47
1957–58	1.53
1958–59	2.60
1959–60	2.19
1960–61	2.66
1961–62	2.71
Total period	2.34

The mean fluoride level for the 8 school years, 2.34 ppm, closely approximates the level called for in the initial plans. However, the water was sampled most frequently after the fluorides were added to the fluoridating unit or just after the equipment was serviced or repaired, and therefore, the averages undoubtedly represent an overestimation of the actual levels of fluoride maintained during the entire period.

Two dental caries surveys were made of children attending the Lincoln and Washington Schools, one in the fall of 1954 before fluoridation and the other in the spring of 1960 after nearly 6 years of school fluoridation. The examinations for both surveys were done by a Public Health Service dentist and two staff members of the Bureau of Dental Health, Virgin Islands Department of Health. A perusal of the data obtained from these surveys indicated that the examination results were of doubtful reliability as measurements for evaluating the procedure. Many inconsistencies in the examination cards, apparently brought about by some misunderstanding in the use of the DMF code, raised questions that could not be resolved as to the validity of the data and the desirability of comparing the two surveys. Accordingly, a more valid test of the program was devised and carried out.

Study Procedures

Early in 1962 it was decided to examine students who had attended Lincoln School and compare the results of these examinations with those of a control group of children who had attended other elementary schools in Charlotte Amalie that never had fluoridated their water supplies. With the help of local health and school personnel, three elementary schools in Charlotte Amalie were selected as controls: the New Nisley, the Dober, and the Commandant Gade. The children attending these schools had the same socioeconomic backgrounds as those from the Lincoln School. Thus it could be expected that under normal conditions their dental caries experience would be similar to that of Lincoln students. Any superiority in the teeth of Lincoln students therefore would be due to the introduction of the variable factor—fluoridation of the water at Lincoln School.

To determine the benefits of 6 full years of school fluoridation, it was necessary to examine children in the seventh grade. Almost all the graduates of the Lincoln School had enrolled in the new Sugar Estates School. These children, along with a considerable number of Lincoln students in the lower grades who had been transferred to the Sugar Estates School because of a school redistricting, were considered part of the test group. Other pupils at Sugar Estates School who had never attended the Lincoln or Washington Schools were added to the control group. Dental examinations of children in grades 2 through 7 in the participating schools were made in early October 1962.

The participating schools had prepared rosters of children, by grade, giving a complete history of schools that each child had attended. Because some of the surrounding islands contain natural fluorides, the examination results for any child who had lived off the island of St. Thomas for more than 90 days were not included. Any child in a control school who had ever attended either the Lincoln or Washington Schools also was eliminated from the analysis.

Four Public Health Service dentists examined the children. Examination criteria were standardized before the survey, and the examiners continued to calibrate their techniques daily. The students were seated in a conventional chair and examined with a mouth mirror and explorer, using the best available natural light. (Electricity was not available.) When necessary, teeth were dried with a chip syringe. The number of children examined, by school and study group classification, are listed in the following tabulation:

School	*Number of children*
Test group	483
Lincoln	206
Sugar Estates	277
Control group	620
Nisley	184
Dober	123
Commandant Gade	228
Sugar Estates	85
Total	1,103

Results

In analyzing the data obtained from examinations of the Lincoln students, it was necessary to disregard the results for those children whose school attendance had not been entirely at Lincoln School. The children who had gone to other schools for varying periods of time made up an assortment of subgroups, each with a different pattern of exposure to fluoridated water and each too small to give meaningful averages of the prevalence of dental caries. Slightly more than 200 children in the test group thus were eliminated from consideration because they did not meet school-residence requirements.

Table 1 presents data on the prevalence of dental caries for the control group and for those of the test group (279 children) who met the study requirements for continuous attendance at Lincoln School. Parallel data are given for children in the test and control groups, by grade, for the average number of permanent teeth that were decayed, missing, or filled; for the average number of erupted permanent teeth; and for the mean proportion of total permanent teeth that were decayed, missing, or filled.

The students were divided into groups by school grade rather than by age because this method of categorization appeared to be more meaningful with regard to exposure to fluoridated water in school. However, in this breakdown of children by grade, some disparities occurred in the average number of erupted permanent teeth between test and control children. For example, among fifth graders, those in the control group averaged approximately one more erupted permanent tooth than those in the test group, and direct comparison of the average number of DMF teeth between the groups was not appropriate.

