Climate and Endemic Dental Fluorosis

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INVESTIGATIONS demonstrating the relationship between trace amounts of fluoride in community water supplies, the prevalence of mottled enamel, and a reduction in dental caries experience have been extensive during the last half century. By 1931 it had been determined that mottled enamel was associated with the presence of fluoride in drinking water (*1*, *2*). Subsequent studies revealed the direct quantitative relationship between fluoride and mottled enamel (*3–6*) and demonstrated the inverse relationship between fluoride and dental caries experience (*7*).

Based upon these data, using the community fluorosis index to measure the extent of mottled enamel (*8*), and the decayed, missing, filled (DMF) index as a measurement of caries experience (*9*), an optimum fluoride concentration was derived for use in the supplementation of fluoride-deficient community water supplies. The range of fluoride concentration most effective in preventing dental caries was established at approximately 1.0 to 1.5 ppm, well below the critical point in the causation of mottled enamel.

A review of the literature reveals that the recommended fluoride levels have been determined from observations made within a fairly limited geographic area, principally in the Midwest (*10*) where mean annual temperatures are approximately 50° F.

Temperatures in the continental United States vary widely, from an average mean annual temperature of 40° to 45° F. in the northern tier of States to 70° F. and above in some areas of California, Arizona, Texas, Louisiana, and Florida (fig. 1).

In view of the temperature distribution in the United States, a fluoride concentration of 1.0 to 1.5 ppm seems justifiable for the major portion of the country. However, Arnold (*11*) has suggested that because of climatic conditions 1.0 to 1.5 ppm of fluoride may not be practical or desirable in every community, and Dean has recently indicated that less than 1.0 ppm of fluoride may represent the optimal level for dental caries control in a southern community (*12*). The early findings of the Smiths (*13*, *14*), while not relating mottled enamel to climatic factors, certainly suggest that mild fluorosis is associated with less than 1 ppm of fluoride in certain areas in Arizona.

Recognition of a probable relationship between fluoride concentration and climate is being observed in the present fluoridation effort. For example, in the State of Wisconsin, 1.3 ppm is recommended. In Charlotte, N. C., the concentration of fluoride is varied from a high of 1.2 ppm in winter to a low of 0.6 ppm in summer, and in Florida, 0.7 ppm is the recommended optimum amount. Nevertheless, if climatologic factors markedly influence the water intake of infants and youth, additional information about optimum concentrations should be obtained for those exceptional areas experiencing extreme climatic conditions.

Since the severity of mottled enamel has a specific relationship to the fluoride content of water consumed, the application of a simple biological test such as a measurement of fluorosis

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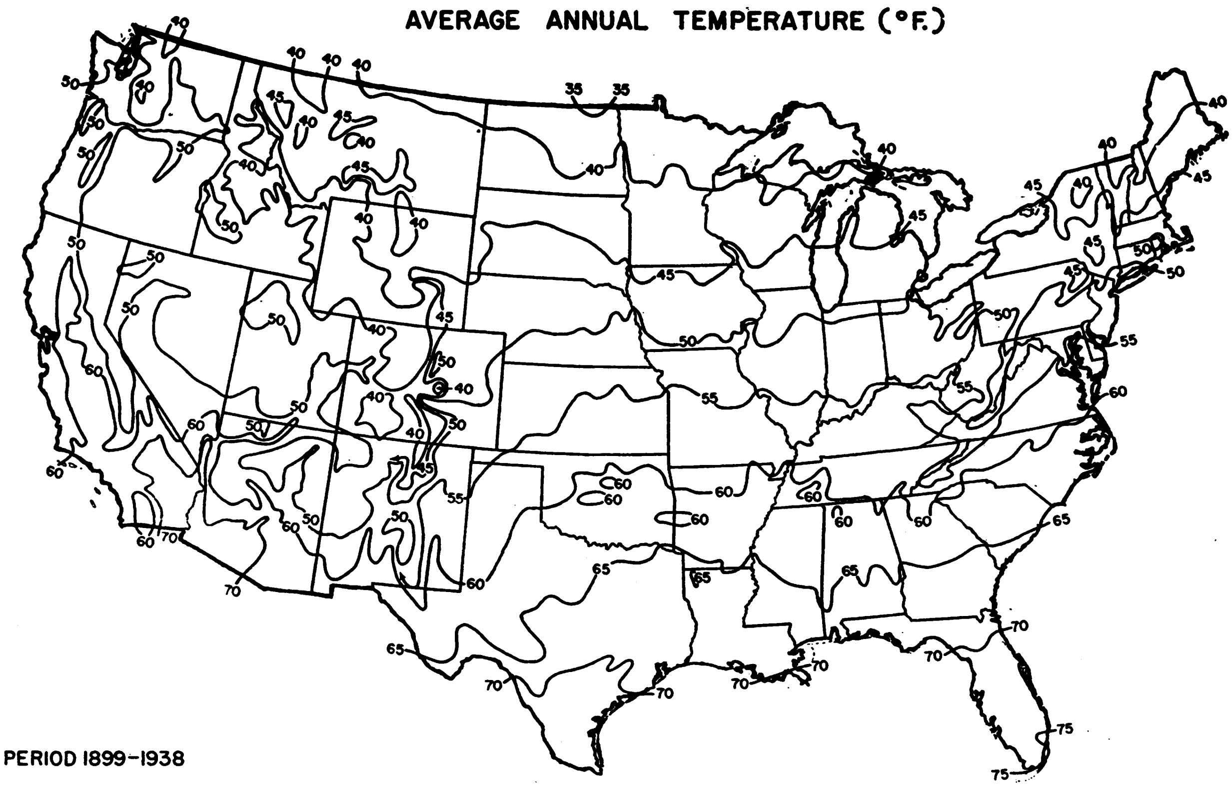
Figure 1. Variations in temperature throughout the continental United States, 1899–1938.



