Domestic Water and Dental Caries: V. Additional Studies of the Relation of Fluoride Domestic Waters to Dental Caries Experience in 4,425 White Children, Aged 12 to 14 Years, of 13 Cities in 4 States

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DOMESTIC WATER AND DENTAL CARIES [1]

V. Additional Studies of the Relation of Fluoride Domestic Waters to Dental Caries Experience in 4,425 White Children, Aged 12 to 14 Years, of 13 Cities in 4 States

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Recent reports (*1*, *2*) have pointed out an inverse relationship between the fluoride content of the public water supply and the dental caries experience of those children continuously using such waters throughout life. A further study of this phenomenon has been made in 21 cities of 4 States where the public water supplies varied not only in fluoride content but with respect to other mineral constituents as well.

A portion of this investigation—a study of 2,832 children in 8 suburban Chicago communities—has recently been reported (*3*). The present paper records the findings observed in 4,425 additional children of 13 other cities, bringing the total number of white urban school children, aged 12 to 14 years, examined to 7,257. All were examined by one or the other of two dental examiners (D. C. J. and E. M. S.), each examining approximately an equal number of children in each city.

The same methods used in the study of the 8 suburban Chicago communities with respect to age, sex, color, continuity of exposure, and other epidemiological factors discussed in detail in that report (*3*) were followed in the study of the 13 additional cities which form

[1] From the Division of Infectious Diseases with the cooperation of the Division of Chemistry, National Institute of Health. Preceding papers in this series are:

Dean, H. T., Jay, P., Arnold, F. A., Jr., and Elvove, E.: Domestic water and dental caries. I. A dental caries study, including *L. acidophilus* estimations, of a population severely affected by mottled enamel and which for the past 12 years has used a fluoride-free water. Pub. Health Rep., **56**: 365–381 (1941).

Dean, H. T., Jay, P., Arnold, F. A., Jr., and Elvove, E.: Domestic water and dental caries. II. A study of 2,832 white children, aged 12 to 14 years, of 8 suburban Chicago communities, including *Lactobacillus acidophilus* studies of 1,761 children. Pub. Health Rep., **56**: 761–792 (1941).

McClure, F. J.: Domestic water and dental caries. III. Fluorine in human saliva. Am. J. Dis. Child., **62**: 512 (1941).

Arnold, F. A., Jr., Dean, H. T., and Elvove, E.: Domestic water and dental caries. IV. Effect of increasing the fluoride content of a common water supply on the *Lactobacillus acidophilus* counts of the saliva. Pub. Health Rep., **57**: 773–780 (1942).

the basis of this paper. For purposes of summarizing these field findings in the discussion which follows later in this paper, certain data from the study of 8 suburban Chicago communities will be included with that of the 13 additional cities which form the basis of this report.

The study of the 8 suburban Chicago communities showed, in part, that the continuous use of a domestic water, the fluoride content of which was close to the minimal threshold of endemic dental fluorosis (mottled enamel), was associated with a relatively low dental caries experience. For example, at Aurora (Ill.), where the domestic water contained 1.2 p. p. m.[2] of fluoride (F) and where a relatively low dental caries prevalence was recorded, mottled enamel as an esthetic problem was not encountered. Strong presumptive evidence suggests that the factor or factors responsible for this increased freedom from dental caries is the fluoride content of the domestic water; the fact that it was operative at concentration levels so low that mottled enamel ceased being an accessory complication was a finding of first importance.

When it was also apparent that all three cities using fluoride-free waters were characterized by relatively high dental caries prevalence, it seemed likely that fluoride levels under 1.0 p. p. m. of fluoride (F) might also influence the intensity of dental caries attack.[3] The study was therefore extended to include certain additional cities whose water supplies contained fluorides in these lower concentration levels.

This paper describes studies made in Illinois, Indiana, Ohio, and Colorado, and reports the amount of dental caries experience found associated with the continuous use of common water supplies obtained from Lake Michigan, the Mississippi, Ohio, and Arkansas Rivers, from deep wells of different fluoride concentration and mineral composition, and in one instance from melted snow high on Pike's Peak (Colorado Springs).

This survey immediately followed the study of the 8 suburban Chicago communities previously reported (*3*), all clinical examinations being made by the same two dental examiners. With the exception of Kewanee[4] (Ill.), all examinations were made during 1940. The order in which these cities were studied was: Kewanee (Ill.); Zanesville, Portsmouth, Middletown, Marion, and Lima (Ohio); Elkhart

[2] P. p. m.=parts per million.

[3] The term "intensity of dental caries attack" as used in this paper may be defined as the force of the factors responsible for the initiation (or inhibition) and rate of progress (or quiescence) of the dental caries process. This force of attack (or force of resistance) is subject to considerable change dependent upon varying circumstances.

[4] Examinations in Kewanee were made in December 1939. The chronological order in which the clinical examinations were made in 1940 was as follows: Zanesville and Portsmouth (January); Middletown (January–February); Marion and Lima (February); Elkhart and Michigan City (March); Colorado Springs (April); Pueblo (May); Quincy (September); Galesburg (September–October); and East Moline (October).

and Michigan City (Ind.); Colorado Springs and Pueblo (Colo.), and Quincy,[5] Galesburg,[5] and East Moline (Ill.).

In the tables to follow these 13 cities will be listed in accordance with the increasing order of observed dental caries experience rates which are: Galesburg (Ill.); Colorado Springs (Colo.); East Moline (Ill.); Kewanee (Ill.); Pueblo (Colo.); Marion, Lima, and Middletown (Ohio); Quincy (Ill.); Zanesville and Portsmouth (Ohio), and Elkhart and Michigan City (Ind.).

Population of cities studied.—Population statistics with respect to the 13 cities studied are given in table 1. As the study was limited to white school children, the percentage of native white was computed on the basis of the total white population, not the total population. Briefly, it shows that at Galesburg, Colorado Springs, East Moline, Kewanee, Pueblo, Marion, Lima, Middletown, Quincy, Zanesville, Portsmouth, Elkhart, and Michigan City the percentage of the native white of the white population was: 92.0, 93.2, 78.9, 85.9, 89.5, 97.7, 96.4, 96.2, 95.7, 97.2, 98.4, 94.9, and 87.1, respectively.

Climatological data (sunshine).—Weather Bureau reports list the number of clear, partly cloudy, and cloudy days [6] as recorded at stations located at or near the cities included in this study. To estimate roughly the amount of sunshine present in these cities the Weather Bureau recordings for clear, partly cloudy, and cloudy days were divided dichotomously into "clear" and "nonclear" days, the term "clear days" as used in this paper being defined as the number of clear days reported by the Weather Bureau plus one-half the number of days listed as partly cloudy. The average number of "clear days" and the percentage of "clear days" per year was determined for the 15-year period covering approximately the life span of the children examined and is shown in table 2. Certain of these values were obtained from stations located in the city studied. Where this was not possible the values recorded at the nearest seemingly comparable city are given and in some cases where two stations were about equidistant, an arithmetic mean of the reports from both stations. These data are shown in table 2.

In connection with the alleged influence of sunshine on dental caries prevalence, it might be noted that cities characterized by high dental caries experience, e. g., Portsmouth and Middletown, show percentages of "clear days" as high or higher than that of Galesburg, a city where a very low dental caries prevalence was observed.

[5] The children of Galesburg and Quincy were examined in December 1939, by Dental Surgeon H. T. Dean, U. S. Public Health Service, and Dr. O. S. Hoag, Illinois Department of Public Health, as reported in reference (*2*). Because of the variation in diagnostic criteria of different dental examiners, the children of Galesburg and Quincy were again examined in September and October 1940, by Assistant Dental Surgeons (R) Johnston and Short in order that all dental caries experience reported in this paper might be on a comparable basis of diagnostic standards.

[6] A day is classified clear, partly cloudy, or cloudy on the basis of hourly estimations, sunrise to sunset, as follows: Clear, sky averages three-tenths or less obscured; partly cloudy, sky averages four-tenths to seven-tenths inclusive, obscured; and cloudy, sky averages more than seven-tenths obscured.

