Analysis of the rib, iliac crest, vertebra, and sternum for fluoride indicates a direct increase in bone fluoride with an increase in fluoride in drinking water up to 4.0 ppm.

Fluoride deposition in human bones

after prolonged ingestion of fluoride in drinking water

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IN CONJUNCTION with microscopic examination of human bones for possible effects of prolonged ingestion of fluoride in drinking water (reported in this issue by Geever and associates, pp. 721–731), essentially the same bones were analyzed for ash and fluoride. These bones were obtained at autopsy from 69 persons, 36 of whom were exposed to 1.0 to 4.0 ppm fluoride for 10 to 76 years. The remaining 33 had lived in areas with less than 1.0 ppm fluoride for 10 to 87 years.

This study represents the first systematic survey of the fluoride concentration of bones of individuals exposed to various concentrations of fluoride in drinking water. Previous studies of exposure to high levels of fluoride, recently reviewed by McClure and associates (pp. 741–746 of this issue), have dealt with no more than four cases (*1–5*). More extensive data have been reported on the fluoride concentration of selected bones of individuals in low-fluoride areas (*6–8*).

Most of the persons whose bones were examined in the present studies died suddenly, the chief causes being trauma, coronary heart disease, and cerebrovascular accidents. Although bones of persons with chronic illness or diseases known to affect bone structure were excluded from the microscopic study, they were included in the fluoride deposition study so that the effect of such conditions might be observed. The fluoride analysis thus included bones from 3 individuals with a malignancy and 3 with renal disease.

The 69 individuals in the fluoride deposition study, 40 men and 29 women aged 26 through 90 years, provided 190 bones and 64 specimens of intervertebral cartilage. Approximately 80 percent of these bones and cartilage specimens were also examined histologically. The bones, consisting of a portion of the iliac crest, the lumbar vertebra, and the sixth rib, were fixed in 10 percent formalin at autopsy.

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Table 1. Percentage ash and fluoride in dry, fat-free bones of individuals ingesting drinking water containing less than 1 ppm fluoride

Subject No.	Sex	Age (years)	Residence (years)	Iliac crest		Rib		Vertebra	
				Ash	Fluoride	Ash	Fluoride	Ash	Fluoride
		0.1 ppm fluoride							
1	Male	27	27	56.8	0.019	61.4	0.020	50.2	0.031
2	Male	32	12	56.2	.044	56.9	.037	50.4	.054
3	Male	35	35	58.1	.045	59.4	.043	43.7	.043
4	Female	38	12					52.2	.024
5	Male	47	10					49.9	.056
6	Female	47	15	57.6	.020	57.9	.024	46.6	.019
7	Male	50	25	59.6	.030	60.9	.024	51.7	.026
8	Female	55	20	58.9	.038	53.9	.043	43.8	.036
9	Male	56	20	52.6	.046	57.8	.047	47.9	.057
10	Male	62	62	54.9	.032	57.6	.028	50.9	.038
11	Male	62	62	58.8	.024	57.3	.031	46.8	.028
12	Male	65	41	54.2	.034	54.0	.062	43.2	.034
13	Male	66	15	57.6	.028	61.9	.039	45.7	.026
14	Female	68	10	62.9	.073	65.5	.077	55.7	.079
15	Male	69	10	58.3	.035	60.0	.037	50.5	.034
16	Male	70	60	54.8	.032	60.2	.039	44.3	.042
17	Female	73	32	54.0	.048	57.6	.060	44.6	.055
18	Female	82	40	56.8	.044	58.8	.037		
19	Male	87	87	59.2	.055	59.8	.062	46.9	.059
		0.2 ppm fluoride							
20	Female	32	10			68.4	0.023	53.6	0.038
21	Male	32	[1] 32	58.8	0.053	64.1	.031	51.7	.043
		0.3 ppm fluoride [2]							
22	Female	48	48			60.5	0.048		
23	Male	53	24	59.7	0.046	54.4	.056	47.3	0.050
24	Male	59	57					46.2	.093
25	Female	74	25	59.0	.078	57.9	.089	43.7	.077
		0.1–0.4 ppm fluoride							
26	Male	32	32			56.2	0.062	45.4	0.061
27	Female	40	10			60.6	.071	49.8	.111
28	Male	44	10			53.4	.039	46.4	.042
29	Male	57	34			60.2	.039	44.9	.040
30	Male	59	10			54.4	.078	48.5	.094
31	Male	64	10			60.4	.064	51.4	.075
32	Male	71	10			60.0	.069	45.3	.083
33	Male	74	20			51.3	.106	49.8	.119
	Mean	55.5	28.1	57.4	.041	58.8	.050	49.0	.054
	SE	2.8	3.4	.3	.003	.7	.004	.6	.005