SOURCE: U. S. Department of Agriculture, Climates of the United States. Yearbook Separate No. 1824, Washington, D. C., 1941.

may be used to evaluate water intake indirectly. In order to use this method of assessing climatic forces upon water intake, it seemed logical to measure fluorosis in communities with extreme temperatures. If objectionable fluorosis was not associated with fluoride levels around 1.0 ppm in the areas with extremely high temperatures, then that concentration would be desirable in the supplementation of fluoride-deficient water in areas with similar climate, and at least that amount would be required in all other parts of the United States.

Field Studies

The Arizona communities of Yuma, Tempe, Tucson, Chandler, Casa Grande, and Florence were selected for initial study. With the exception of Yuma these comunities lie south and east of Phoenix on the plains of the Arizona Desert. Yuma is situated on the Yuma Desert on the northern edge of the Great Desert of Sonora, Mexico.

These six communities met the necessary requirements for investigation. They had water supplies with adequate continuity and with fluoride concentrations ranging around 1.0 ppm. They were of sufficient size to yield a sample of native-born children large enough to be significant (*15*). They had mean annual temperatures ranging from 67° to 72° F., with an average mean annual temperature of approximately 70° F. This area is consistently reported as one of the hottest inhabited areas in the United States, exceeded in temperatures only by certain communities adjacent to Death Valley, Calif.

Public Water Supplies

The general characteristics of the water systems of the six study communities are shown in table 1. The data on fluoride determinations of the common water supplies of the six communities are presented in table 2.

These data were available as samples taken from individual wells and from the general distribution system after pooling. The arithmeti-

Table 1. Characteristics of the common water supplies in six Arizona communities, 1935–51

Community	Source of supply	Treatment
Yuma	Colorado River.	Desilting; aluminum sulfate; flocculation; copper sulfate; filtration; chlorination.
Tempe	4 wells	Chlorination.
Tucson	17 wells	Chlorination; ammoniation.
Chandler	4 wells	None.
Casa Grande	5 wells	Do.
Florence	4 wells	Do.

cal mean of all available analyses of individual well water and of finished water has been accepted as the figure most nearly representing the fluoride concentration of the several water supplies. They represent analyses made intermittently from 1935 through 1950 and quarterly during 1951. The fluoride concentrations range from 0.4 ppm at Yuma to 1.2 ppm at Florence.

A more detailed description of each of the water supplies follows.

Yuma. The public water supply of Yuma has been obtained from the Colorado River since 1892. The treatment plant in current use was put into operation in 1945. The first treatment starts about 18 miles above Yuma, where a desilting plant is located. The main treatment plant is situated on the Arizona bank of the Colorado River in Yuma proper. A 4,500-gallons-per-minute turbine pumps water directly into the first settling basin in the plant. A second turbine, with a 5,000-gallons-per-minute capacity, pumps water from the Bureau of Reclamation canal, 1,200 feet away. Treatment at the plant consists of the addition of aluminum and copper sulfate, flocculation, filtration, and chlorination. Storage is obtained by means of two 500,000-gallon reservoirs from which the water is pumped into the distribution system.

(In the summer of 1937, sewage backed up in the Colorado River, and the water became unsafe for drinking purposes. During a 3-month period water from the City Park well, normally used to supply the municipal swimming pool, was pumped into the distribution system and supplied the water for the community. No data are available indicating the fluoride concentration of the well water at the time it was used for drinking purposes, but a sample of the water as of May 12, 1951 showed 0.6 ppm.

The mean of 79 fluoride determinations shows the Yuma water supply to have a fluoride concentration of 0.4 ppm.

Tempe. During the study period the water for the community of Tempe was obtained from four wells. These wells, established in 1894, were located side by side, were pumped by a single piston, and were approximately 140 feet deep. No data are available to show whether they were cased, but the local waterworks operator thought they probably were not.

Finished water is stored in a 1,000,000-gallon tank. Chlorination was instituted in 1939; no other treatment is given. The average fluoride concentration for the common water supply is 0.5 ppm.

Tucson. The city of Tucson presented a special investigative problem. The water supply for the community is derived from more than one source, and is distributed through two systems, the Northside system with a fluoride concentration of about 0.3 ppm. and the Southside system with a fluoride concentration of 0.7 ppm. This study was concerned exclusively with the area served by the Southside system and hereafter will be the one under consideration.