TABLE 1.—*Statistics with respect to the composition of the population of the 13 cities studied (census of 1930)*

City	Population								
	Total	White	Negro	Other races [1]	Total	White	Negro	Other races [1]	Percent native white of white population
	Number				Percent				
Galesburg, Ill	28,830	27,671	891	268	100.0	95.98	3.09	0.93	92.0
Colorado Springs, Colo	33,237	31,828	965	444	100.0	95.76	2.90	1.34	93.2
East Moline, Ill	10,107	9,462	470	175	100.0	93.62	4.65	1.73	78.9
Kewanee, Ill	17,093	16,720	278	95	100.0	97.82	1.63	.55	85.9
Pueblo, Colo	50,096	45,131	1,305	3,660	100.0	90.10	2.60	7.30	89.5
Marion, Ohio	31,084	30,690	387	7	100.0	98.73	1.25	.02	97.7
Lima, Ohio	42,287	40,848	1,422	17	100.0	96.60	3.36	.04	96.4
Quincy, Ill	39,241	38,062	1,145	34	100.0	97.00	2.92	.08	96.2
Middletown, Ohio	29,992	27,186	2,805	1	100.0	90.64	9.35	.01	95.7
Zanesville, Ohio	36,440	34,659	1,776	5	100.0	95.11	4.87	.02	97.2
Portsmouth, Ohio	42,560	40,658	1,891	11	100.0	95.53	4.44	.03	98.4
Elkhart, Ind	32,949	32,394	539	16	100.0	98.31	1.64	.05	94.9
Michigan City, Ind	26,735	25,533	1,071	131	100.0	95.50	4.00	.50	87.1

[1] Although the Negro was excluded from this study because of the possibility of a racial difference in attack by dental caries, no attempt was made to eliminate children of "Other races." This segment of the population comprised a relatively small percentage of the general population (1.2 percent) of the 13 cities studied, and it seemed unnecessary to eliminate the occasional child who may have belonged in this classification. They are, accordingly, included with the white children in the tables that follow in this paper. Persons of Mexican birth or parentage who were not definitely reported as white or Indian were designated "Mexican" in the 1930 census and included in the general class of "Other races." In previous censuses most of the Mexicans have been classified as white. Of the 4,594 persons listed in this column, East Moline and Kewanee (Ill.) excluded, 4,356, or close to 95 percent, were Mexicans.

TABLE 2.—*A 15-year summary (1925–39) of the actual, or estimated, average number of "clear days" per year recorded for the 13 cities studied*

(From Climatological Data, Weather Bureau)

City	Number of days		Number of clear days [2] (A+B)	Number of years of observation	Clear days		Increasing order of—	
	Clear [1]	½ partly cloudy [1]			Average per year $\left(\frac{C}{D}\right)$	Percent $\frac{E}{365}$	Dental caries experience	Percent of clear days [2]
	A	B	C	D	E			
Galesburg, Ill	2,625	556	3,181	15	212.1	58.1	1	9
Colorado Springs, Colo	3,040	791	3,831	15	255.4	70.0	2	13
East Moline, Ill	2,053	810	2,863	15	190.9	52.3	3	3
Kewanee, Ill	2,612	625	3,237	15	215.8	59.1	4	10
Pueblo, Colo	2,489	1,094	3,583	15	238.9	65.5	5	12
Marion, Ohio	1,415	1,004	2,419	15	161.3	44.2	6	1
Lima, Ohio	2,190	707	2,897	15	193.1	52.9	7	4
Quincy, Ill	2,508	563	3,071	15	204.7	56.1	8	6
Middletown, Ohio	2,688	695	3,383	15	225.5	61.8	9	11
Zanesville, Ohio	2,491	603	3,094	15	206.3	56.5	10	7
Portsmouth, Ohio	2,818	360	3,178	15	211.9	58.1	11	8
Elkhart, Ind	1,811	758	2,569	15	171.3	46.9	12	2
Michigan City, Ind	2,615	454	3,069	15	204.6	56.1	13	5
Total	31,355	9,020	40,375	195	207.1	56.7		

[1] "Clear days" and "partly cloudy days" as defined by the Weather Bureau. (See footnote 6, p. 1155.)
[2] "Clear days" as defined in text.

Selection of study groups.—The study groups were selected in a manner described in detail in a previous report (*3*). *The groups*

examined generally represent all 12-, 13-, and 14-year-old white public[7] *school children continuously exposed to the variable under investigation (the public water supply).* All public schools in the community having a seventh, eighth, or ninth grade were included in the study, but no effort was made to locate 12- to 14-year-old children in grades other than the three specified, with the exception of those instances where an appreciable number of children of the age group studied were in the sixth grade.

At Kewanee, Zanesville, and Portsmouth the selection was done by the same individual (H. T. D.) as in the study of the 8 suburban Chicago communities. In the other 10 cities the selection was carried out by the two dental examiners (D. C. J. and E. M. S.) in a manner similar to that followed in the cities previously studied. Table 3 shows the number of 12- to 14-year-old pupils present the day the study group was selected and the number and percentage of these whose histories on repeated questioning indicated continuity of exposure and who were examined.

TABLE 3.—*Summary of data with relation to continuity of exposure to the public water supply of 4,425 selected white children, aged 12 to 14 years, residing in 13 cities of Illinois, Indiana, Ohio, and Colorado*

City	Number of 12- to 14-year-old children in attendance on the day study group was selected	Number of 12- to 14-year-old white children whose histories on repeated questioning [1] indicated continuity of exposure and who were examined	Percentage of the total present who were examined
Galesburg, Ill	918	273	29.7
Colorado Springs, Colo	1,444	404	28.0
East Moline, Ill	352	152	43.2
Kewanee, Ill	522	123	23.6
Pueblo, Colo	1,412	614	43.5
Marion, Ohio	1,010	263	26.0
Lima, Ohio	1,411	454	32.2
Middletown, Ohio	1,013	370	36.5
Quincy, Ill	1,063	330	31.0
Zanesville, Ohio	1,248	459	36.8
Portsmouth, Ohio	1,228	469	38.2
Elkhart, Ind	942	278	29.5
Michigan City, Ind	654	236	36.1
Total	13,217	4,425	33.5

[1] About 14 percent of the group (5,127) for whom sampling cards were made out were not examined. The detailed subsequent questioning which disclosed breaks in continuity of exposure warranting elimination from the study accounted for about half of the cases excluded (7 percent) and these together with those absent on the day of examination (2.5 percent), colored (4 percent), and miscellaneous comprised the 14 percent referred to.

Clinical examinations.—All clinical examinations were made in a manner similar to that followed in the study of the 8 suburban Chicago communities (*3*), and by the same two dental examiners.

[7] At Colorado Springs and East Moline children of the parochial schools were examined in addition to the public school children.

CLINICAL FINDINGS

In table 4 are shown the number of children examined, the age distribution, the number and percentage of children with one or more permanent teeth[8] showing dental caries experience, the number and percentage of children with no dental caries experience, and the total dental caries experience (permanent teeth) observed in each city.

TABLE 4.—*Prevalence of dental caries experience, permanent teeth, in 4,425 selected white school children, aged 12 to 14 years, classified by cities, according to: (a) age distribution, the number and percent of children showing dental caries experience, and (b) the amount of dental caries experience*

City	Number of children examined				Children showing—		Permanent teeth showing dental caries experience
	All ages	Age in years, last birthday			Dental caries experience	No dental caries experience	
		12	13	14			
	Number						
Galesburg, Ill	273	89	100	84	197	76	643
Colorado Springs, Colo	404	143	137	124	289	115	994
East Moline, Ill	152	54	58	40	121	31	461
Kewanee, Ill	123	42	40	41	101	22	422
Pueblo, Colo	614	188	253	173	549	65	2,528
Marion, Ohio	203	88	78	97	248	15	1,461
Lima, Ohio	454	147	148	159	444	10	2,962
Middletown, Ohio	370	116	141	113	363	7	2,601
Quincy, Ill	330	100	125	105	322	8	2,329
Zanesville, Ohio	459	147	175	137	447	12	3,366
Portsmouth, Ohio	469	128	177	164	463	6	3,622
Elkhart, Ind	278	79	122	77	274	4	2,289
Michigan City, Ind	236	77	84	75	236	0	2,448
	Percent						Number per 100 children examined
Galesburg, Ill		32.6	36.6	30.8	72.2	27.8	236
Colorado Springs, Colo		35.4	33.9	30.7	71.5	28.5	246
East Moline, Ill		35.5	38.2	26.3	79.6	20.4	303
Kewanee, Ill		34.2	32.5	33.3	82.1	17.9	343
Pueblo, Colo		30.6	41.2	28.2	89.4	10.6	412
Marion, Ohio		33.5	29.6	36.9	94.3	5.7	556
Lima, Ohio		32.4	32.6	35.0	97.8	2.2	652
Middletown, Ohio		31.4	38.1	30.5	98.1	1.9	703
Quincy, Ill		30.3	37.9	31.8	97.6	2.4	706
Zanesville, Ohio		32.0	38.1	29.9	97.4	2.6	733
Portsmouth, Ohio		27.3	37.7	35.0	98.7	1.3	772
Elkhart, Ind		28.4	43.9	27.7	98.6	1.4	823
Michigan City, Ind		32.6	35.6	31.8	100.0	0.0	1,037

The amount of dental caries in the populations studied is expressed quantitatively in terms of the total caries experience[9] of the group. This is determined by totaling the number of filled teeth (past dental caries), the number of teeth with untreated dental caries (irrespective of the number of defects per tooth), the number of teeth indicated for

[8] All data in the tables to follow refer to permanent teeth only.

