

## Dental effects of fluoridation of water with particular reference to a study in the United Kingdom

By E. R. BRANSBY and J. R. FORREST, *Ministry of Health, Alexander Fleming House, Elephant and Castle, London, S.E.1*, and J. N. MANSBRIDGE, *Department of Public Health and Social Medicine, Usher Institute, Warrender Park Road, Edinburgh, 9*

### *Plan of the study*

Fluoride is present, naturally, in almost all water supplies, usually in trace amounts, but in many parts of the United States it occurs in concentrations of between 1.0 and 8.0 p.p.m. It was in that country that most of the earlier research into its effect on dental conditions was done and that the beneficial effect of relatively low levels of fluoride in the drinking water was first demonstrated. As a logical extension of that research the idea was conceived of adding fluoride to some water supplies to see if the same beneficial effect could be obtained; accordingly in 1945 controlled fluoridation studies were set up in two areas in the United States and in one in Canada.

Fluoride was added to the water supplies in these areas to give a concentration of from 1.0 to 1.2 p.p.m., the level which epidemiological studies had shown to give maximum protection to the teeth without causing enamel mottling. The studies were planned to last for at least 10 years so that the effect of fluoridation during the whole period of development and calcification could be assessed on both the deciduous and permanent dentitions. Interest in fluoridation was aroused in this country by the results achieved in these studies after even 5 years. A mission was sent by the British Government to study fluoridation in operation and to assess its effectiveness, safety and practicability. The mission reported favourably (Ministry of Health, Department of Health for Scotland, Ministry of Housing and Local Government, 1953) but recommended that, before the general adoption of fluoridation, its effect should be demonstrated in a few selected areas in the United Kingdom. Accordingly studies were begun in 1955-6 in three areas in the United Kingdom.

### *Selection of areas*

The areas selected were: Watford in England, Kilmarnock in Scotland, and part of the county of Anglesey in North Wales. Three comparable areas were selected also, to serve as controls: Sutton, the town of Ayr and the remainder of the county of Anglesey respectively.

The main criteria for the selection of areas were that (1) the population should be large enough to provide adequate samples of children; (2) the study area and its associated control area should be situated near to each other and be of the same character; (3) the pairs of study and control areas should be in different parts of the country so that the effect of fluoridation could be assessed in different environmental and dietary conditions; (4) the water supplies of each study area and of its control area should if possible be from the same geological sources and undergo the same

kind of chemical treatment before entering the domestic supply; (5) the water supplies of the study and control areas should have a negligible fluoride content.

Particulars of the study and control areas were:

	Approximate population	Distance apart (miles)	Nature of locality	Water supply
Anglesey, N. Wales:				
Bodafon zone, control	20 000	Adjacent	Agricultural	} Soft; from the same source
Gwalchmai zone, study	20 000		Agricultural	
Holyhead, study	10 000		Market and dock town	} Soft
England:				
Sutton, control	70-80 000	30	Mainly residential	Hard, softened before distribution
Watford, study	70-80 000			
Scotland:				
Ayr, control	43 000	12	Mainly industrial	Soft
Kilmarnock, study	43 000			

### *Selection of children*

The aim, which was largely achieved, was to examine 100 children of each of the ages 3 and 4 years and 100-150 schoolchildren of each age in each area. Only those children were included who had lived in the area since birth, other than for short breaks such as annual holidays.

For the selection of preschool children, a list was compiled from available local sources. Children ineligible on the grounds of non-continuous residence were excluded; a representative sample of the remainder was then drawn. Mothers of the selected children were invited to bring the children to the clinic for examination; if such a procedure did not yield sufficient children, others attending infant welfare centres, day nurseries and nursery schools were included.

In the Gwalchmai and Bodafon zones of Anglesey, all the preschool children examined were selected from a list compiled as described above and were a reasonably good cross-section of Anglesey children of those ages. In Holyhead and in Watford and Sutton, children attending welfare centres, nurseries and nursery schools were included. Although the children in these areas might not be representative of all the children of these ages in the areas, they were derived from much the same groups of children each year. In Kilmarnock and Ayr a cross-section of children was examined each year together with the children in nurseries and nursery schools, but only the findings for the cross-section of children have been used.

The selection of schoolchildren presented no such difficulties. In the Gwalchmai and Bodafon zones of Anglesey all eligible schoolchildren up to 15 years of age were examined. In Holyhead only those up to the age of 11 years attending primary and junior schools were included, as the senior schools have a mixed population, many of the children coming from outlying areas. In Watford and Sutton, Kilmarnock and Ayr, representative samples of children were drawn from the school registers.