The water for the Southside system is obtained from ground water in the Santa Cruz River basin. It is produced from 17 wells located south of the city on the east bank of the river (dry). The water from these wells is pumped into a 30-inch concrete conduit which carries it to two reservoirs, with

Table 2. Reported fluoride concentration of water from all available single source and distribution system samples in six Arizona communities, 1935–51

Community	Number of samples	Mean fluoride content
Yuma	79	0. 4
Tempe	7	. 5
Tucson	31	. 7
Chandler	16	. 8
Casa Grande	20	1. 0
Florence	22	1. 2

SOURCES: University of Arizona, College of Agriculture, Agricultural Experiment Station, Tucson, Ariz.; U. S. Department of Agriculture, Bureau of Plant Industry, Soils and Agricultural Engineering, Salinity Laboratory, Riverside, Calif.

1,500,000- and 7,300,000-gallon capacities, respectively. The water is chlorinated at a point in the conduit before arriving at the reservoir. This is followed by ammoniation at 0.05 ppm.

Fourteen of the 17 wells were in operation prior to 1930. Two additional wells were placed in use in 1946, one in 1947. The wells are pumped alternately in the winter; in the summer, when demand is greater, all wells operate most of the time. The first 6 wells sunk are 125 feet deep. The remaining 11 extend from 200 to 300 feet in depth. Their individual output varies from 300 to 1,300 gallons per minute, with a total capacity of 9,000 gallons per minute.

Since 1938, when a set of control valves was installed to separate the two systems, no water has passed from the Northside into the Southside system. Prior to 1938, small amounts of water may have passed from the Northside into the Southside system. Since the fluoride concentration of the Northside system is the lesser of the two, the contamination of the water under investigation, if any, would result in a lowered fluoride concentration.

Only children who had continuous exposure to the common water supply of this community within a community were included in the study group. A buffer zone of three to five blocks was set up within the limits of the Southside system. Children were excluded from the study if they had lived in or beyond the buffer zone at any time. The normal range of a child at play probably is not greater than that; consequently, exposure to fluoride concentrations less than that of the Southside system would be casual.

The broken line on the map of the city of Tucson (fig. 2) shows the limits of the Southside water system as of 1935. The solid line indicates the area from which the study children were selected.

Chandler. During the study period the water supply for the city of Chandler has been produced by four wells. The initial two wells, 335 and 987 feet deep, were drilled and put into operation in December 1926. Both wells drew water from the 300- to 325-foot level, the depth at which they were perforated. In 1938 the casing above the perforations broke, and a considerably harder water began to enter the wells. Because of this, two new wells were put into operation, one in 1944 and one in 1948. They are both 650 feet deep, perforated from the 360-foot level to the bottom. The original wells were sealed off in September 1944.

The arithmetical mean of the fluoride determinations made while the original wells were in use is 0.75 ppm; of those made subsequent to that date, 0.85 ppm. The single analysis available for the period during which water was entering the wells from above the perforations indicates that the fluoride concentration at that time was 0.8 ppm the same as the numerical average for all observations. It seems clear that the fluoride concentration of the common water supply has remained constant during the study period.

Casa Grande. The water for Casa Grande is obtained from five wells, which were put into operation in 1922, 1930, 1937, 1946, and 1950. The location of each new well site was moved consistently to the northeast to get better water, but they are in fairly close proximity, all but one being within the city limits. The wells range in depth from 210 to 302 feet, with the exception of one 759-foot well which is used for emergency purposes only. No data were available as to the depth of the perforations in the well casing.