[9] This method of reconstituting the complete caries experience in the permanent teeth of children with a fair degree of precision has been described by Klein and Palmer in Pub. Health Bulletin No. 239, reference (4), this paper, and other publications. Although the method of estimating the total amount of past and present dental caries described in this paragraph deals with teeth *per se*, similar criteria may be applied in measuring dental caries prevalence for tooth surfaces as may be seen in table 7 of this paper.

extraction, and the number of missing teeth.[10] In computing this index, no single tooth was counted more than once even though one surface may have shown a carious lesion and another surface a filling.[11] To express the dental caries experience (teeth) in terms of a rate per hundred children examined, the sum of the four aggregates referred to is divided by the number of children examined and the quotient multiplied by 100. These data are given in table 4.

In addition to reporting the total dental caries experience, it seems desirable to show how much each of the following items contributed to the rates shown: Filled teeth (past dental caries), teeth with untreated dental caries, teeth in which extraction is indicated, and missing teeth (teeth lost because of accident or extracted because of malposition excluded). These data are shown in table 5.

TABLE 5.—*Summary of the dental caries experience in the permanent teeth of 4,425 white school children, aged 12 to 14 years, of 13 cities in Illinois, Indiana, Ohio, and Colorado, classified on the basis of filled teeth (past dental caries), teeth with untreated dental caries, extraction indicated, and missing teeth (presumably because of dental caries)*

City	Children examined	Dental caries experience, permanent teeth				
		Filled teeth (past dental caries) (a)	Teeth with untreated dental caries (b)	Extraction indicated (c)	Missing teeth (d)	Total (a+b+c+d)
(A) NUMBER						
Galesburg, Ill	273	217	385	15	26	643
Colorado Springs, Colo	404	240	734	5	15	994
East Moline, Ill	152	103	334	9	15	461
Kewanee, Ill	123	77	308	9	28	422
Pueblo, Colo	614	377	2,017	48	86	2,528
Marion, Ohio	263	213	1,175	17	56	1,461
Lima, Ohio	454	653	2,037	59	213	2,962
Middletown, Ohio	370	653	1,687	41	220	2,601
Quincy, Ill	330	917	1,167	75	170	2,329
Zanesville, Ohio	459	908	1,961	156	341	3,366
Portsmouth, Ohio	469	1,202	2,041	108	271	3,622
Elkhart, Ind	278	789	1,404	25	71	2,289
Michigan City, Ind.	236	770	1,463	61	154	2,448
(B) NUMBER PER 100 CHILDREN EXAMINED						
Galesburg, Ill		79.5	141.0	5.5	9.5	236
Colorado Springs, Colo		59.4	181.7	1.2	3.7	246
East Moline, Ill		67.8	219.7	5.9	9.9	303
Kewanee, Ill		62.6	250.4	7.3	22.8	343
Pueblo, Colo		61.4	328.5	7.8	14.0	412
Marion, Ohio		81.0	446.8	6.5	21.3	556
Lima, Ohio		143.8	448.7	13.0	46.9	652
Middletown, Ohio		176.5	455.9	11.1	59.5	703
Quincy, Ill		277.9	353.6	22.7	51.5	706
Zanesville, Ohio		197.8	427.2	34.0	74.3	733
Portsmouth, Ohio		256.3	435.2	23.0	57.8	772
Elkhart, Ind		283.8	505.0	9.0	25.5	823
Michigan City, Ind		326.3	619.9	25.8	65.3	1,037

[10] In this study third molars are excluded from consideration; the occasional instance of teeth lost by accident or extracted because of malposition is also excluded.

[11] In this study a tooth showing both an untreated lesion and a filling was counted as a "filled tooth."

Proximal dental caries.[12]—Outstanding differences in the amount of dental caries in the proximal surfaces of the four superior permanent incisors have been reported (*2*, *3*). For instance, in the study of 8 suburban Chicago communities, there was 14.3 times as much of this type of caries in the 1,008 children using fluoride-free waters (Evanston, Oak Park, and Waukegan) as was observed in the 1,421 children using a water whose fluoride (F) content exceeded 1.0 p. p. m. (Elmhurst, Maywood, Aurora, and Joliet).

The dental caries experience of the eight proximal surfaces of the four superior permanent incisors in the children of the 13 cities included in this report are shown in table 6.

TABLE 6.—*Summary of the findings relative to the dental caries experience, proximat surfaces, of the four superior permanent incisors of 4,425 selected white school children, aged 12 to 14 years, of 13 cities*

City	Number of children examined	Dental caries experience, proximal surfaces, superior permanent incisors				
		Children showing 1 or more surfaces with dental caries experience		Total number of proximal surfaces [1]	Number of proximal surfaces with dental caries experience [2]	Dental caries experience per 100 surfaces
		Number	Percent			
(A) CITIES WHOSE WATER SUPPLIES CONTAINED 0.5 P. P. M. OR MORE OF F.						
Galesburg, Ill.	273	9	3.3	2,162	10	0.46
Colorado Springs, Colo.	404	5	1.2	3,186	10	.31
East Moline, Ill.	152	2	1.3	1,214	2	.16
Kewanee, Ill.	123	6	4.9	976	14	1.4
Pueblo, Colo.	614	12	2.0	4,854	23	.47
Total	1,566	34	2.2	12,392	59	.48
(B) CITIES WHOSE WATER SUPPLIES CONTAINED LESS THAN 0.5 P. P. M. OF F.						
Marion, Ohio	263	34	12.9	2,076	69	3.3
Lima, Ohio	454	52	11.5	3,580	113	3.2
Middletown, Ohio	370	78	21.1	2,904	205	7.1
Quincy, Ill.	330	100	30.3	2,596	291	11.2
Zanesville, Ohio	459	136	29.6	3,618	412	11.4
Portsmouth, Ohio	469	136	29.0	3,704	386	10.4
Elkhart, Ind.	278	86	30.9	2,208	248	11.2
Michigan City, Ind.	236	101	42.8	1,874	339	18.1
Total	2,859	723	25.3	22,560	2,063	9.1
Grand total	4,425	757	17.1	34,952	2,122	6.1

[1] Teeth lost by accident, unerupted, extracted because of malposition, and proximal surfaces restored by prosthesis (inlays, ¾ crowns, etc.) because of traumatic injury, excluded. The maximum possible number of surfaces in a population of this size (4,425) is 35,400. The number of surfaces excluded for the reasons stated was 448, or approximately 1.3 percent.

[2] Teeth listed as "extraction indicated" and "missing," not covered by the foregoing exceptions, were assumed to have had both surfaces attacked by caries and were so counted. These, together with the number of filled proximal surfaces (past caries) and the number of proximal surfaces with untreated carious lesions constitute the complete caries experience.

Marked differences were noted in the amount of this type of dental caries between the 8 cities whose public water supplies contained less than 0.5 part per million of fluoride (F) and the 5 cities whose water

[12] For those unfamiliar with dental nomenclature proximal caries is defined as that type of dental caries which ordinarily originates in the neighborhood of the contact points of adjoining teeth in the same jaw.

supplies contained 0.5 part per million or more. When comparisons are made on the basis of affected tooth surfaces, the rate in the cities with the lower fluoride water supplies was about 19 times as high as in the cities with the higher fluoride content; on the child-unit basis of comparison there was 11.5 times as much in the former cities as in the latter.

First permanent molar mortality.—The first permanent molar mortality [13] rate for each of these 13 cities was computed. As tooth mortality may to some extent be influenced by the amount of remedial treatment received (*4*), data with respect to the number and percent of filled first permanent molars are also included for a fuller interpretation of the molar mortality rates reported in table 7. These data are shown in table 7.

Incidence of endemic dental fluorosis (mottled enamel).—The incidence [14] and degree of mottled enamel observed in the groups of children studied are shown in table 8.

In accordance with a previously described method of computing a community mottled enamel index (*5*) on the basis of the percentage distribution of clinical severity, the approximate mottled enamel index of Galesburg and Colorado Springs is "slight"; that of East Moline and Kewanee, "border line"; and that of Pueblo, Marion, Lima, Middletown, Quincy, Zanesville, Portsmouth, Elkhart, and Michigan City, "negative."

PUBLIC WATER SUPPLIES [15]

Galesburg, Ill.—For a description of the Galesburg public water supply, see PUBLIC HEALTH REPORTS, **54**:862–888 (May 26, 1939). No changes in either source or treatment have occurred during the interim between the 1938 study and the present one.

[13] Knutson and Klein (Pub. Health Rep., **53**: 1021–1032 (June 24, 1938) define tooth mortality as referring to "not only extracted permanent teeth but also those which are indicated for extraction and still present in the mouth." First permanent molar mortality rates reported in table 7 were computed in accordance with this definition.