### *Dental examinations*

Several methods of dental examination have been used in fluoridation studies in America and elsewhere. In the majority, clinical methods are employed, that is, with

Table 1. Fluoridation studies in different countries and the results achieved

Study	Fluoridation began	Age (years) of children included	Method of examination	Frequency of examination	Results in fluoridation areas				
					Age groups	Presentation Indices	Report period (years)	Percentage reduction in caries	Prevalence of permanent teeth
Grand Rapids Michigan, USA (F. A. Arnold, R. C. Likins, A. L. Russell and D. B. Scott, unpublished)	1945	4-16	Clinical + X-ray of selected groups in 1947, 1949, 1953	Annual	Each year of age separately	DMF/child def/child	6 10 13 15	5 9 10 14 15	58 49 52 51 50
Newburgh New York, USA (A. S. Smith, Wachs & Cantwell, 1956)	1945	6-14	Clinical + X-ray of first permanent molars in 1949-50, 1953-54, 1954-55	Annual	Earlier reports, each year of age separately. Later reports, groups 6-9, 10-12, 13-14 years	DMF per 100 erupted teeth on per cent of both erupted teeth on per cent of children	7 10	5 6 6-9 10-12	59 47 58 53
Brantford Ontario, Canada (Hutton, Linscott & Williams, 1956)	1945	6-14	Clinical	1945, 1946, 1948, 1951, 1953, 1954, 1955	6-8, 9-11, 12-14 years	DMF/child def/child	10	6-9	41 52
Evanston Illinois, USA (Hill, Blayney & Wolf, 1956)	1947	6, 7, 8, 12, 13, 14	Clinical + full-mouth X-ray	Annual	6-8 years	DMF/100 children def/100 children	47-58 months	6-8 6-8	46 64
Sheboygan Wisconsin, USA (Data published in report of UK mission)*	1946	5-6, 9-10, 12-14	Clinical	Annual	5-6, 9-10, 12-14 years	DMF/child def/child	5	5-6 9-10 12-14	30 23
Marshall Texas, USA (Data published in report of UK mission)*	1946	6-14	Clinical	Annual	Each year of age separately	DMF/child def/child	5	6	57 (deciduous and permanent teeth combined)
Maryland, USA (Russell & White, 1961)	1952	5-15	Clinical	Annual	Each year of age separately	DMF/child def/child	5 7 3	5 6 5 5 5 6	53 75 65 36 14 42 61 26 14
Hastings New Zealand (Ludwig, 1959)	1954	5-16	Clinical + X-ray of child on 11 years and over	Annual	Each year of age separately	DMF/child def/child	6	7 8	42 46 20 14
Tiel Holland (Becker-Dirks, Houwink & Kwant, 1961)	1953	9-15	Mainly full-mouth X-ray; clinical of small selected groups	Biennial	10, 11-15 years	Carious lesions on deciduous, approximal, buccal and lingual surfaces	6½	10	67 in approximal surfaces 69 in buccal and lingual surfaces 28 in occlusal surfaces

D or d, decayed; e, extracted or in the Grand Rapids study 'indicated for extraction'; F or f, filled; M or m, missing; upper and lower case letters denote permanent and deciduous teeth respectively.  
\*Ministry of Health, Department of Health for Scotland, Ministry of Housing and Local Government (1953).

mouth mirror and probe. In some studies however, radiological examination is also included, either throughout the study or periodically. Table 1 shows for various studies in different parts of the world the type of dental examination, the groups studied, the indices used and the results obtained.

In the studies now described, clinical examination was preferred. The dental examinations were made by a number of dental officers, who both before and during the period of study were given a special course of training in the method of examination and recording. On two occasions during the study period, the assessments of caries made by the individual dental officers were compared; they, as one would expect, showed some variation. Diagnosis of early enamel lesions is often difficult, which usually explains the variations between assessments by dentists taking part in a survey.

The steps taken to improve the reliability of the dental examinations were: (1) the same dentists carried out the dental examinations in each pair of study and control areas, (2) each dentist examined children in the same schools on each occasion, and (3) each dentist examined during alternate weeks in the study and control areas.

This plan was, in the main, followed throughout the study period although for various personal reasons it could not be adhered to entirely. The dental findings presented in the official report of the studies (Ministry of Health, Scottish Office, Ministry of Housing and Local Government, 1962) and in this paper were derived from those dental examinations that adhered strictly to this plan.

Only those lesions with definite breach of the enamel and palpable softening of the underlying dentine were counted as carious, that is cavities that should be filled and were thus of practical importance. The site and extent of each carious lesion was noted, the surfaces involved and the depth of penetration of caries being shown.

Although this was a clinical study, radiological examinations were carried out in 1958 on 12-year-old children in the study areas in England and Wales, mainly to determine whether or not the use of radiographs would add materially to the value of the clinical examinations. The findings showed that the use of radiographs made little difference to the caries count.