[1] Resident of Baltimore, Md.; water fluoridated to 1 ppm in November 1952; received fluoridated water for 2 years.

[2] Residents of Washington, D. C.; water fluoridated to 1 ppm in June 1952; received fluoridated water 4, 2, 3, and 3 years, respectively.

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The intervertebral cartilage was separated from the vertebra, and all specimens were cleaned of adhering soft tissues. Each sample was dried overnight at 105° C., broken into pieces, and extracted with alcohol for 8 hours and with ether for 4 hours. After the sample was ground to pass a 60-mesh sieve, a portion was ashed for 3 hours at 550° C. and analyzed for fluoride (*9–11*). The significance of the differences in means was calculated according to Fisher's *t* test for paired values. The sodium, potassium, calcium, magnesium, phosphorus, carbon dioxide, and citrate contents of these tissues will be reported later.

Bone Fluoride

The percentages of ash and fluoride in dry, fat-free bones for each individual in the study, grouped according to the level of fluoride in the drinking water, are recorded in tables 1 through 4. Ages and years of residence are also given, but it is not possible to detect any definite relation between the fluoride concentration and these factors.

The fluoride values for the 15 bones from the individuals who had a malignancy or renal disease were within the variations encountered for others in the same group (subject No. 5 in table 1; subjects Nos. 8, 10, and 11 in table 3; iliac crest, subject No. 1 in table 4) or slightly higher (subject No. 2 in table 2; rib and vertebra, subject No. 1 in table 4). No significance can be attached to the somewhat higher values since they occurred in individuals from the two smaller groups (tables 2 and 4). Moreover, approximately a tenfold increase in fluoride concentration of the bones from the lowest to the highest fluoride areas (tables 1 and 4) was seen without any apparent tissue damage.

Less Than 1 ppm Fluoride

Individuals exposed to less than 1 ppm fluoride were residents of several localities, with fluoride concentrations in the drinking water varying from 0.1 ppm in New York City to 0.4 ppm in San Antonio, Tex. The mean was 0.2 ppm. Five persons in this group, aged 32 through 74 years, drank water fluoridated to 1 ppm fluoride for 2 to 4 years. The fluoride content of the bones of these five was within the variations encountered in other samples in this group (table 1).

On a dry, fat-free basis, the mean concentrations of fluoride in the various bones of individuals exposed to less than 1 ppm fluoride were similar, 0.041, 0.050, and 0.054 percent for the iliac crest, the rib, and the vertebra, respectively. As expected, the fluoride concentrations of the rib and the vertebra were generally highest in the individuals from San Antonio.

Five samples of sternum from this group varied from 0.040 to 0.101 percent fluoride with a mean, ± standard error, of 0.066±0.012 percent (not including one inordinately high value of 0.229 percent fluoride). On an ash basis, they ranged from 0.078 to 0.188 with a mean of 0.134 percent. The mean concentration of fluoride in the ash of the vertebra (0.112±0.010

Table 2. Percentage ash and fluoride in dry, fat-free bones of individuals ingesting drinking water containing 1 ppm fluoride, Grand Rapids, Mich.[1]