[14] As in previous studies a child is classified as having endemic dental fluorosis (mottled enamel) when a positive diagnosis of even the mildest type of this affection is made for as few as two teeth. In communities where the fluoride content of the public water supply is in the neighborhood of the minimal threshold of mottled enamel (1.0 p. p. m. of F) the common practice in mottled enamel studies of reporting the incidence as a percentage of children affected (table 8) rather than the percentage of teeth affected, overstates rather than understates the extent of the affection. For instance, at Kewanee (Ill.) where a 12.2 percentage incidence of affection is reported in 123 children examined, a further analysis of the 3,196 permanent teeth, present and in position, of this group shows that approximately 95 percent are free of macroscopic evidence of dental fluorosis. Of the 163 teeth (5.1 percent) diagnosed as positive for dental fluorosis 155 (4.8 percent), were "very mild" and 8 (0.3 percent) were "mild." Distribution of the teeth diagnosed as positive with respect to specific teeth affected showed that 126, or 77 percent, were bicuspids or second molars. As noted in a previous report (*3*) somewhat similar findings were observed at Aurora (Ill.), and as stated in that report such sporadic instances of the mildest forms of dental fluorosis are of no practical esthetic significance.

[15] Information concerning these water supplies was furnished by a number of individuals; that for Colorado Springs and Pueblo by Dr. O. R. Gillett and Dr. W. E. Buck, city health officers, respectively, of these two cities; those for the Ohio cities by F. H. Waring and J. H. Bass of the Engineering Division of the Ohio Department of Health; description of the Elkhart and Michigan City supplies was furnished by B. A. Poole, Bureau of Sanitary Engineering, Indiana State Board of Health; and that relative to East Moline and Kewanee was obtained from C. W. Klassen, Division of Sanitary Engineering, Illinois Department of Public Health, from Bulletin No. 21, including Supplement No. 1 thereto, of the State Water Survey Division, and from local information.

TABLE 7.—*Summary of data respecting first molar mortality rates, and information on the number and percent of filled teeth, in selected white children, aged 12–14 years, of 13 cities*

[All teeth referred to in this table are first permanent molars]

	Galesburg, Ill.	Colorado Springs, Colo.	East Moline, Ill.	Kewanee, Ill.	Pueblo, Colo.	Marion, Ohio	Lima, Ohio	Middletown, Ohio	Quincy, Ill.	Zanesville, Ohio	Portsmouth, Ohio	Elkhart, Ind.	Michigan City Ind.
Number of children examined	273	404	152	123	614	263	454	370	330	459	469	278	236
Percent of children with 1 or more missing molars (including extraction indicated)	10.6	3.5	12.5	15.4	14.5	17.5	31.7	36.5	40.9	49.0	38.4	21.9	40.3
Estimated molar population (number of children examined × 4)	1,092	1,616	608	492	2,456	1,052	1,816	1,480	1,320	1,836	1,876	1,112	944
Number of molars showing dental caries experience:													
(a) Filled teeth	170	185	84	57	321	162	457	422	533	502	629	523	444
(b) Teeth with untreated dental caries	234	437	194	172	1,057	515	814	555	360	614	676	399	274
(c+d) Extraction indicated and missing	41	19	24	36	124	66	254	244	235	458	346	95	189
(a+b+c+d) Total	445	641	302	265	1,502	743	1,525	1,221	1,128	1,574	1,651	1,017	907
Percent of molars showing dental caries experience	40.8	39.7	49.7	53.9	61.2	70.6	84.0	82.5	85.5	85.7	88.0	91.5	96.1
Percent of molars with dental caries experience that are filled $\left(\frac{a}{a+b+c+d}\right)$	38.2	28.9	27.8	21.5	21.4	21.8	30.0	34.6	47.3	31.9	38.1	51.4	49.0
First permanent molar mortality, number per 100 children	15.0	4.7	15.8	29.3	20.2	25.1	55.9	65.9	71.2	99.8	73.8	34.2	80.1

TABLE 8.—*Incidence and distribution of endemic dental fluorosis (mottled enamel) in children examined, classified according to the degree of affection*

Macroscopic signs of mottled enamel	Galesburg, Ill.	Colorado Springs, Colo.	East Moline, Ill.	Kewanee, Ill.	Pueblo, Colo.	Marion, Ohio	Lima, Ohio	Middletown, Ohio	Quincy, Ill.	Zanesville, Ohio	Portsmouth, Ohio	Elkhart, Ind.	Michigan City, Ind.
NUMBER													
Children examined	273	404	152	123	614	263	454	370	330	459	469	278	236
Absent:													
Normal	69	26	56	65	444	151	382	312	307	392	417	254	230
Questionable	74	80	48	43	130	96	62	54	22	60	46	23	6
Present:													
Very mild	110	170	45	13	38	14	10	4	1	7	6	1	0
Mild	17	86	3	2	2	2	0	0	0	0	0	0	0
Moderate	3	36	0	0	0	0	0	0	0	0	0	0	0
Severe	0	6	0	0	0	0	0	0	0	0	0	0	0
PERCENT													
Total examined	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Absent:													
Normal	25.3	6.4	36.8	52.8	72.3	57.4	84.1	84.3	93.0	85.4	88.9	91.3	97.5
Questionable	27.1	19.8	31.6	35.0	21.2	36.5	13.7	14.6	6.7	13.1	9.8	8.3	2.5
Present:													
Very mild	40.3	42.1	29.6	10.6	6.2	5.3	2.2	1.1	.3	1.5	1.3	.4	0
Mild	6.2	21.3	2.0	1.6	.3	.8	0	0	0	0	0	0	0
Moderate	1.1	8.9	0	0	0	0	0	0	0	0	0	0	0
Severe	0	1.5	0	0	0	0	0	0	0	0	0	0	0
Incidence of affection	47.6	73.8	31.6	12.2	6.5	6.1	2.2	1.1	.3	1.5	1.3	.4	0

Colorado Springs, Colo.—The Colorado Springs public water supply has been obtained from surface sources for many years. In connection with a mottled enamel survey made in this city in 1935 (Pub. Health Rep., **50:**1719–1729 (Dec. 6, 1935)) the report noted that the source of the public water supply was melted snow from the south, west, and east slopes of Pike's Peak, and the east and west slopes of Mount Baldy. The water was stored in a system of seven mountain reservoirs located at altitudes ranging from 9,000 to 12,000 feet. From this chain of reservoirs the water was conveyed through a transmission system to settlers at Manitou, thence by gravity to three distribution reservoirs known as the High Line, Mesa No. 1, and Mesa No. 2. These distributing reservoirs were located on a mesa just west of the city and from these reservoirs began the city distribution system and the service mains. Water impounded in both the High Line and the Mesa Reservoirs was obtained from a common source and represented the type of water used by the inhabitants for many years.[16]

According to information furnished by Dr. O. R. Gillett, health officer of Colorado Springs, the following changes have occurred in the physical set-up and source of the water used by the inhabitants of Colorado Springs since 1935. Two dams on the north slope of Pike's Peak were completed, one in 1935, the other in 1937, with a total capacity of 1,133,273,400 gallons. A small settler on French Creek also on the north slope has been completed. Between 25 and 30 percent of the water used at present is obtained from these sources. The transmission line capacity to the city reservoirs has been enlarged and is now about twice the peak load demand. These changes subsequent to 1935 have apparently not influenced the fluoride (F) content of the public water supply. The mean annual fluoride (F) content of 12 monthly samples of the public water supply collected during 1933–34 was 2.5 parts per million. As will be shown later in this paper, 12 monthly samples collected during 1940–41 showed a fluoride (F) content of 2.6 parts per million. The supply is now chlorinated throughout the year.

East Moline, Ill.—The East Moline public water supply is obtained from three deep wells.

Well No. 1 was drilled in 1895 to a depth of 1,340 feet, and was repaired in 1913 and deepened to 1,532 feet. After the installation of well No. 3 in 1937, well No. 1 was held in reserve as a stand-by unit for emergencies; in 1940 well No. 1 was abandoned. Samples of well No. 1 collected in September 1936, and January 1937, showed a fluoride (F) content of 1 part per million.

Well No. 2 was drilled in 1911 to a depth of 1,371 feet. This well was redrilled in 1913 to a depth of 1,850 feet. A sample of water collected in January 1937, showed a fluoride (F) content of 1.6 parts per million.