#### *Index for assessing the effects of fluoridation*

The index for assessing the dental affects of fluoridation was the average number of decayed, missing and filled teeth per child. This index (DMF for permanent teeth, dmf for deciduous teeth) in which the tooth is the unit, is simple and easily understood. An Expert Committee on Dental Health of the World Health Organization (World Health Organization, 1962) recommends its use in dental surveys. It is a measure of the lifetime experience of caries. As the object of fluoridation studies is eventually to assess the effect of fluoridation on children who have had fluoridated water all their lives, the total caries experience of the deciduous teeth and of the permanent teeth is an appropriate criterion.

For children aged 3 and 4 years, the full deciduous dentition was assessed, any missing teeth being counted as carious, because natural shedding of such teeth is unusual at those ages. For children aged from 5 to 7 years, only the deciduous canines

Table 2. *Percentage reduction in the mean number/child of carious teeth in the three study and in the three control areas combined, between the base-line year\* and 1961*

Age (years)	Study areas		Control areas		Adjusted† reduction in study areas
	No. of children examined	Mean no. of carious teeth/child	No. of children examined	Mean no. of carious teeth/child	
	Base-line	1961	Base-line	1961	Reduction
3†	301	3.80	297	3.53	6
4†	405	5.39	334	5.78	7
5‡	536	5.81	461	5.66	5
6‡	616	6.49	566	6.32	2
7‡	678	7.06	577	7.58	3

\* 1955 and 1956 for the Anglesey areas, 1956 for the other areas.

† For the change in the control area.

‡ Full dentition.

§ Deciduous canines and molars only.

and molars were assessed (any of those missing, being counted as carious) to avoid complications arising from the shedding of the incisors, which is frequent at those ages.

### Results

The effects of fluoridation were assessed from the trends over the study period, from the consistency of the results in the different study and control areas and from the findings for the study areas combined and for the control areas combined.

Table 2 shows the changes between the base-line years and 1961 in the three study areas and the three control areas combined, together with the changes in the former after adjustment for the changes in the latter. The reduction was very substantial for the younger children; some reduction was apparent even for children aged 7 years. Table 3 shows the findings for the individual areas; the similarity between them is obvious.

Table 3. *Percentage reduction\* in the mean number/child of carious† teeth in the three study areas between the base-line year‡ and 1961*

Study area	Age (years)				
	3§	4§	5	6	7
Anglesey, Gwalchmai zone	68	51	56	25	9
Anglesey, Holyhead	77	51	45	13	12
Watford	73	53	44	25	10
Kilmarnock	55	56	42	24	15

\*After adjustment for the changes in the control areas.

†Decayed, missing or filled.

‡1955 and 1956 for the Anglesey areas, 1956 for the other areas.

§Full dentition.

||Deciduous canines and molars only.

Table 4 shows, as an example, the changes in one fluoridation area, the Gwalchmai zone of Anglesey, for each year from 1957 to 1961 for children aged 3–7 years. Over the study period there was a reasonably consistent trend in the percentage reduction in the amount of caries and also from the younger to the older children. The results for the other study areas followed the same pattern.

Table 4. *Mean number/child, in children aged 3–7 years in the Gwalchmai zone of Anglesey, of carious deciduous canines and molars in each of the years from 1957 to 1961, expressed as a percentage of the base-line number\**

Age (years)	1957	1958	1959	1960	1961
3	98	87	24	51	40
4	119	91	91	36	44
5	99	98	85	74	46
6	102	90	91	79	73
7	110	105	98	99	88

\*Mean of the number in 1955 and 1956.

The change over the study period in the mean number of carious teeth per child naturally affects the proportions of children with different numbers of carious teeth. Table 5 shows for the base-line years and 1961 the proportions of children aged 3

and 4 years with different numbers of carious teeth. For children aged 3 years the percentage free from caries rose from 32.5 to 60.5, while the percentage with ten or more carious teeth fell from 14.9 to 1.7. The corresponding figures for children aged 4 years were from 22.2 to 42.0 and from 21.6 to 3.6.

Table 5. *Percentage of children aged 3 and 4 years in the three study areas combined with different numbers of carious\* teeth (deciduous teeth, full dentition)*

No. of carious teeth	Children aged 3 years		Children aged 4 years	
	Base-line†	1961	Base-line†	1961
0	32.5	60.5	22.2	42.0
1 or 2	23.2	20.9	15.9	23.4
3-5	16.5	12.2	20.8	20.7
6-9	12.9	4.7	19.7	10.3
10 or more	14.9	1.7	21.4	3.6

\*Decayed, missing or filled.

†1955 and 1956 for the Anglesey areas, 1956 for the other areas.