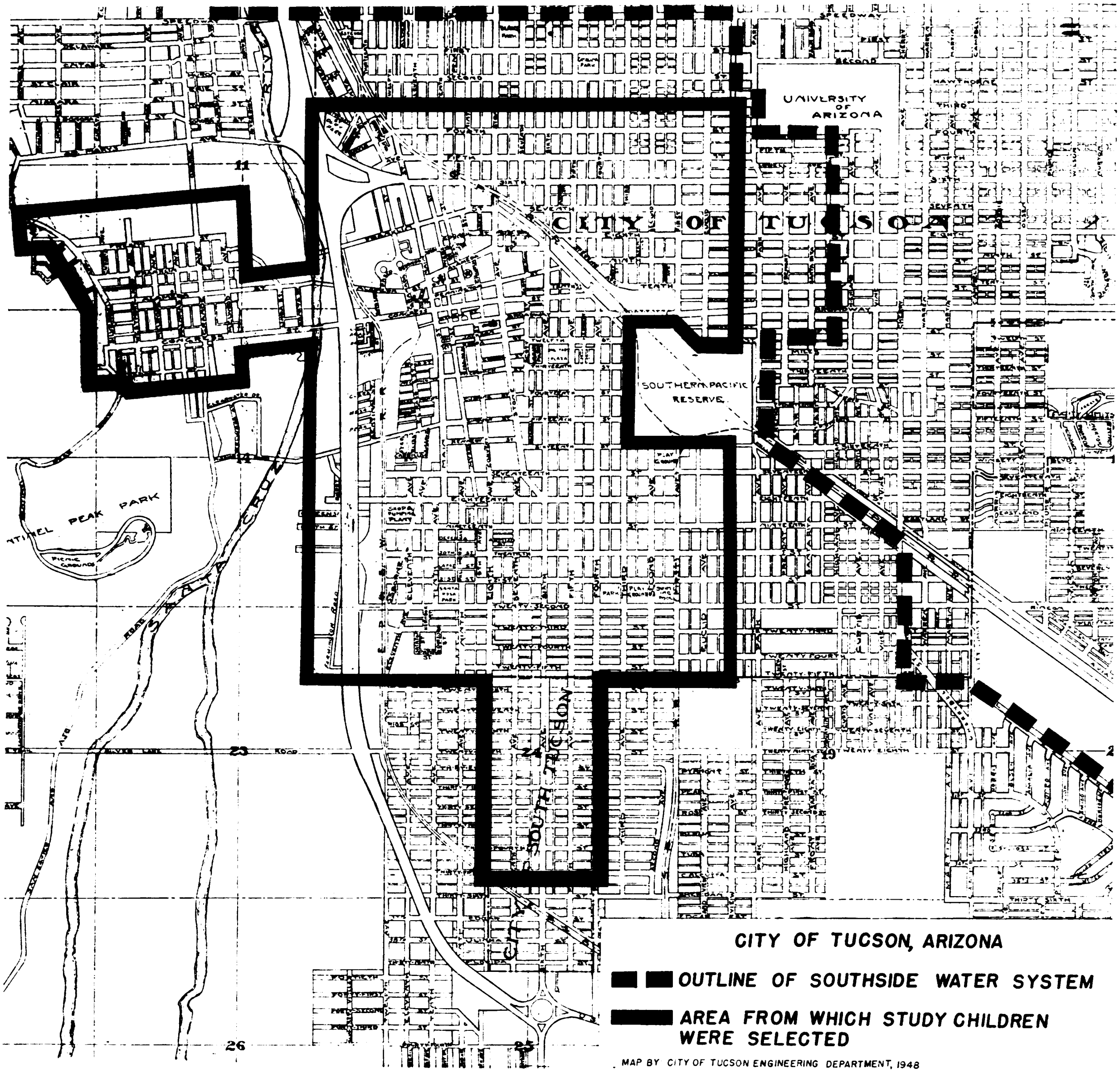
The wells have a total rated output of 1,700 gallons per minute with an average reported daily output of 594,000 gallons. The water is stored in a ground level storage tank of 500,000-gallon capacity and in an elevated tank holding 100,000 gallons. It is not treated.

The new wells added to the system during the present study do not seem to have changed the fluoride concentration of the water supply. Samples from the distribution system have ranged from 0.9 ppm to 1.2 ppm of fluoride. Twenty analyses, for the years 1931 through 1951, are available, representing all seasons of the year. The numerical average of all available fluoride concentrations reported for samples taken from the system and from individual wells is 1.0 ppm.

Florence. During the study period the community of Florence has obtained its water from four wells. The two original wells, 180 and 190 feet deep, were put into operation in 1919. A new 400-foot well, perforated the last 40 feet, was put into operation in 1939, and the two old wells were closed. Because of increased demand, another 400-foot well, perforated at the same level, was put into operation in July 1947. The new and the original wells are adjacent to each other within the city limits.

The wells now in use have a rated output of 350 gallons per minute, and an average daily output of

Figure 2. Map of the city of Tucson, Ariz., showing outline of Southside water distribution system, buffer zone, and area from which study children were selected.



386.5 thousand gallons per day. The water is not treated. Overflow is stored in a 55,000-gallon elevated standpipe.

Since there was a complete change in well usage during the early part of the study period, the available fluoride concentrations have again been divided into those taken prior to the date the old wells were closed, July 1939, and those taken after that date. A total of 21 fluoride analyses, with a numerical average of 1.2 ppm, was reported during the study period. Fourteen of the samples were taken prior to July 1939, and 7 were taken after that date. Both average 1.2 ppm of fluoride. It seems evident that the fluoride content of the Florence water supply was not altered by the change in wells.

Materials and Methods

Since these studies were designed to determine the extent of dental fluorosis in children with continuous exposure to common water supplies containing low fluoride concentrations, it was necessary to get accurate information regarding the water history of the children

Table 3. Percentage age distribution of 726 children examined in six Arizona communities, 1951

Number of children in each community	Age (years) and percent in each age group							
	9	10	11	12	13	14	15	16
Yuma (82)	5	9	7	10	7	18	16	28
Tempe (113)	5	13	16	18	11	12	13	12
Tucson (316)	3	7	8	11	18	24	17	12
Chandler (95)	8	15	14	20	15	9	12	7
Casa Grande (50)	8	12	22	12	18	14	8	6
Florence (70)	3	9	9	16	18	14	20	11

studied. The following screening procedure was adopted in each community:

Screening Step 1. Public and parochial school children from the fourth through the ninth grades were each issued a card which asked the following questions:

Were you born in this town?

Have you lived here all your life?

Have you been away from this town for more than 30 days in any 1 year?

This initial screening served to eliminate those children obviously not continuous residents of the community.

Screening Step 2. Each child who indicated that he was born in the community and had lived there all his life was given a questionnaire to take home to his parents or guardian, with an explanatory letter. The parents were requested to record the birthplace of the child, the addresses of all his residences, continuously and in sequence, from birthdate to date of the questionnaire, and the source of the water used for drinking and cooking purposes at each residence. They were also asked to describe specifically the absences of the child from the community for more than 30 days.