To compensate for the differences in number of erupted permanent teeth, the proportion of permanent teeth that were decayed, missing, or filled to total number of permanent teeth was computed for each child. Then a mean proportion of the caries attack rates was calculated for test and control group children in each grade. The figures in the difference (percent) column in table 1 show a comparison of the average proportion of DMF teeth in children of the test group with those in the control group. For example, the average proportion of permanent teeth that were decayed, missing, or filled among sixth-grade children was 0.145 for the test group and 0.196 for the control group. For children in this grade, the test group averaged about 26 percent less than the control group in mean proportion of DMF teeth.

Similarly, among children of grades 2, 3, 5, and 7, the mean proportion of decayed, missing, or filled teeth for the test group was below that for the control group, in each case by 17 percent or more. The only exception to this pattern occurred in the fourth grade, where the

Table 1. Comparison of DMF teeth in test and control groups, by school grade, school fluoridation study, St. Thomas, V.I.

Grade	Test group				Control group				Difference (percent)	Probability [1]
	Number of children	Average number of DMF teeth	Average number of permanent teeth per child	Mean proportion, DMF teeth to permanent teeth	Number of children	Average number of DMF teeth	Average number of permanent teeth per child	Mean proportion, DMF teeth to permanent teeth		
2	52	0. 57	9. 79	0. 056	95	0. 94	9. 60	0. 087	35. 6	0. 10
3	50	1. 08	12. 92	. 077	92	1. 71	13. 23	. 126	38. 9	. 01
4	42	2. 36	17. 33	. 128	126	2. 10	17. 26	. 117	[2] 9. 4	. 68
5	53	3. 11	21. 13	. 139	95	3. 96	22. 16	. 170	18. 2	. 12
6	40	3. 55	24. 78	. 145	110	5. 00	25. 07	. 196	26. 0	. 02
7	42	4. 74	25. 81	. 182	83	5. 93	26. 70	. 221	17. 6	. 10
Total	279	2. 47	18. 20	. 118	601	3. 21	18. 94	. 151	21. 9	<. 001

[1] One-tailed t test.
[2] Increase in test group over control group.

average proportion of DMF teeth in the test group exceeded that for the controls by about 9 percent. This exception is due partly to the unusually low mean proportion of DMF teeth in the control group for this grade (0.117), even lower than the corresponding proportion for the third-grade children in that group (0.126). Also, as can easily occur with a small sample size, the average proportion of DMF teeth for the fourth-grade children in the test group was raised considerably, from 0.111 to 0.128, by one child with 12 of 17 permanent teeth which were decayed, missing, or filled. This combination of factors apparently was enough to increase the total dental caries experience of fourth-grade children in the test group as compared with their corresponding controls.

Approximately 15.1 percent of the erupted permanent teeth of all children in the control group were decayed, missing, or filled. For the test group, the figure was 11.8 percent (table 1). The difference for the combined group of test children in comparison with the control group was about 22 percent.

A test of whether the mean proportion of DMF teeth for the test group was significantly lower than that for the control group (a one-tailed test) was performed for each of the corresponding grades, and for the total sample of test and control children. The analysis revealed that, by grade, only the results in the third and sixth grades were significant at a probability level of 0.05 or less. Because of the small sample sizes, by grade, the percent reductions experienced by test children in the second, fifth, and seventh grades could have occurred by chance at the probability levels shown in the final column of table 1.

The total reduction of 21.9 percent in the mean proportion of permanent teeth affected by dental caries in the test group compared with the control group was significant at the probability level of less than 0.001. In less than one time in a thousand could a reduction of this magnitude be expected to occur by chance.

Table 2 shows a cumulative distribution of all children in the study, by group, according to proportion of DMF teeth to total permanent teeth. In the test group for example, 99 children, or approximately 35 percent, had no DMF teeth as compared with 170 children or 28 percent of the control group. Fifty-three percent of the test group children had 9.9 percent or less of their teeth that were decayed, missing, or filled, whereas 45 percent of the control group had scores equal to or lower than this magnitude.