The changes over the study periods in the three fluoridation areas in the individual deciduous teeth are shown in Table 6 and in the individual tooth surfaces in Table 7. Both in the base-line period and in 1961 caries experience was greatest in the molars and least in the canines and incisors. The results for the individual areas do not indicate any consistently different effect of fluoridation on the individual teeth. The surface most frequently affected was the occlusal, and least frequently the lingual. The results for the separate areas do not show a consistently different effect of fluoridation on the individual surfaces, although there is some suggestion of a less-than-average reduction on the occlusal surfaces of the molars.

Table 6. *Percentage reduction in the mean number of carious teeth (a, b, c, d, e, separately) (deciduous teeth, full dentition) for children aged 3 and 4 years in the three study areas combined between the base-line year\* and 1962*

Tooth	Children aged 3 years			Children aged 4 years		
	Base-line	1961	Reduction	Base-line	1961	Reduction
a	0.77	0.15	81	0.84	0.34	60
b	0.49	0.10	80	0.57	0.16	72
c	0.24	0.05	79	0.45	0.10	78
d	1.07	0.41	62	1.56	0.68	56
e	1.23	0.58	53	1.97	1.03	48
Total	3.80	1.29	66	5.39	2.31	37

\*1955 and 1956 for the Anglesey areas, 1956 for the other areas.

Table 7. *Percentage reduction in the mean number/child of carious surfaces in children aged 3 and 4 years (deciduous teeth, full dentition) in the three study areas combined between the base-line year\* and 1961*

Tooth surface	Children aged 3 years			Children aged 4 years		
	Base-line	1961	Reduction	Base-line	1961	Reduction
Occlusal	2.07	0.94	55	3.14	1.59	49
Mesial	1.73	0.34	80	2.71	0.86	68
Distal	1.32	0.37	72	2.61	0.87	67
Buccal	1.11	0.32	71	1.89	0.76	60
Lingual	0.99	0.28	72	1.76	0.70	60
Total	7.22	2.25	69	12.11	4.78	61

\*1955 and 1956 for the Anglesey areas, 1956 for the other areas.

*Discussion and conclusions*

In the official report on the studies (Ministry of Health, Scottish Office, Ministry of Housing and Local Government, 1962) comparison is made between the findings in Great Britain and those in the Grand Rapids study in the United States (Arnold, Dean, Jay & Knutson 1956). After adjustment for changes in the control areas, the reduction among children aged 4 years was 42% in Grand Rapids and 54% in Great Britain, the corresponding figures for children of 5 years being 45% and 47%. The same order of reduction was thus being achieved in this country as in Grand Rapids, and it is reasonable to expect that over a longer period of fluoridation in this country results for both the deciduous and permanent teeth similar to those in Grand Rapids will be obtained.

The findings from these American and British studies themselves provide clear evidence of the value of fluoridation as a preventive measure against dental caries. In conjunction with the findings from studies in other parts of the world, they provide massive evidence.

## REFERENCES

- Arnold, F. A. Jr., Dean, H. T., Jay, P. & Knutson, J. W. (1956). *Publ. Hlth Rep., Wash.*, **71**, 652.  
 Ast, D. B., Smith, D. J., Wachs, B. & Camtwell, K. T. (1956). *J. Amer. dent. Ass.* **52**, 314.  
 Backer-Dirks, O., Houwink, B. & Kwant, G. W. (1961). *Arch. oral Biol.* **5**, 284.  
 Hill, I. N., Blayney, J. R. & Wolf, W. (1956). *J. Amer. dent. Ass.* **53**, 327.  
 Hutton, W. L., Linscott, B. W. & Williams, D. B. (1956). *Canad. J. publ. Hlth*, **47**, 89.  
 Ludwig, T. G. (1959). *N.Z. dent. J.* **55**, 262.  
 Ministry of Health, Department of Health for Scotland, Ministry of Housing and Local Government (1953). *The Fluoridation of Domestic Water Supplies in North America*. London: H.M. Stationery Office.  
 Ministry of Health, Scottish Office, Ministry of Housing and Local Government (1962). *Rep. publ. Hlth med. Subj., Lond.*, no. 105.  
 Russell, A. L. & White, C. L. (1961). *Publ. Hlth Rep., Wash.*, **76**, 1087.  
 World Health Organization (1962). *Tech. Rep. Wld Hlth Org.* no. 242.

**Fluoridation and public relations**

By A. J. DALZELL-WARD, *The Central Council for Health Education, Tavistock House, Tavistock Square, London, W.C.1*

*Background*

At first glance, it might seem extraordinary that a precise scientific matter like the fluoridation of public water supplies should call for a special public relations policy. There is no public health measure or prophylactic procedure that has been so exhaustively examined and tested. It shares with vaccination against smallpox, alone, the distinction of being based on observations of entirely natural phenomena. The benefits it can offer promise an impressive saving in suffering and money, and the safety margin exceeds that offered by any other prophylactic procedure. It must be remembered, however, that proponents of this measure have encountered opposition in the USA, Sweden, New Zealand, Eire and the UK.