Screening Step 3. Children who passed through the first two steps were scheduled for dental examination. At the time of examination, each child was questioned by a dentist or a dental hygienist to verify the information obtained in steps 1 and 2. A school or public health nurse was present to add her knowledge of the home situation to the water history data.

Screening Step 4. If the data obtained in any of the first three steps was inconsistent the parent was interviewed by a member of the survey team and was asked to clarify the discrepancies.

Only children who had consumed water from the common municipal supply continuously from birth through their ninth year were included in the study. Children who experienced interruption in the continuity of consumption of the community water for periods of more than 30 days in any one calendar year were excluded. The remaining children served as study material.

Clinical Examinations

All dental examinations were made by the same examiner. The children were seated in a portable dental chair; and a mouth mirror, a Burton light, and compressed air were available for the examiner's use. Each tooth was assigned a fluorosis classification according to Dean (*8*). The tooth-unit fluorosis classification was later transposed into child-unit classification for use in computing the community fluorosis index. The percentage age distribution of the 726 Arizona children examined is shown in table 3.

Findings

The data relative to the prevalence and severity of fluorosis obtained in the six communities are presented in table 4. The occasional child falling into the moderate or severe classification when exposed to relatively low fluoride concentrations is worthy of note.

The community fluorosis index may be used for an objective measurement of the extent of endemic dental fluorosis. The direct relationship between fluoride concentration and fluorosis noted in prior investigations is evident. As the fluoride concentration rises the community fluorosis index is increased and the number of children without visible fluorosis is reduced. The community fluorosis index ranges from 0.21, associated with 0.4 ppm of fluoride at Yuma, to 1.12 for Florence which has 1.2 ppm of fluoride in its water supply.

Comparison With Midwestern Indexes

To compare possible variations in the intensity of dental fluorosis under different climatological conditions, data obtained from 10 com-

Table 4. Prevalence of fluorosis, distribution of signs of fluorosis and community fluorosis indexes in relation to fluoride concentrations of common water supplies continuously used by 726 children examined in six Arizona communities, 1951

Community	Fluoride concentration	Number children examined	Number children affected	Number of examined children with signs of fluorosis						Community fluorosis index
				Fluorosis absent		Fluorosis present				
				Normal	Questionable	Very mild	Mild	Moderate	Severe	
Yuma	0.4	82	3	53	26	2	1			0.21
Tempe	.5	113	11	59	43	10	1			.30
Tucson	.7	316	53	120	143	38	10	5		.46
Chandler	.8	95	18	40	37	9	6	2	1	.52
Casa Grande	1.0	50	24	7	19	15	9			.85
Florence	1.2	70	39	17	14	18	10	9	2	1.12

munities with similar fluoride concentrations were selected from the study of "21 cities" by Dean and his co-workers (*10*). The communities in the 21 cities group, which may be considered as a base line, have a mean annual temperature of approximately 50° F., whereas the six communities in Arizona have a mean annual temperature of approximately 70° F.

Data on the prevalence and severityof fluorosis in both groups of communities are presented in table 5.

Comparison of the data reveals that the Arizona communities have a somewhat higher percentage of children affected by fluorosis than communities with a cooler climate and comparable fluoride concentrations in their water supplies. There is also a wider distribution throughout the fluorosis classification. Some of the Arizona children present moderate to severe fluorosis associated with exposure to less than the generally recommended fluoride concentration of 1.0 ppm.

Dean has stated that a community fluorosis index below 0.4 is of little or no public health concern. He considers the range from 0.4 to 0.6 as borderline. For indexes above 0.6 the removal of excessive fluorides from the water is recommended (*8*). From table 5 it may be seen that the fluorosis indexes for communities with fluoride concentrations above 0.5 ppm are considerably higher in the Arizona communities. Yuma, Ariz., and Marion, Ohio, both have fluoride concentrations of 0.4 ppm and fluorosis indexes of 0.21 and 0.25, respectively.

As the fluoride concentration rises, the disparity between indexes becomes marked, so that Florence, Ariz., and East Moline, Ill., with fluoride concentrations of 1.2 ppm, present fluorosis indexes of 1.12 and 0.49, respectively.

The fluorosis indexes for the two groups of communities have been plotted on figure 3.

The least squares method was used to calculate the index lines. (Trend line formula for 70° F. communities is $y=-0.291+1.132x$ and for 50° F. communities is $y=0.021+0.353x$.) The line for the Arizona group has a much steeper slope than that representing the midwestern communities. The index line for the Arizona communities accelerates at approximately twice the rate as the one for the midwestern communities. The line for the midwestern cities crosses from the negative area into the borderline zone at approximately 1.1 ppm and from the borderline into the objectionable zone at 1.7 ppm. On the other hand, the line for the Arizona communities crosses from the negative area into the borderline zone at 0.6 ppm and into the objectionable zone at 0.8 ppm.

These data would indicate that the children residing in the Arizona communities under consideration develop twice as much fluorosis as midwestern children when exposed to water containing the same concentration of fluoride. (It should be noted that the two groups of children were diagnosed by different examiners. The data are therefore subject to the error of examiner differences.)