Subject No.	Sex	Age (years)	Residence (years)	Iliac crest		Rib		Vertebra	
				Ash	Fluoride	Ash	Fluoride	Ash	Fluoride
1	Female	64	12			57. 8	0. 135	45. 9	0. 130
2	Female	64	15	61. 9	0. 176	59. 7	. 195	48. 4	. 238
3	Male	82	10	59. 5	. 137	54. 5	. 119	51. 3	. 140
4	Female	83	20	61. 1	. 137			53. 3	. 135
5	Male	85	50	62. 2	. 100	57. 4	. 106	50. 9	. 159
	Mean	75. 6	21. 5	61. 2	. 138	57. 4	. 139	50. 0	. 160
	SE	1. 5	7. 4	. 6	. 016	1. 1	. 020	1. 3	. 020

[1] Fluoride added to drinking water January 1945. Subjects received fluoridated water for 12 years with exception of male aged 82 years.

percent) was similar to that of the sternum ash (0.134±0.023 percent), but it was significantly higher than that in the ash of the iliac crest (0.072±0.006 percent, $P<0.01$) or in the rib (0.086±0.008 percent, $P<0.05$).

While ash concentrations of the vertebra and the sternum were similar (49.0 percent and 49.4 percent), they were significantly lower than that of the iliac crest (57.4 percent, $P<0.01$) or the rib (58.8 percent, $P<0.01$).

Fluoride Level of 1 ppm

A second group, composed of 5 persons, were residents of Grand Rapids, Mich., where the water supply was fluoridated to 1 ppm in January 1945. The autopsy specimens were obtained between November 1956 and January 1957; thus exposure to 1 ppm fluoride was for a maximum of 12 years during the last years of life.

As with the low-fluoride group, no differences were found in the concentration of fluoride in the various bones of this group (table 2). On a dry, fat-free basis, the mean percentages were 0.138 for the iliac crest, 0.139 for the rib, and 0.160 for the vertebra. The fluoride concentrations of the ash of the iliac crest (0.225±0.026 percent) and of the rib (0.241± 0.030 percent) were similar, but they were significantly lower than that of the vertebra (0.323±0.043 percent, $P<0.05$). Appreciable amounts of fluoride thus accrued during the last 10 to 12 years of life of these 5 individuals aged 64 through 85 years.

For the 5 exposed to 1 ppm fluoride, the concentrations of ash in the iliac crest (61.2 percent) and the rib (57.4 percent) were similar but significantly higher than that of the vertebra (50.0 percent, $P<0.01$).

Fluoride Level of 2.6 ppm

Colorado Springs, Colo., and Amarillo, Tex., were the residences of 27 subjects. Colorado Springs has had a uniform and verified history

Table 3. Percentage ash and fluoride in dry, fat-free bones of individuals ingesting drinking water containing a mean of 2.6 ppm fluoride, Colorado Springs, Colo., and Amarillo, Tex.