Well No. 3, located about 50 feet from well No. 1, was drilled in 1937 to a depth of 1,600 feet. The casing is perforated through the St. Peter sandstone (1,000

[16] Years ago Colorado City (that part of the present Colorado Springs lying west of 20th Street, but annexed to Colorado Springs in 1917) was a separate community, comprising according to the 1900 and 1910 Censuses about 12 percent of the total population of the two communities. In its early days Colorado City used water from Sutherland and Bear Creeks in addition to water purchased by contract from Colorado Springs. Dr. Gillett states, however, that as nearly as he can ascertain from some of the old records, Colorado City was using water from a source similar to that of Colorado Springs as far back as 1878. There would seem some justification, therefore, for assuming that the inhabitants of Colorado Springs including the annexed portion, Colorado City, have been using a relatively similar type of water for approximately 60 years. There is, moreover, strong epidemiological evidence that the population of Colorado Springs has been ingesting water with appreciable amounts of fluoride for at least as long as 45 years. A survey made in 1909 (McKay, F. S., in collaboration with Black, G. V.: An Investigation of Mottled Teeth. Dental Cosmos, **58:**477 (May), 627 (June), 781 (July), 894 (Aug.) 1916) of 927 native born children of this city disclosed an 87.5 percent incidence of mottled enamel. As noted in table 9 of this report, an examination of 404 children in 1940 showed a 73.8 percent incidence of affection, observations that would indicate little difference in the fluoride content of the water used for a decade or more before the first survey and the concentration of fluoride in the water being used at present.

to 1,060 feet) and water is apparently being obtained from both the St. Peter and the Jordan sandstone (1,495 to 1,585 feet). A sample of water collected July 16, 1937 (Bulletin No. 21, Supplement No. 1, 1938, State Water Survey Division) showed a fluoride (F) content of 0.8 part per million. Water from wells Nos. 2 and 3 is discharged into a new concrete reservoir. Prior to its abandonment in 1940 water from well No. 1 was discharged into the "old" reservoir.

Well No. 4, drilled to a depth of 1,600 feet and drawing water from the Cambrian sandstone, was completed and put into service late in 1940.

The monthly samples collected during the 1935–1936 study (Pub. Health Rep. **52:** 1249 (September 10, 1937)) would indicate that the water used by the population during this period (from wells Nos. 1 and 2) contained about 1.3 parts per million of fluorides (F). As a matter of record, it might also be noted that there is a cross connection between the public water supply and the 60-foot Fairbanks-Morse well.

Kewanee, Ill.—The Kewanee public water supply is obtained from two deep wells into the Cambrian sandstone. Wells into the St. Peter sandstone, which formerly furnished part of the city supply, were abandoned in 1925.

Well No. 1, drilled in 1919, is 2,497 feet in depth. The upper 500 feet of the well is cased with 16-inch pipe and below this casing joined to it by a swedge nipple is 506 feet of 14-inch pipe. Below the 14-inch pipe the well is 12 inches in diameter and is not cased. Well No. 2, drilled in 1927, is 2,438 feet in depth. This well is cased with 20-inch pipe from the surface to 439 feet and with 14-inch pipe from 439 feet to 1,488 feet. Below a depth of 1,488 feet the well is 12 inches in diameter and uncased. The casings do not exclude water from the St. Peter sandstone. A third well, 2,477 feet in depth, was completed in 1940; the mineral composition of the water from this well, however, has no bearing on this study because the clinical examinations were completed prior to its installation.

The Kewanee public water supply is reported to have cross connections with the private water supplies of the Kewanee Boiler Co. and the Walworth Manufacturing Co. for emergency purposes.

Pueblo, Colo.—The public water supply of Pueblo is obtained from surface sources, the Arkansas River. The city of Pueblo has two water systems, that part of the city north of the Arkansas River being supplied by what is known as the Pueblo Water Works, District No. 1 or the North Pueblo water supply, whereas that half of the city located south of the Arkansas River gets its water from another system known as the Pueblo Water Works, District No. 2 or the South Pueblo water supply. Both systems, however, obtain water from the Arkansas River which has been the source of the Pueblo public water supply for more than 50 years. A description of each supply follows:

North Pueblo water supply.—Water is taken from the Arkansas River about 3 miles west of the city and diverted into reservoirs. In 1925 there were six reservoirs and in 1928 one more was added. Treatment consists of preliminary sedimentation, coagulation with aluminum sulfate, followed by sedimentation and disinfection with ammonia-chlorine. Reservoirs Nos. 1, 2, 3, and 4 are used for preliminary sedimentation and reservoirs Nos. 5, 6, and 7 for sedimentation after coagulation. The treatment does not include filtration. Prior to 1928 iron sulfate and lime were used as coagulants, and prior to November 1931 chlorine was used without ammonia.

South Pueblo water supply.—Water is taken from the Arkansas River about 2 miles west of the city and diverted into reservoirs. In 1931 there were four reservoirs and in 1932 three more were added. Treatment consists of preliminary sedimentation, coagulation with aluminum sulfate followed by sedimentation and disinfection with ammonia chlorine.

Reservoirs Nos. 1, 2, and 3 are used for preliminary sedimentation and reservoirs Nos. 4, 5, 6, and 7 for sedimentation after coagulation. Under adverse conditions when the water is very turbid, lime and sulfate of iron are used. The treatment does not include filtration. Prior to November 1931, chlorine was used without ammonia.

Marion, Ohio.—The common water supply is obtained from 13 drilled wells located adjacent to the pump house and in the same well field. All of these wells penetrate a limestone deposit which extends within 20 feet of the surface of the ground and is adjacent to the Little Scioto River. The wells vary in diameter from 10 to 14 inches and in depth from 140 to 210 feet.

There have been no changes in the source of this supply during the lifetime of the group of children in this study, but marked changes in the chemical composition of the water probably occurred in 1928.

Until 1928 the supply was untreated but in that year the Marion Water Co. installed a lime-soda softening plant. The treatment is unique in that the holding capacities for the chemical treatment are nearly 24 hours and no filters are used. The plant is operated as follows: Water from the wells is aerated by flowing from a wooden trough over a weir to a splash board. The water then passes to two mixing chambers having a combined detention period of 1.2 hours at 5 m. g. d.[17] (the nominal capacity of the softening plant) and equipped with mechanical stirring devices. Lime, 16 to 20 grains per gallon, and soda ash, 16 to 19 grains per gallon, are applied as the water enters the mixing basin. Occasionally small quantities of alum are used. From the mixing chamber water flows to the clarifier which is equipped for the continuous removal of sludge and has a detention period of 9.4 hours at 5.0 m. g. d. Water is then recarbonated and passes to a settling tank having a detention period of 9.4 hours at 5 m. g. d. The water is then recarbonated a second time after which it is discharged to a clear well from which it is pumped to the distribution system. Marion was one of the cities where it was first noted [18] that the use of lime-soda softening resulted in a reduction of the fluoride concentration of the water.

In our study monthly samples were collected of both the raw water and the treated water. As will be shown later in this paper (table 9), the raw water contained a mean fluoride (F) content of 1.1 parts per million; the treated water, 0.4 part per million.

The hardness of the raw well water averages between 700 and 800 parts per million, that of the treated water in the neighborhood of 200 parts per million. For a year or two after the plant was put into service the water was softened down to less than 100 parts per million, but dropped back to the amount previously indicated (about 200 parts per million) on account of the large expense for the chemicals which, in the company's estimate, could not be justified by the present earning power.

Lima, Ohio.—The water supply of Lima is obtained from surface sources, the Ottawa River, a tributary of the Anglaize, a branch of the Maumee, and is from the Lake Erie watershed. Water is given long storage in the two shallow impounding reservoirs and then filtered through a rapid sand water purification plant.

The water is pumped from the Ottawa River into two storage reservoirs, Lima Lake (400,000,000 gallons capacity) constructed in 1904 and Lost Creek Reservoir (750,000,000 gallons capacity) installed in 1921. The water from these storage reservoirs flows through a 30-inch conduit to two receiving reservoirs located near the pumping station and filtration plant.

[17] M. g. d.=million gallons per day.

[18] See Scott, R. D., Kimberly, A. E., Van Horn, A. L., Ey, L., and Waring, F. H.: Fluoride in Ohio water supplies. J. Am. W. W. Assoc., 29: 9-25 (January 1937).

The water purification was placed in operation in 1919. Water from the reservoir passes through an over and under baffle mixing chamber having a detention period of 6 minutes at the nominal capacity of the plant (8 m. g. d.). Alum, 1.5 to 3.0 grains per gallon, and sodium silicate, 0.20 to 0.85 grains per gallon, are used as a coagulant (sodium silicate treatment began March 1939). From the mixing chambers the water enters two coagulation basins having a combined detention period of 2 hours at 8 m. g. d. from whence the water passes through rapid sand filters. From the filters water flows to the clear well from where it is pumped to the distribution system. Post-chlorination with liquid chlorine is provided at all times and activated carbon is applied when necessary.

This surface water supply has been augmented by ground water [19] from wells during periods of extreme drought, as follows:

(*a*) In 1925 four of the "Tony's Nose" wells (a portion of the formerly abandoned supply) supplied 20 percent of the water consumed for a period of 6 months, or approximately 10 percent of the annual supply for that year.

(*b*) In the winter of 1930–31 the "Tony's Nose" wells supplied approximately 25 percent of the total supply for a 6-month period. The two new wells which were drilled near the Lima Lake Reservoir were also used during 1931. All existing supplies became inadequate in January of 1931 and it became necessary to obtain additional water from four private wells located within the city. It is estimated that during the winter of 1930–31 approximately 60 percent of the water supply was obtained from the various wells in use.