Climatological Variables

About two-thirds of man's total fluid intake is water, the remainder, other fluid substances. Except for temporary circumstances of an emotional nature, the amount of fluid ingested is determined by water deficiency. Every bit of body water lost must be replaced, and the replacement amounts are obligatory. (In growing children fluid intake may be slightly greater than water loss since some additional water is needed to build new tissues, but generally speaking, water intake and water loss will be equal over a 24-hour period.)

Temperature

Excessive temperatures result in a bodily demand for fluid over and above that usually required for normal physiological processes (*16*). When environmental temperatures rise above skin temperature (92° to 95° F.), the only method by which the body can cool itself is vaporization. Heat loss can no longer be effected by radiation or conduction. The water output of the body is therefore increased in proportion to the need for increased vaporization. It follows that there will be an equal increase in the amount of water ingested in order to maintain body water balance.

The extremely high temperature occurring in the southwestern communities is undoubtedly a major factor contributing to the increased severity of endemic fluorosis observed in the Arizona children through its influence on water consumption. Some indication of the differ-

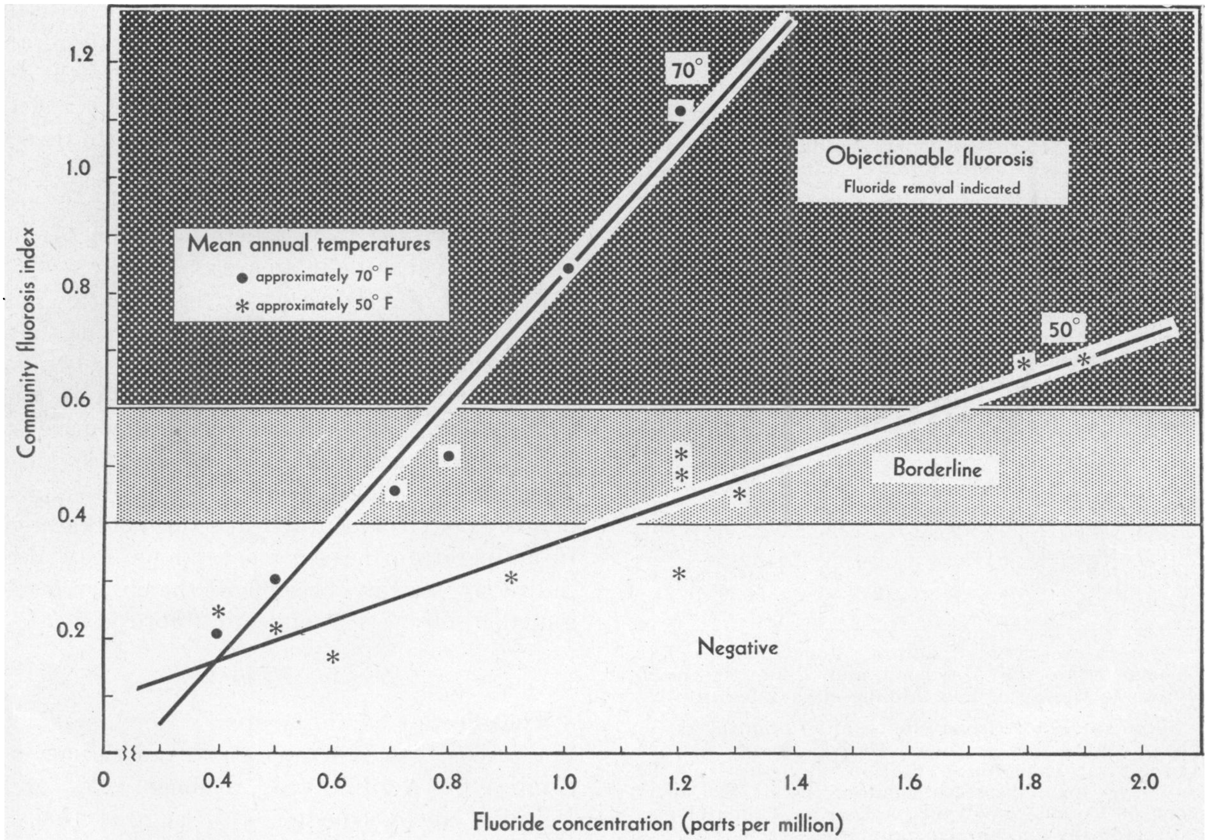
Table 5. Prevalence of fluorosis, percentage distribution of signs of fluorosis and community fluorosis indexes in relation to fluoride concentration of common water supplies of 16 communities in two temperature zones