Subject No.	Sex	Age (years)	Residence (years)	Iliac crest		Rib		Vertebra	
				Ash	Fluoride	Ash	Fluoride	Ash	Fluoride
1	Male	36	10	59.6	0.095	57.8	0.106	47.3	0.098
2	Male	36	36	58.9	.092	61.1	.103	49.7	.145
3	Female	47	10	57.3	.219	59.7	.194	54.3	.239
4	Female	47	15	61.4	.481	66.7	.370	56.8	.521
5	Male	50	10	57.9	.129	58.3	.199	52.7	.179
6	Female	53	22	61.2	.111	62.2	.134	52.4	.163
7	Female	54	20	62.0	.247	65.0	.179	53.8	.332
8	Male	54	20	---	---	56.1	.269	43.7	.325
9	Male	56	10	57.3	.141	55.1	.104	44.9	.150
10	Male	57	46	58.2	.288	59.5	.278	32.7	.197
11	Male	58	25	---	---	58.9	.391	45.0	.334
12	Female	63	25	60.0	.297	58.0	.279	47.8	.305
13	Male	65	30	60.0	.268	56.9	.276	47.9	.299
14	Female	66	10	62.7	.214	59.4	.194	44.3	.244
15	Female	69	28	59.9	.458	58.2	.453	50.7	.548
16	Male	71	36	53.3	.454	57.2	.363	47.2	.400
17	Female	75	16	60.8	.237	59.3	.244	42.6	.262
18	Male	76	76	61.6	.371	55.5	.347	54.0	.346
19	Male	79	40	61.7	.176	59.4	.161	47.3	.189
20	Female	80	13	60.4	.190	59.5	.205	50.2	.293
21	Female	81	52	60.1	.321	59.3	.293	36.6	.264
22	Female	82	76	56.4	.334	52.3	.338	46.0	.382
23	Female	83	54	62.0	.325	62.4	.267	51.9	.367
24	Female	83	60	58.6	.348	62.4	.373	56.1	.363
25	Male	84	32	60.9	.154	58.6	.121	53.7	.177
26	Female	84	62	59.3	.431	61.7	.443	45.4	.321
27	Male	90	55	60.9	.304	62.2	.245	48.1	.295
	Mean	65.9	32.9	59.7	.267	59.7	.257	48.3	.286
	SE	3.0	4.0	.4	.023	.6	.020	1.1	.023

Table 4. Percentage ash and fluoride in dry, fat-free bones of individuals ingesting drinking water containing a mean of 4.0 ppm fluoride, Lubbock, Tex.

Subject No.	Sex	Age (years)	Residence (years)	Iliac crest		Rib		Vertebra	
				Ash	Fluoride	Ash	Fluoride	Ash	Fluoride
1	Male	26	17	58. 6	0. 445	62. 8	0. 458	51. 2	0. 564
2	Male	53	10	60. 8	. 374	54. 5	. 401	47. 5	. 348
3	Male	71	48	62. 1	. 542	53. 3	. 449	59. 9	. 470
4	Female	74	10	58. 1	. 291	59. 4	. 284	44. 3	. 261
	Mean	56	21. 3	59. 9	. 413	57. 5	. 398	50. 7	. 411
	SE	11	9. 1	. 9	. 053	2. 2	. 040	3. 4	. 068

of 2.5 ppm fluoride within narrow limits for some 75 years (*12*, *13*). The fluoride level of the water of Amarillo from 1934 to 1948 ranged from 3.6 ppm to 6.2 ppm (*14*). According to a personal communication from the city chemist, 33 new wells were added between 1948 and 1953, and the fluoride level ranged from 2.6 to 3.2 ppm. In 1955 and 1956 the water supply of Carson County, which probably contains less than 1 ppm fluoride inasmuch as Dean (*15*) considered the incidence of mottled enamel virtually negative, was developed to augment that of Amarillo. In 1957, 92 wells were pumping into the Amarillo reservoir, and the fluoride content averaged 1.6 ppm. From 1948 to 1957, the fluoride level of the drinking water in Amarillo averaged 2.8 ppm, and the weighted mean for the two cities was 2.6 ppm.

For the 27 individuals, the mean fluoride concentration, on a dry, fat-free basis, of the iliac crest was 0.267 percent; of the rib, 0.257 percent; and of the vertebra, 0.286 percent (table 3). On an ash basis, the mean concentration of fluoride in the vertebra (0.598±0.015 percent) was significantly higher than that in the iliac crest (0.450±0.040 percent, $P<0.01$) or in the rib (0.432±0.036 percent, $P<0.01$). The concentration of ash in the iliac crest and the rib (59.7 percent) was significantly higher than that in the vertebra (48.3 percent, $P<0.01$).