(*c*) In 1934 both the "Tony's Nose" wells and the "Lima Lake" wells were pumped from May to November. Approximately 12 percent of the annual supply was obtained from ground water sources during 1934.

(*d*) In 1936 the "Lima Lake" wells again supplied approximately 5 percent of the annual consumption in that year.

Middletown, Ohio.—The city of Middletown has obtained its water supply from drilled wells in the valley of Miami River for the past 25 years or more. Except for new wells added from time to time in the same general well field, no changes in the water supply have occurred. In 1924 the water supply of Middletown was obtained from twelve 6-inch and two 12-inch drilled wells. All of these wells are 35 feet deep and obtain water from a gravel and sand deposit which extends practically to the surface of the ground. In 1925 three wells having a diameter of 38 inches were installed in this same well field. Two of the large diameter wells are 165 feet deep and penetrate a gravel and sand deposit which underlies the deposit from which the small diameter wells obtain their supply. The third large diameter well is 40 feet deep and obtains water from the upper gravel stratum. From a chemical standpoint water from the two strata is practically identical. No changes have occurred in the water supply since 1925. Chlorination of the water supply was instituted in 1936 as a general factor of safety. The water receives no other treatment.

Quincy, Ill.—For a description of the Quincy public water supply, see PUBLIC

[19] Four wells at "Tony's Nose" are connected to the suction of a motor-driven centrifugal pump discharging into the line connecting Lima Lake with the receiving reservoirs. These wells were drilled some time between 1894 and 1900, were abandoned when Lost Creek Reservoir was constructed between 1918 and 1921, and have again been used at times of depleted water supply. Their estimated yield is approximately 1½ million gallons daily, but the water is undesirable on account of its gas and hardness.

In 1930, after the storage reservoirs had been nearly depleted because of deficient rainfall, two deep wells were drilled on the east side of Lima Lake, discharging into that reservoir. The estimated combined yield of these two wells is about 1 million gallons daily but because of the hydrogen sulfide content and the fact that this water materially increases the hardness of the general supply, the use of these wells is held to a minimum.

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HEALTH REPORTS, 54: 862–888 (May 26, 1939). No pertinent changes [20] in either source or treatment have occurred during the interim between the 1938 survey and the present study.

Zanesville, Ohio.—Since 1918 the Zanesville public water supply has been obtained from drilled wells located in a 40-acre area situated in the flood plains of and adjacent to the Muskingum River. The original installation consisted of 20 wells, but in 1925 wells Nos. 19 and 20 were abandoned and between that date and 1930 wells Nos. 1 to 18 supplied the city. In 1930, wells Nos. 1 to 11, inclusive, were replaced by 11 new wells located in the same well field. The city at the time of this study (January 1940) was supplied by new wells Nos. 1 to 11 and the original wells Nos. 12 to 18.

The wells, varying in diameter from 10 to 13 inches, are all approximately 85 feet deep, and are cased to their entire depth. Water enters the casing through perforations located in that portion of the casing which extends through the water-bearing stratum. Water is obtained from a gravel and sand deposit extending throughout the entire well field which varies in thickness from 20 to 50 feet. This deposit lies below a layer of impervious clay having a minimum depth of 10 feet and a maximum depth of approximately 40 feet. All the water is pumped from the well field to a receiving reservoir by air lift. The water receives no treatment.

Portsmouth, Ohio.—The Portsmouth public water supply is obtained from the Ohio River. The supply is treated in a water purification plant placed in service in 1914. Various improvements and additions have been installed since that date, none of the principal treatment units, however, having been materially changed. Water is pumped from an intake in the Ohio River through mixing basins which have a retention period of 0.25 hour at a flow of 8 m. g. d. Alum, from 0.75 to 2 grains per gallon, is used as a coagulant. It is also necessary to apply from 0.30 to 0.70 grain per gallon of lime to obtain proper coagulation with the alum. The water then passes through two coagulation basins operated in series. Basins Nos. 1 and 2 have a retention period of 6.5 and 3 hours, respectively, based on a flow of 8 m. g. d. From the coagulation basins the water passes through rapid sand filters and then to a clear well from whence it is pumped to the distribution system. Post-chlorination with liquid chlorine is applied at all times.

Elkhart, Ind.—The public water supply of Elkhart is obtained from various wells, the description of which follows:

1. Plant wells

Year of installation	*Diameter*	*Depth*
1897	39 ft	31 ft. 4 in.
1899	38 ft. 6 in	30 ft. 6 in.
1901	41 ft	28 ft.

These three wells have been in constant service since their respective dates of installation.

2. Four gravel wall wells 24 inches in diameter and 70 feet deep were installed in 1927. Water from these four wells is pumped into a sand trap; thence the water flows by gravity directly into the reservoir.

3. The Bucklin well, installed in 1891, is 28 feet 4 inches in diameter and 31 feet 5 inches deep. Water from the Bucklin well, and also water from the three dug wells (Plant wells), is pumped directly into the distribution system.

4. Some water is also obtained during the peak-load season from a well installed in 1924 and made by drilling inside of a dug well to a depth of 45 feet, installing a

[20] The carbon dioxide used for removing excess lime is obtained from a natural gas instead of flue gas as stated in the earlier report. Also, while post-chlorination is provided for, it has not been necessary to use it since 1933.

16-inch casing, and filling the dug well with gravel. The amount of water, however, contributed by this well to the city supply during the year is negligible.

5. The two Bower Street wells were installed in the summer of 1936. They are gravel packed, 20 inches in diameter and 68 and 70 feet deep, respectively. These wells are used to supplement the other sources of supply during peak-load periods, May to September. During operation water from these wells is pumped directly into the distribution system. These wells are not used during the winter months. Since 1936 the Bower Street wells have furnished approximately 20 percent of the water used during the period of peak demand; this is about 5 percent of the total amount of water used throughout the entire year. During the time that the Bower Street wells are in use, the water is fairly well mixed and the monthly samples collected during the year would constitute a mixture of the several sources that constitute the water supply.

General.—To equalize daily fluctuation and hourly pressure a storage reservoir of 1.25 million gallon capacity and an elevated tank in the center of the distribution system of 500,000 gallon capacity were constructed in 1927. The reservoir is kept filled by the four deep wells installed in 1927. As will be seen in table 10, there was practically no change in the fluoride content of the water supply throughout the year.

Michigan City, Ind.—The public water supply of Michigan City is obtained from Lake Michigan. Prior to 1935 water direct from Lake Michigan was supplied to consumers, no treatment except chlorination being used. The complete filtration plant was placed in service late in 1935.

The water supply is obtained from Lake Michigan through two wooden crib intakes located about 3,000 feet from shore. Water is conveyed from the intakes to the suction wells through a 42- and a 24-inch cast-iron inlet pipe.

Raw water, to which ammonia and chlorine have been added, is pumped to a mixing chamber (detention 30 minutes) equipped with Dorr flocculators. Aluminum sulfate and activated carbon are applied to the suction side of the raw water pumps using dry feed equipment. The water then flows to either of two 1 million gallons settling basins providing 3 hours' detention. The settled water is filtered through four rapid sand gravity filters, each having a capacity of 2 m. g. d. Filtered water flows by gravity to a 1.5 MG underground reinforced concrete reservoir. The water is given additional treatment with chlorine before being pumped to the distribution system and a 750,000-gallon elevated tank.

Chemical analyses of the common water supplies.—As was customary in previous studies, samples of the common water supply were collected, generally monthly, for approximately 1 year. The fluoride content of these waters was estimated colorimetrically by means of the zirconium-alizarin reagent (*6*). The results are given in table 9.

Analyses were made of constituents, other than the fluorides, using a sample from each of the water supplies of the cities studied. Results of these chemical analyses are given in table 10.