A nonparametric statistical test, Kolmogorov-

Table 2. Cumulative distribution of test and control groups, by proportion of DMF teeth to total permanent teeth, school fluoridation study, St. Thomas, V.I. [1]

Cumulative proportion of DMF teeth to permanent teeth	Number of children		Proportion of children		Difference in proportion
	Test	Control	Test	Control	
0.000	99	170	0. 35	0. 28	0. 07
0.000–0.049	114	195	. 41	. 32	. 09
0.000–0.099	149	271	. 53	. 45	. 08
0.000–0.149	195	326	. 70	. 54	. 16
0.000–0.199	221	399	. 79	. 66	. 13
0.000–0.249	235	458	. 84	. 76	. 08
0.000–0.299	249	502	. 89	. 84	. 05
0.000–0.349	261	538	. 94	. 90	. 04
0.000–0.399	265	561	. 95	. 93	. 02
0.000–0.400 or more	279	601	1. 00	1. 00	. 00

[1] Chi-square formula for one-tailed test:

$$X^2 = \frac{4D^2(N_1N_2)}{N_1+N_2}$$

where D = maximum difference in proportions (0.16)
N_1 = number in test group (279)
N_2 = number in control group (601)

thus $X^2 = \frac{4(0.16)^2(279)(601)}{279+601} = 19.51$

for $X^2_{(\mathrm{DF}2)} = 19.51$, $P < 0.001$.

Smirnov (*15*), was used to determine whether there was any meaningful difference in the cumulative distributions between the test and control groups. The null hypothesis (H_0) formulated was that no difference occurs in the distribution of cumulative proportions of DMF teeth to total teeth between the test and control groups. Conversely, the research hypothesis (H_1) states that children in the test group have proportionally a lower percentage of permanent teeth that are decayed, missing, or filled than do those in the control group. The largest difference in the cumulative distributions between test and control groups (0.16) occurred in the column of scores 0.149 or less. A difference in cumulative proportions this large could be expected to occur by chance less than one time in a thousand. (Formula for determining significance of Kolmogorov-Smirnov test is shown at bottom of table 2.) The null hypothesis thus can be rejected and the conclusion drawn that children in the test group have a lower proportion of DMF teeth than children in the control group.

Cumulative distributions similar to those in table 2 were prepared separately for test and control children of each grade, and the Kolmogorov-Smirnov test was applied. Again, because of the small sample size by grade, only the differences in the third and sixth grades were significant at 0.05 or less, although the results for the seventh grade closely approached significance.

Discussion

The geographic area chosen for this study is one in which the prevalence level of caries had previously been surveyed and reported to be high by Shourie and Marshall-Day in 1950 (*11*). They found the rates of DMF teeth for children 8 years old to be 2.02, those 10 years old, 3.78, and for the 12-year-old children, 6.22. These rates can be approximately compared with the DMF rates for children in the third, fifth, and seventh grades of the control group, 1.71, 3.96, and 5.93, respectively (table 1). The comparability of these figures lends credence to the use of the control group for comparison with the test group in this study.

Only limited data report benefits to the teeth of children who have received intermittent exposure to fluoridated water. Klein (*16*), reporting on data collected in New Jersey, found that children who lived on farms and drank well water (presumably low in fluoride content) at home but who attended school in an area where the drinking water contained from 1.2 to 2.2 ppm fluoride experienced lower dental caries rates than children exposed to a similar home water supply but who also attended school in a fluoride-deficient area. The overall improvement in fluoride-exposed children, ages 6 through 18, was approximately 30 percent.

Jacovone and Lisanti (*17*) reported a 10 percent lower prevalence of caries in the permanent teeth of children ages 10 through 13 who, for at least 4 years, were exposed only at school to drinking water which contained 1.0 to 1.3 ppm of natural fluoride. They were compared with a group of children who attended schools where drinking water was free of fluorides. All the schools had individual water systems as the areas had no community water supplies. The authors concluded, "Even the small amounts of fluorides consumed at school when no fluorides are ingested at home resulted in a definitely lower caries incidence. . . ."

A 1962 survey by Jordan (*18*) in Ely, Minn., after 10 years of water fluoridation in the community, indicated a reduction of approximately 37 percent in the caries rate of students from rural areas who used private, fluoride-deficient water at home but who consumed optimally fluoridated city water while attending school. Their caries rates were compared with baseline results established before fluoridation was started. Two reports from other communities in Minnesota have shown similar findings (*19*, *20*).