Community	Fluoride concentration	Community fluorosis index	Number children examined	Percent children affected	Percentage distribution of signs of fluorosis: Absent		Present				Mean annual temperature ° F.[1]
					Normal	Questionable	Very mild	Mild	Moderate	Severe	
Arizona											
Yuma	0.4	0.21	82	4	65	32	2	1	------	------	72.2
Tempe	.5	.30	113	10	52	38	9	1	------	------	68.6
Tuscon	.7	.46	316	17	38	45	12	3	2	------	67.4
Chandler	.8	.52	95	19	42	39	9	6	2	1	67.6
Case Grande	1.0	.85	50	48	14	38	30	18	------	------	71.0
Florence	1.2	1.12	70	56	24	20	26	14	13	3	69.3
Midwest											
Marion, Ohio	.4	.25	263	6	57	37	5	1	------	------	52.1
Elgin, Ill	.5	.22	403	4	61	35	4	1	------	------	49.4
Pueblo, Colo	.6	.17	614	7	72	21	6	(2)	------	------	52.6
Kewanee, Ill	.9	.31	123	12	53	35	10	2	------	------	50.9
Aurora, Ill	1.2	.32	633	15	53	32	14	1	------	------	49.4
East Moline, Ill	1.2	.49	152	32	37	32	30	2	------	------	50.9
Maywood, Ill	1.2	.51	171	33	39	28	29	4	------	------	50.1
Joliet, Ill	1.3	.46	447	25	41	34	22	3	------	------	49.4
Elmhurst, Ill	1.8	.67	170	40	28	32	30	9	1	------	50.1
Galesburg, Ill	1.9	.69	273	48	25	27	40	6	1	------	50.9

[1] Average: Arizona, 69.3° F.; Middle West, 50.6° F.
[2] Less than 0.5 percent.
NOTE: Age range for Arizona group, 9–16 years; midwestern group, 12–14 years.

SOURCES: Fluorosis data for midwestern communities from Dean, H. T.: Epidemiological studies in the United States. American Association for the Advancement of Science: Dental caries and fluorine, Science Press, Lancaster, Pa., 1946; mean annual temperature for 6 Arizona communities from Smith, H. V.: The climate of Arizona. University of Arizona, Agricultural Experiment Station, Bulletin No. 197, July 1945; for midwestern communities; from U. S. Department of Commerce, Weather Bureau: Climatological data. Monthly and annual summaries: The mean annual temperature for Aurora, Joliet, and Elgin is represented by the 19-year average mean temperature for Aurora; that for Kewanee, East Moline, and Galesburg by the 19-year average mean temperature for Galva; and that for Maywood and Elmhurst by the 19-year average mean temperature for Chicago.

Figure 3. Relationship between fluoride concentration of municipal waters and fluorosis index for communities with mean annual temperatures of approximately 50° F. (Midwest) and 70° F. (Arizona).



Source: Table 5.

ence in temperature between the two geographic areas is reflected in their mean annual temperatures of 50° and 70° F. (table 6).

Temperature Range

The mean annual temperature is a simple measure of the climatic conditions to which man is exposed. It is the mean of the daily high and low temperatures for a year, and does not critically reflect differences in daytime and nighttime temperatures.

During most of their tooth-forming years children are active almost exclusively during daytime hours. Consideration of mean temperature alone may therefore result in an underestimation of the actual temperatures to which they have been exposed in warm, semiarid climates. Comparisons of temperature ranges may reflect more clearly the real difference in temperature experienced by the children residing in two geographic locations. The data on mean maximum and mean minimum temperatures and the temperature ranges for the Arizona communities under consideration, and for the midwestern communities (or representative communities if complete weather data for each city were not available) are also presented in table 6.

Although the difference between the mean annual temperatures of the two groups of communities is considerable, the difference in the range of high and low temperatures, or day and night temperatures, is even more marked. The midwestern communities have an average range of 22° F. between the daytime maximum and the nighttime minimum, whereas the Arizona communities have an average range of 33° F. Daily variations are considerably greater in any semiarid area (*17*), and daytime temperatures well above 100° F. are common

Table 6. Annual mean maximum, mean minimum, mean temperature, and temperature range for six Arizona communities and five representative [1] midwest communities

Community (station)	Number of years of record	Temperature (° F.)			
		Mean maximum	Mean minimum	Mean	Range
Arizona					
Yuma Citrus Station	20	87. 2	56. 9	72. 2	30. 3
Tempe No. 2	15	84. 3	53. 0	68. 6	31. 3
Tucson (University of Arizona)	49	82. 5	51. 3	67. 4	31. 2
Chandler	21	85. 3	50. 3	67. 6	35. 0
Casa Grande	26	87. 8	51. 7	71. 0	36. 1
Florence	26	86. 3	52. 7	69. 3	33. 6
Midwest					
Marion, Ohio	19	62. 4	42. 3	52. 1	20. 1
Pueblo, Colo	19	67. 3	36. 8	52. 6	30. 5
Aurora, Ill	19	60. 5	39. 0	49. 4	21. 5
Chicago, Ill	19	58. 4	42. 7	50. 1	15. 8
Galva, Ill	19	62. 2	40. 6	50. 9	21. 6

[1] Aurora represents Aurora, Joliet, and Elgin; Chicago represents Maywood and Elmhurst; Galva represents Kewanee, East Moline, and Galesburg.

SOURCES: For Arizona communities: Smith, H. V.: The Climate of Arizona. University of Arizona, Agricultural Experiment Station, Bulletin No. 197, July 1945; for midwestern communities: U. S. Department of Commerce, Weather Bureau, Climatological data, monthly and annual summaries.

for many weeks in the Arizona communities. The interpretation of these data makes even more striking the difference in temperatures to which the children of the two zones are exposed.

Radiant Heat Gain

Water needs vary with other factors beside temperature. Body weight, physical activity, direct radiation, and humidity may all play a part in the amount of fluid lost by the body and therefore in the amount of fluid ingested to maintain water balance. Certain of these variables, such as body weight and physical activity, which contribute to physiological heat gain, will obviously not differ greatly between geographic areas. Other factors contributing to environmental heat gain should be taken into consideration, however.