DISCUSSION

General findings.—In order that the results of this study might be presented as a coherent whole, the general findings of the study of the 8 suburban Chicago communities previously reported (*3*) will be included with the findings of the study of the 13 cities which form the basis of this report. A summary of the basic observations on the

TABLE 9.—*Fluoride* (F) *content of the public water supplies of the cities studied*

[All samples collected from a tap in the distribution system having average domestic use unless otherwise specified]

[Parts per million]

	Galesburg, Ill.	Colorado Springs, Colo.	East Moline, Ill.	Kewanee, Ill.	Pueblo, Colo.		Marion, Ohio		Lima, Ohio	Middletown, Ohio	Quincy, Ill.	Zanesville, Ohio	Portsmouth, Ohio	Elkhart, Ind.	Michigan City, Ind.
					North supply	South supply	Raw	Treated							
1939															
December				[1] 0.9 [2] 2.9											
1940															
January								0.5	0.3	0.2		0.2	0.2	0.1	0.1
February								.4	.2	.1		.2	.2		
March		2.8			0.7	0.7	1.0	.4	.4	.2		.2	.1	.1	.1
April		2.6			.7	.8	1.1	.4	.3	.3	0.1	.1	.1	.1	.1
May		2.6			.6	.5	1.1	.6	.2	.2	.1	.2	.2	.1	.1
June		2.4		.9	.4	.5	1.1	.4	.3	.2	.1	.2	.1	.1	.0
July		2.5			.5	.6	1.2	.4	.4	.3	.1	.2	.1	.1	.0
August		2.4			.5	.7	1.1	.4	.3	.2	.1	.2	.1	.1	.1
September		2.5			.6	.6	1.1	.4	.4	.2	.1	.2	.1		.1
October		2.5	1.3		.5	.5	1.1	.4	.4	.2	.1	.2	.1	.2	.1
November		2.6			.6	.5	1.1	.4	.3	.2	.1	.2	.1	.1	.1
December		[3]	1.3		.6	.6	1.1	.4	.3	.2	.2	.2	.1	.1	.1
1941															
January		2.6			.6	.7					.1			.1	.1
February	1.9	2.6			.6	.6					.2			.1	.1
March			1.0								.2				
Mean	[4] [5] 1.9	[5] 2.55	1.20	.90	[5] .58	.61	1.10	.43	.32	.21	[4] .13	.19	.13	.11	.09

[1] Well No. 1.
[2] Well No. 2.
[3] Container broken.
[4] Single samples of the Galesburg and Quincy public water supplies received in December 1938 disclosed a fluoride (F) content of 1.9 and 0.2 p. p. m., respectively.
[5] 12 monthly samples collected between November 1933 and October 1934 (Pub. Health Rep. **50**: 1719–1729 (Dec. 6, 1935) showed a mean fluoride (F) content of 1.86, 2.53, and 0.57 p. p. m. for Galesburg, Colorado Springs, and Pueblo (north supply), respectively.

NOTE.—The limit of the sensitivity of the procedure used for the fluoride determinations may be considered as about 0.1 part per million.

TABLE 10.—*Mineral analyses of the common water supplies of the cities studied*

	Galesburg, Ill.	Colorado Springs, Colo.	East Moline, Ill.	Kewanee, Ill.	Pueblo, Colo.		Marion, Ohio		Lima, Ohio	Middletown, Ohio	Quincy, Ill.	Zanesville, Ohio	Portsmouth, Ohio	Elkhart, Ind.	Michigan City, Ind.
					North supply	South supply	Raw	Treated							
Residue on evaporation	1,094.4	46.4	1,055.2	1,908.0	524.8	514.4	1,052.8	754.4	372.0	348.0	132.0	485.2	154.4	248.8	196.8
Loss on ignition	40.0	7.2	48.8	86.0	56.0	74.4	106.4	32.0	106.0	45.0	14.0	92.0	35.2	36.8	49.6
Fixed residue	1,054.4	39.2	1,006.4	1,822.0	468.8	440.0	946.4	722.4	266.0	303.0	118.0	393.2	119.2	212.0	147.2
Silica (SiO_2)	7.2	8.0	7.5	38.0	14.4	16.0	28.0	19.6	2.0	8.0	10.0	13.0	8.0	12.0	17.6
Iron (Fe)	.1	.04	.04	.01	.06	.06	.08	.04	.01	.04	0	.05	.01	.01	.02
Aluminum (Al)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calcium (Ca)	57.2	8.0	64.6	115.7	76.0	78.1	206.8	52.0	60.0	85.0	22.9	87.9	25.2	54.9	36.6
Magnesium (Mg)	25.3	1.6	27.8	38.0	27.2	25.5	55.9	19.2	17.9	28.4	7.4	17.4	4.2	20.1	12.0
Sodium and potassium (calculated as Na)	296.7	2.6	282.0	506.2	41.1	38.8	17.7	145.7	12.1	5.0	3.7	33.2	8.8	4.5	1.7
Carbonate (CO_3)					9.6	8.4									
Bicarbonate (HCO_3)	295.2	23.2	309.9	300.1	154.9	164.7	341.6	42.7	148.8	317.2	37.8	153.7	28.0	245.2	136.6
Sulfate (SO_4)	351.7	4.9	240.3	308.6	213.1	203.8	463.2	450.9	89.7	49.4	45.3	89.3	57.6	16.0	21.4
Nitrate (NO_3)	3.1	1.0	3.9	6.6	5.5	4.8	1.0	1.0	5.5	5.3	4.4.	.4	3.4	.4	0.6
Chloride (Cl)	190.5	.5	265.0	689.0	10.5	9.0	4.0	4.0	18.0	6.0	5.0	106.0	8.0	3.0	5.0
Phosphate (PO_4)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fluoride (F)	1.9	2.6	1.3	.9	.7	.7	1.1	.4	.3	.2	.1	.2	.1	.1	.1

The dates of receipt of these samples of water were as follows: Galesburg Feb. 1941, Colorado Springs May 1940, East Moline October 1940, Kewanee December 1939, Pueblo March 1940, Marion April 1940, Lima June 1940, Middletown January 1940, Quincy May 1940, Zanesville October 1939, Portsmouth April 1940, Elkhart November 1940, and Michigan City January 1940.

Assistant Chemist C. G. Remsburg carried out the determinations other than fluoride, using mostly the methods given in the Standard Methods of Water Analysis of the American Public Health Association. The phosphate was determined colorimetrically by an adaptation of the Benedict and Theis method (J. Biol. Chem., **61**: 63 (1924)).

TABLE 11.—*Summary of dental caries findings in 7,257 selected white school children, aged 12 to 14 years, in 21 cities of 4 States in relation to the fluoride (F) content of the public water supply*

	Galesburg, Ill.	Colorado Springs, Colo.	Elmhurst, Ill.	Maywood, Ill.	Aurora, Ill.	East Moline, Ill.	Joliet, Ill.	Kewanee, Ill.	Pueblo, Colo.	Elgin, Ill.	Marion, Ohio	Lima, Ohio	Evanston, Ill.	Middletown, Ohio	Quincy, Ill.	Oak Park, Ill.	Zanesville, Ohio	Portsmouth, Ohio	Waukegan, Ill.	Elkhart, Ind.	Michigan City, Ind.
SELECTION OF STUDY GROUPS																					
Total number of 12- to 14-year-old children present at time of selection	918	1,444	633	873	1,625	352	1,412	522	1,412	1,030	1,010	1,411	2,125	1,013	1,063	1,662	1,248	1,228	1,354	942	654
Number of 12- to 14-year-old white children whose histories on repeated questioning indicated continuity of exposure and who were examined	273	404	170	171	633	152	447	123	614	403	263	454	256	370	330	329	459	469	423	278	236
Percentage of the total present who were examined	29.7	28.0	26.9	19.6	39.0	43.2	31.7	23.6	43.5	39.1	26.0	32.2	12.0	36.5	31.0	19.8	36.8	38.2	31.2	29.5	36.1
WATER SUPPLY																					
Source [1]	G	S	G	G	G	G	G	G	S	G	G	S	S	G	S	S	G	S	S	G	S
Total hardness in parts per million	247	27	323	75	329	276	349	445	302	103	209	223	131	329	88	132	291	80	134	220	141
Mean fluoride (F) content in parts per million of cities studied	1.9	2.6	1.8	[2] 1.2	1.2	[3] 1.2	1.3	0.9	0.6	0.5	[4] 0.4	0.3	0	0.2	0.1	0	0.2	0.1	0	0.1	0.1
[5]		> 1.4			1.4 to 1.0				0.9 to 0.5							< 0.5					
CLINICAL EXAMINATION																					
Unit basis of measurement: Teeth: Dental caries experience, permanent teeth, per 100 children examined	236	246	252	258	281	303	323	343	412	444	556	652	673	703	706	722	733	772	810	823	1,037
		244			294				416							740					

First permanent molar mortality, per 100 children examined	15.0	4.7	11.8	11.7	14.5	15.8	19.5	29.3	20.2	20.3	25.1	55.9	42.6	65.9	71.2	31.0	99.8	73.8	79.9	34.2	80.1
Tooth surface:																					
Dental caries experience, proximal surfaces, superior permanent incisors, per 100 surfaces	0.46	0.31	0.60	0.59	0.78	0.16	1.3	1.4	0.47	4.1	3.3	3.2	10.7	7.1	11.2	9.0	11.4	10.4	17.7	11.2	18.1
Child:																					
Percent of children with 1 or more permanent teeth showing dental caries experience	72.2	71.5	74.7	70.2	76.5	79.6.	81.7	82.1	89.4	88.6	94.3	97.8	96.1	98.1	97.6	95.7	97.4	98.7	96.9.	98.6	100.0
Percentage incidence of endemic dental fluorosis (mottled enamel)	47.6	73.8	40.0	33.3	15.0	31.6	25.3	12.2	6.5	4.2	6.1	2.2	1.6	1.1	0.3	0.6	1.5	1.3	0.2	0.4	

[1] S=surface water; G=ground water.