Fluoride Level of 4.0 ppm

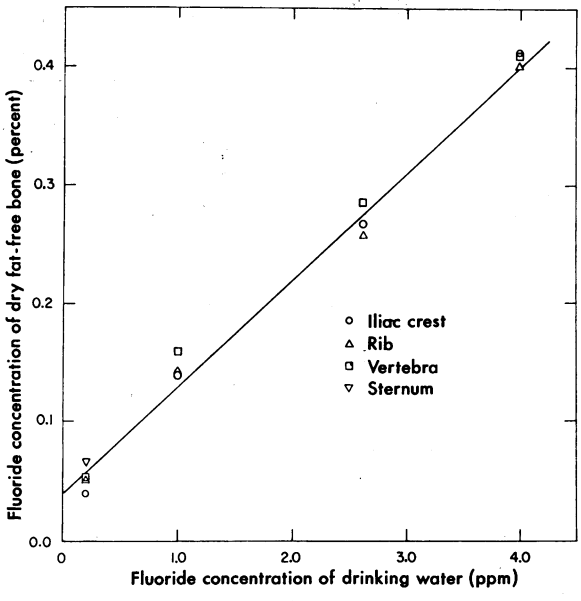
Prolonged exposure to about 4.0 ppm fluoride in the drinking water took place in Lubbock, Tex., now the largest community in the United States reported to have this much fluoride. Because of the unusually high fluoride content of its drinking water, Lubbock, as well as Amarillo, has been the scene of a number of previous studies of the effects of fluoride (*14–18*). The water fluoride of Lubbock up to 1948 ranged from 3.5 to 4.4 ppm (*14*). In a recent letter from the Lubbock City-County Health Department, the fluoride content of the water supply from storage reservoirs was reported to have varied from 3.1 to 5.2 ppm from 1948 through 1955, with a mean of 4.0 ppm. The four subjects from Lubbock were autopsied from May through July 1955.

For the Lubbock residents as for the other subjects, the fluoride concentrations of the dry, fat-free iliac crest, rib, and vertebra were not significantly different, being 0.413, 0.398, and 0.411 percent, respectively. Although the concentration of fluoride in the ash of the vertebra (0.802 ±0.109 percent) was greater than that of the iliac crest (0.687 ±0.081 percent) or that of the rib (0.629 ±0.095 percent), the difference was not significant ($P>0.05$). The ash content of the iliac crest (59.9 percent) and that of the rib (57.5 percent) were similar but higher than the ash content of the vertebra (50.7 percent). An unusually high value of 59.9 percent ash for a specimen of vertebra prevented any level of significance being attached to the difference in the mean ash content of the various bones.

Group Comparison

To summarize these data, the mean concentrations of fluoride in the various bones were plotted against the fluoride level of the drinking water to which the individuals were exposed (see chart). The result indicates that the relation between fluoride in the bones and fluoride

Relation of fluoride in dry, fat-free bones to fluoride in drinking water.



in the drinking water up to 4.0 ppm is adequately described by a straight line function.

Other Findings

The concentration of fluoride in the dry, fat-free intervertebral cartilage also appeared to increase somewhat with elevated levels of waterborne fluoride (table 5). Calcification of this tissue, however, appears not to have been affected by the fluoride concentration of the drinking water.

In addition to the fluoride and ash analyses reported in the preceding tables, it may be of interest to note that the fat content of neither the bones nor the intervertebral cartilage was related to the fluoride content of the drinking water. The mean concentrations of fat in the oven-dry bones had the following range:

	Fat content (percent)	
	Lowest	*Highest*
Iliac crest	23. 2±5. 7	35. 3±2. 6
Rib	23. 4±3. 6	30. 2±5. 7
Vertebra	32. 2±7. 6	43. 8±4. 3
Sternum [1]	41. 3±4. 3	41. 3±4. 3
Intervertebral cartilage	1. 8± . 2	3. 3± . 8

[1] Only one fluoride group examined.

Discussion

The fluoride concentrations in the bones examined in the present study from both low-fluoride areas and high-fluoride areas approximate those observed in the previous limited studies (tables 6 and 7). For one resident of London, a low-fluoride area, a very high value of 0.687 percent fluoride in rib ash was obtained (*7*). The highest concentration of fluoride found in the present study in bones of individuals who had been drinking water containing less than 1.0 ppm fluoride was 0.428 percent in a sample of ashed sternum, and the next high value was 0.238 percent fluoride for a sample of vertebral ash. In considering the data for high-fluoride areas, some reservations must be attached to the high values presented by Kilborn and associates (*5*), since these results may have been due to the subnormal living standards and the low nutritional status of this area (Chengtu, China).