Individuals exposed to the same air temperatures and different amounts of direct sunlight are subject to varying influences on water loss. It has been demonstrated that there is an increase in the sweating rate of about 20 grams per hour for each degree of increase in air temperature. Direct sunlight causes an elevation in the sweating rate equivalent to that resulting from a 10°F. increase in air temperatures (*18*). Therefore, exposure to direct sunlight increases water loss by increasing radiant heat gain. An indication of this factor may be obtained from a determination of the amount of sunshine in an area.

The part of Arizona under consideration has a greater percentage of possible sunshine than any other area in the United States—80 to 85 percent compared to 50 to 60 percent in the Chicago area (*17*). Therefore in the southwest desert there is extremely high radiant heat gain from the sun. This climatic factor, causing a degree of environmental heat stress not reflected in temperature measurements alone, may also indirectly account for some of the observed regional differences in endemic fluorosis.

Relative Humidity

The effect of humidity upon water loss is not as clear as that of temperature and radiation. Studies by Adolph (*18*), Rubner (*19*), and Benedict and Carpenter (*20*) suggest that a lower relative humidity tends to increase water loss, temperatures being equal. On the other hand, Newburgh (*21*) points out that since moisture demand is decreased in humid air, more skin surface has to be wetted (and more sweat produced) to achieve the equivalent of cooling experienced in dry, absorbent air of comparable temperature. Therefore, a humid atmosphere would tend to increase water loss merely by making the body secrete more sweat in order to gain the same amount of evaporative cooling accomplished in arid areas with less water loss. Since the data appear to be conflicting, the influence of relative humidity upon the water intake of infants and children is difficult to assess.

Considerable difference does exist between the relative humidities of the two areas in the study. For example, the annual mean relative humidity for the Tucson-Yuma area is 35 to 37 percent, and for the Chicago area, 74 percent (*17*). The data available indicate that the Arizona communities have relative humidities approximately half that observed in the midwestern communities. On hot summer afternoons the relative humidity in the Arizona desert may be 5 percent or less.

It is questionable whether the marked difference in relative humidity between the two areas is influential in the water intake of infants and children. Measurement of its influence is further complicated by the difficulty encountered in obtaining comparable humidity data and by the fact that other meteorological conditions appear to have a greater effect on water loss.

Nonclimatic Variables

The Arizona area under consideration is desert country with very little rainfall. Consequently, all productive land is under irrigation. Since many water supplies in Arizona contain fluoride in some amount, the soil may potentially have fluoride added to it by irrigation. Smith and associates (*22*) were unable to show any appreciable increase in the uptake of fluoride by grains and vegetables, even when concentrations up to 3,200 ppm were artificially added to the soil in which they were grown. In a comprehensive review of the literature, McClure (*23*) concludes that fluoride in soil has little or no influence on the fluoride content of edible plant produce. Increased fluoride intake through use of food products grown in soil irrigated with water containing the amounts of fluoride naturally occurring in Arizona therefore seems extremely unlikely.

One other nonclimatic factor should be recognized when attempting to account for the observed regional differences in the severity of fluorosis. Generally speaking, the children included in the Arizona group were of Spanish descent (83 percent). Their dietary staple, beans, is usually prepared by boiling for rather long periods of time. Since boiling in fluoride-bearing water results in a concentration of the fluoride ion in many cooked vegetables (*24*), there may have been an increase in the dietary fluoride intake of this group to a greater degree than would be observed for a group of children on a more varied diet. It was not within the scope of this study to measure the influences of dietary variables upon fluoride intake.

Summary

1. The prevalence and severity of endemic dental fluorosis in 726 children were studied in six Arizona communities. The cities were located in a desert area, with mean annual temperatures of approximately 70° F., mean relative humidities of approximately 37 percent, 80 to 85 percent of possible sunshine, and extremely high daytime temperatures.

2. In water supplies of the Arizona communities studied, concentrations of fluoride above 0.8 ppm resulted in objectionable dental fluorosis; concentrations of 0.6 to 0.8 ppm resulted in an occasional diagnosis of fluorosis; concentrations below 0.6 ppm did not cause objectionable fluorosis.

3. Comparisons of the community fluorosis indexes for the Arizona communities with those obtained from selected midwestern communities indicate that fluorosis occurs at about twice the intensity in that section of Arizona as it does in the midwestern area with comparable fluoride concentrations but markedly different climatic factors.

4. Variation in temperature, radiant heat gain and relative humidity have been discussed as possible influential factors in the observed differences in endemic fluorosis between the two areas.

5. The application of a simple biological test in two areas suggests that, because of several climatological influences, Arizona children drink more water than children living in more temperate climates. As a result, there is increased ingestion of fluoride in relation to the concentration found in the water supply.

ACKNOWLEDGMENTS

The authors acknowledge the assistance given by H. V. Smith, associate professor of agricultural chemistry and soils, University of Arizona. Without his help in planning and conducting the investigations the studies could not have been accomplished.

The information concerning the Arizona water supplies was obtained from George W. Marx, director, bureau of sanitation, Arizona State Department of Health, and from the local waterworks superintendent in each community.

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