[2] There is both presumptive and direct evidence that prior to a few years ago the Maywood water contained probably 1.4 to 1.6 p.p.m. of F (Pub. Health Rep. **56**: 761–792 (Apr. 11, 1941)).

[3] There is both presumptive and direct evidence that prior to a few years ago the East Moline water contained as much as 1.5 p.p.m. of F (Pub. Health Rep. **52**: 1249–1264 (Sept. 10, 1937))

[4] Prior to 1928 this water supply probably contained about 1.1 p. p. m. of F. See reference in text concerning treatment of raw water; see table 9 for its analysis.

[5] Range of fluoride (F) concentration of water supply and dental caries experience rate of children in these specified groupings.

permanent teeth of 7,257 selected white urban school children, aged 12 to 14 years, of these 21 cities is shown in table 11 and figure 1.

Probably the outstanding epidemiological characteristic of these data is the striking variation in the intensity of dental caries attack as evidenced by the marked differences in the amount of dental caries experience. Considering the relative homogeneity of these populations, the method of selecting the study groups, and the similarity of diagnostic standards used, it does not seem likely that such differences can be due to other than the mineral composition of the public water supply. Study of the cause or causes of these differences may shed

AMOUNT OF DENTAL CARIES (PERMANENT TEETH) OBSERVED IN 7257 SELECTED 12-14 YEAR OLD WHITE SCHOOL CHILDREN OF 21 CITIES OF 4 STATES CLASSIFIED ACCORDING TO THE FLUORIDE CONCENTRATION OF THE PUBLIC WATER SUPPLY.

NUMBER OF CITIES STUDIED	NUMBER OF CHILDREN EXAMINED	NUMBER OF PERMANENT TEETH SHOWING DENTAL CARIES EXPERIENCE* PER 100 CHILDREN EXAMINED	FLUORIDE (F) CONCENTRATION OF PUBLIC WATER SUPPLY IN P.P.M.
		0 100 200 300 400 500 600 700	
11	3867		< 0.5
3	1140		0.5 TO 0.9
4	1403		1.0 TO 1.4
3	847		> 1.4

* DENTAL CARIES EXPERIENCE IS COMPUTED BY TOTALING THE NUMBER OF FILLED TEETH (PAST DENTAL CARIES), THE NUMBER OF TEETH WITH UNTREATED DENTAL CARIES, THE NUMBER OF TEETH INDICATED FOR EXTRACTION, AND THE NUMBER OF TEETH MISSING (PRESUMABLY BECAUSE OF DENTAL CARIES).

FIGURE 1.

important light upon either the etiology or the means of partially controlling dental caries.

That the inhibitory agent is the fluoride content of the water supply seems highly probable. An inspection of the range of dental caries experience associated with the use of domestic water of different fluoride concentration discloses an inverse relation in general between the amount of dental caries and the fluoride concentration of the common water supply. Relatively low dental caries experience rates are found associated with the use of domestic waters whose fluoride (F) concentrations have a range of 1 or more parts per million. Intermediately, e. g., at concentrations of 0.9 to 0.5 part per million, the influence is less marked than at the higher concentrations; nevertheless, the dental caries experience rates are distinctly lower than those associated with the use of relatively fluoride-free waters. A further inspection of the data reported in table 11 and figure 2 for those cities whose public water supplies contain less than 0.5 part per million discloses a considerable variation among those cities characterized by

high dental caries experience. This variation is marked, particularly between those communities whose public water supplies did not show fluoride (F) in excess of 0.2 part per million. As has been pointed out, however, the limit of sensitivity of the method of determination may be considered as about 0.1 part per million and hence further discussion at present of this variation would not seem justified.[21]

A correlation between the dental caries experience rates and the

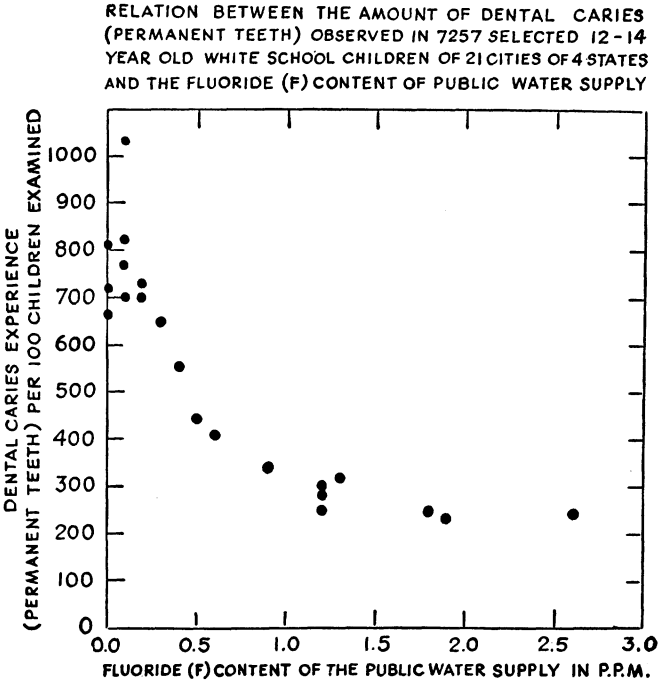

FIGURE 2

mean fluoride (F) content of the public water supply of each of the 21 cities studied is shown in figure 2.

SUMMARY

1. A study of the intensity of dental caries attack, as evidenced by the observed dental caries experience, disclosed striking differences among children of different cities. This study embraced 7,257 [22] white urban school children, aged 12 to 14 years, of 21 cities; in the main the children were apparently of largely comparable circumstances and the groups examined were relatively equitable respecting sex ratio. The groups studied were limited to those children *continuously exposed throughout life to the variable under investigation* (the com-

[21] For this reason no attempt was made at this time to fit a curve to the data shown in figure 2.

[22] These totals, 7,257 children of 21 cities, represent the 4,425 children of 13 cities reported in detail in this paper and the 2,832 children of 8 suburban Chicago communities previously reported (3). See table 11 and figures 1 and 2 of this report.

mon water supply). Clinical examinations in all 21 cities were made by the same two dental officers and in each city an equal number of children were examined by each examiner. It seems unlikely that such marked differences in the prevalence of dental caries can be explained on the basis of the hardness of the domestic water, the hours of sunshine, or gross dissimilarities in diet (water excluded).

2. A general inverse correlation between the fluoride concentrations of the public water supplies in the 21 cities studied and the amount of dental caries was observed. Differences in dental caries experience rates of as much as 2 and 3 times the observed minimal were not unusual; the highest rate, 1,037, at Michigan City (Ind.) was 4.4 times that observed in the city with the lowest rate, 236, at Galesburg (Ill.). Strikingly low dental caries prevalence was found associated with the continuous use of domestic waters whose fluoride (F) content was as low as about 1 part per million, a concentration which under the conditions prevailing in the localities studied produced only sporadic instances of the mildest forms of dental fluorosis of no practical esthetic significance.

3. As in previous studies, marked differences were observed with respect to: (*a*) The amount of dental caries experience in the proximal surfaces of the four superior permanent incisors, and (*b*) the first permanent molar mortality rates. Of the 4,425 children of the 13 cities whose caries experience is reported in detail in this report, the 2,859 children living in communities whose public water supply contained less than 0.5 p. p. m. of fluoride (F) showed about 19 times as much proximal surface caries experience in the four superior permanent incisors as was observed in the 1,566 children living in cities where the common water supplies contained from 0.6 to 2.6 p. p. m. of fluoride (F). In these same two groups of children, the first permanent molar mortality rate for those living where the water supply contained less than 0.5 p. p. m. of fluoride (F) was about 4 times as high as that observed in the children using a domestic water containing more than 0.5 p. p. m. of fluoride (F) (66.0 and 15.6 per 100 children examined, respectively). Inasmuch as the group with the higher first permanent molar mortality rate showed 38 percent of its total first permanent molar caries experience with fillings as opposed to only 26 percent in the group characterized by the lower mortality rate, there would seem justification in assuming that such differences in first permanent molar mortality rates are influenced to a considerable degree by a variation in either the intensity of dental caries attack, and/or the resistance of the teeth to caries attack.

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PREVALENCE OF COMMUNICABLE DISEASES IN THE UNITED STATES

June 21–July 18, 1942

The accompanying table summarizes the prevalence of nine important communicable diseases, based on weekly telegraphic reports from State health departments. The reports from each State are published in the Public Health Reports under the section "Prevalence of disease." The table gives the number of cases of these diseases for the 4-week period ended July 18, 1942, the number reported for the corresponding period in 1941, and the median number for the years 1937–41.

DISEASES ABOVE MEDIAN PREVALENCE

Influenza.—The number of cases (1,690) of influenza reported for the four weeks ended July 18 was less than one-half of the number reported for the corresponding period in 1941, but it was about 16 percent above the 1937–41 median figure for this period. The increase over the seasonal expectancy seemed to be due largely to an excess of cases in the West South Central, Mountain, and Pacific regions.