Fluoride in the drinking water up to 4.0 ppm did not affect the ash content of any of the bones analyzed.

For any given level of fluoride in the drinking water, the mean concentrations of fluoride in the

Table 5. Percentage ash and fluoride in intervertebral cartilage in relation to fluoride level of drinking water

Fluoride level of water (ppm)	Number of samples	Dry, fat-free basis		Ash basis
		Ash	Fluoride	Fluoride
<1.0	29	4. 8±0. 3	0. 003±0. 000	0. 049±0. 008
1.0	5	3. 9± . 3	. 004± . 001	. 090± . 029
2.6	26	3. 8± . 2	. 004± . 001	. 098± . 015
4.0	4	4. 2± . 1	. 007± . 003	. 159± . 056

NOTE: Data are expressed as mean±standard error.

Table 6. Percentage fluoride in human bone ash from low-fluoride areas

Fluoride level of water (ppm)	Bone	Number of samples	Fluoride in bone ash (percent)	Source of data
0.0	Rib	1	0.01	Boissevain and Drea (*3*).
	Humerus	1	.1	Do.
	Tibia	1	.02	Do.
	"Toe"	1	.16	Do.
Not given, presumably low.[1]	Skull	1	.059	Klement (*19*).
	"Long bones"	[2]	.070	Do.
	Rib	11	0.048–.21	Roholm (*1*).
0.1	Iliac crest	13	[3] .028–.128	Martin (*8*).
	Rib	83	.006–.252	Smith and associates (*7*).
	Vertebra	83	.005–.331	Do.
0.0–0.5	Rib	25	.115–.687	Glock and associates (*6*).
1.0	Iliac crest	20	.034–.132	Present study.
	Rib	30	.033–.207	Do.
	Vertebra	31	.040–.238	Do.
	Sternum	5	.078–.188	Do.

[1] Designated as "normal" individuals.
[2] Not given.
[3] Data originally given on dry, fat-free basis; calculated to ash basis assuming mean ash value of 59.0 percent for iliac crest from present study.

Table 7. Percentage fluoride in human bone ash from high-fluoride areas

Fluoride level of water (ppm)	Bone	Number of samples	Fluoride in bone ash (percent)	Source of data
2.0	Rib	4	0.12 –0.35	Boissevain and Drea (*3*)
5.9 and 6.3	Miscellaneous	15	1.47 –2.21	Kilborn and associates (*5*)
4.4–12.0	Sternum	1	.69	Linsman and McMurray (*4*).
	Vertebra	1	.75	Do.
8.0	Miscellaneous	8	.715–.967	McClure and associates.[1]
1.0–4.0	Iliac crest	33	.157–.872	Present study.
	Rib	35	.150–.843	Do.
	Vertebra	36	.208–1.103	Do.

[1] This issue of *Public Health Reports*, pp. 741–746.

dry, fat-free iliac crest, rib, and vertebra were similar. On an ash basis, however, the fluoride concentration of the vertebra was significantly higher than that of the rib at fluoride levels up to 2.6 ppm. At higher amounts of fluoride in the drinking water, this difference did not obtain.

Previous studies dealing with fluoride deposition in the white rat (*20–22*) and urinary fluoride excretion by the rat (*23*) and by man (*24, 25*) have indicated that as bone ages it may lose some of its capacity to store fluoride. This decrease in fluoride deposition with increasing age has been presented in graphic form by Hodge (*26*) based on the data on man of Smith and associates (*7*). In the present study, most of the subjects were of advanced age, and the means for the four groups varied only from 55.5 to 75.6 years. Hence, on the one hand, it was unlikely that a relation between fluoride deposition and age would be apparent; on the other hand, the age factor would tend not to bias any relation between bone fluoride and water fluoride.