The findings in the present study show considerable variation in the reduction of caries in the test group, by grade, ranging from a decrease of 38.9 percent among third-grade children to an increase of 9.4 percent for the fourth graders. With the exception of the findings in the fourth grade, however, the results demonstrate a consistent reduction in dental caries for children who drank fluoridated water in school. The present data provide further evidence of the therapeutic value of fluoridation on a part-time basis. The question of what constitutes an optimal level of fluoride concentration if exposure is limited to school-water consumption, however, remains to be determined.

The results of this study may understate the potential dental benefits that can be obtained from this method of administering fluorides. The operation was plagued with intermittent failures of equipment during the study, and close, continuous supervision of the fluoridating unit was not maintained. All the technical problems that were encountered have since been satisfactorily resolved, as evidenced by successful operation, for the past 6 years, of the division's two other school fluoridation projects.

The age and stage of dental development of the children included in this study should also be considered. Most of the oldest children examined, seventh graders, were 12 years of age, just beginning to erupt their bicuspids and second molars. These teeth, theoretically, should derive the greatest benefits from belated exposure to fluoridated water since they are still developing when first exposed and thus are amenable to both systemic and topical benefits from fluoride incorporation. Those who had these teeth had not had them long enough to demonstrate a differential in caries susceptibility between the test and control groups. The older age groups that are needed to test this hypothesis will be included in the division's school-water fluoridation studies in Kentucky and Pennsylvania.

Summary and Conclusions

Since the fall of 1954, fluoride has been added to the water supply of the Lincoln School in the town of Charlotte Amalie, St. Thomas, V.I., a community with fluoride-deficient sources of drinking water. To compensate for exposure of the children to fluoridated water at school but not at home and for their age when first exposed, a fluoride level of 2.3 ppm was postulated as a suitable level for investigation. Analysis of 96 water samples taken during 8 school years indicated an average school-year fluoride level of 2.34 ppm. However, the water was sampled most frequently after the fluorides were added or just after the equipment was serviced or repaired, and this figure therefore may represent an overestimation of the actual levels of fluoride maintained during the study period.

A dental survey conducted in the fall of 1962 showed that the caries level of children who had attended only the test school was substantially lower for all but one grade than the caries level of children who attended other comparable schools in the same community where the water was fluoride deficient. The difference of 21.9 percent for all children in the test school in their mean proportion of teeth affected by dental caries was significant at a probability level of less than 0.001.

Evidence has been presented that the addition of fluorides to school water in an area where the community water supply is fluoride deficient results in a reduction of dental caries in the permanent teeth of children attending that school. This method of administering fluorides should prove to be of considerable value in areas where fluoridation of community water is impossible. School-water fluoridation produces benefits without conscious effort on the part of the beneficiaries. The costs of equipment, chemicals, and maintenance are minimal, and no professional dental personnel are required to render preventive treatments. These are important factors in isolated areas with little or no dental manpower or economic levels so low as to make dental care prohibitively expensive.

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Pesticide Study

The Public Health Service has announced plans for the first large-scale study ever made to determine possible relationships between long-term health effects and the use of pesticides.

The study, begun in March 1965 in nine States, is expected to be extended next year to at least three other areas. Initial cost will be $1.2 million and will rise to $2.3 million next year. The research will continue at least 5 years in all areas.

Areas participating are the Windsor-Greeley region of Colorado, Dade County, Fla., to be supplemented by a statewide survey of pesticide applications, the island of Oahu, Hawaii, Berrien County, Mich., Monmouth County, N.J., the lower Rio Grande in Texas, the Wenatchee-Quincy Basin in Washington, and areas to be designated in California and Louisiana.

One of the first tasks of the community researchers will be to determine the kinds and amounts of pesticides used and methods of application; pesticide retention characteristics of the soil; local weather features; methods employed for farm, garden, household, public health, and commercial pest control; and rural and urban population distribution patterns, disease incidences, and mortality rates.

Instances of persons receiving heavy chronic pesticide exposure will be scrutinized, with researchers focusing upon the health of pest control operators. Particular attention will be given to liver and kidney ailments, neurological diseases, and allergies, among other disorders. Deaths from unknown causes will be checked to determine if unrecognized pesticide fatalities have been occurring.