From this extensive survey on the fluoride content of human skeletal tissues, it appears that the deposition of fluoride is directly related to the fluoride content of the drinking water up to 4.0 ppm. The deposition of fluoride in dentin and enamel is also elevated proportionately with an increasing concentration of fluoride in the drinking water (*27*).

There is no indication in these data or in those of previous studies that these human calcified

tissues approach their theoretical capacity of about 3.5 percent fluoride, although drinking water containing as much as 4.0 ppm fluoride was ingested. Prolonged exposure to the water of Colorado Springs, Colo., and Amarillo, Tex. (2.6 ppm fluoride), and to that of Lubbock, Tex. (4.0 ppm fluoride), elevated the fluoride content of the bone ash to a maximum of 1.080 and 1.103 percent, respectively.

The data from the five subjects of Grand Rapids, Mich., are of special interest. Exposure to water containing 1 ppm fluoride did not exceed 12 years, and the average age of the subjects at the time they started to use fluoridated water was about 63 years. Nevertheless, a mean concentration of 0.146 percent fluoride on a dry, fat-free basis was found in these relatively old bones, compared with an average value of 0.049 percent in the bones of individuals of an average age of 56 years ingesting water containing less than 1.0 ppm fluoride.

The fluoride data in the present study coupled with the microscopic findings on essentially the same individuals constitute substantial evidence that a concentration of fluoride as high as 0.548 percent in the dry, fat-free bone and 1.080 percent in the bone ash (for subjects in both studies) may be present without producing any apparent tissue damage.

Summary

Selected bones and skeletal tissue—iliac crest, rib, vertebra, sternum, and intervertebral cartilage—obtained from 69 individuals 26 through 90 years of age who had drunk water containing 0.1 to 4.0 ppm fluoride for at least 10 years were analyzed for ash and fluoride. These bones, which showed no significant histological changes, contained up to 0.548 percent fluoride on a dry, fat-free basis and 1.080 percent fluoride on an ash basis. The mean ash content of the iliac crest and ribs varied from 57.4 to 61.2 percent and that of the sternum and vertebra from 44.6 to 53.7 percent.

At any given level of fluoride in the drinking water, the various bones contained, on a dry, fat-free basis, similar concentrations of fluoride. The fluoride concentration of the intervertebral cartilage was considerably less than that of the bones.

The concentration of fluoride in the bones increased in an essentially linear fashion with an increase of fluoride in the drinking water up to 4.0 ppm.

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Training in Radiological Health

Sanitary Engineering Center. A course in the medical and biological aspects of radiological health will be given at the Robert A. Taft Sanitary Engineering Center, Public Health Service, October 20-31, 1958. Designed for medical, dental, and biological personnel responsible for program decisions in Federal, State, and local health agencies, the course will present data pertinent to radiological health program planning, with emphasis on radiation exposure in the healing arts.

Areas to be covered include biological effects of radiation, philosophy and procedures of radiation protection, practical methods of reducing exposure from medical and dental X-rays, administrative problems of a radiological health program, and the current status of legislative and regulatory procedures.

No previous formal training in radioactivity or radiation is necessary, and there are no tuition or fee charges. Application forms and further information concerning the course may be obtained from the Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio.

University of Pittsburgh. Beginning in 1958-59, 2- and 3-year courses in the health aspects of nuclear technology leading to master's and doctor's degrees will be offered by the Graduate School of Public Health. Although focused on occupational and health aspects of nuclear reactors, the new program will cover the fields of health physics and radiation biology. In addition to graduate school facilities, other University Medical Center facilities and some community installations will be used.

Pittsburgh's radiation health training program, located in the department of occupational health, was made possible by a 10-year grant from the Rockefeller Foundation. An additional grant of $30,000 awarded by the Atomic Energy Commission will be used for equipment and instruments.

Applications and more information may be obtained from the Secretary, Graduate School of Public Health, University of Pittsburgh, Pittsburgh 13, Pa.