

A SIMPLE METHOD FOR DETERMINATION OF TOTAL FLUORIDE INTAKE

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SUMMARY: Determination of fluoride intake by human subjects must include the fluoride contribution through water and food. Fluoride intake through water means fluoride through drinking water and also through water used for cooking food. Thus fluoride intake through food must exclude the fluoride through water used for cooking, as the amount of water used for cooking depends on the diet pattern of the people. On this basis, the total fluoride intake by 80 subjects is determined in 3 fluorotic and 2 non-fluorotic areas. The fluoride intake through water is found less than that through food in the non-fluorotic areas and even in one low fluorotic area. People of highly endemic fluorotic areas however, are exposed to greater fluoride intake through water than through food.

KEY WORDS: Fluoride intake; Water fluoride; Food fluoride; Fluorosis; Endemic areas.

INTRODUCTION

The prevalence of fluorosis in an endemic area is normally interpreted on the basis of the percentage of fluorosis and the fluoride levels of the drinking water sources of the region. The fluoride concentration in the water samples of a region has necessarily to be reliable in order to establish the degree of fluorosis. The contribution of fluoride through food, water used for drinking and cooking and also through beverages, if any, constitute the total fluoride intake by the subjects.

While explaining the dietary intake of fluoride, either food alone or food and beverages at meal time or food, beverages and water at and between meals are to be considered as sources of fluoride. An easy and reliable method is employed successfully to determine the contribution of water and food to the total fluoride intake by the subjects of selected areas and the details of this method are reported here.

There have been several reports¹⁻³ in the literature about the role of fluoride through food and water and also the total fluoride intake by human subjects in explaining the prevalence of fluorosis in fluorotic areas. Evidence for quantitative attempts to develop a methodology to evaluate the contribution of water and food to the total daily intake of fluoride is lacking. The fluoride present in water used for the preparation of food and beverages should not be ignored even though the concentration of water is fairly low. In the absence of such precautions the results obtained may attribute to incorrect conclusions about the actual values of fluoride through food and water. Therefore the total fluoride intake must include the contribution of fluoride from food, water and also from other food drinks if any, the subjects consume during a prescribed period of study. A new workable methodology was developed to determine the contribution of fluoride through water and food in order to find out the total fluoride intake and the details are reported in the following pages.

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MATERIALS AND METHODS

Sampling: 80 human subjects were selected from five areas. Two areas were identified as control areas, C-I & CII with no fluorosis of any kind. The three others were identified as fluorotic areas of this investigation, F-I, F-II & F-III. The criteria adopted for the selection of areas were the same as reported earlier by the authors.⁴ Selection of families and subjects was done using purposive sampling technique⁵ from the five mentioned areas. Collection of samples of food and water consumed by the subjects was done for four alternate days. The exact quantity of diet and volume of drinking water consumed by each subject in a day were obtained separately in high-density polyethylene containers. The solid part and liquid part of the diet were analysed to determine the fluoride concentrations. The liquid diet was filtered and whatever solids remained in it was added to the solid diet. The solid diet was weighed and ground to a homogeneous mixture.

Analysis. The liquid diet and water were measured separately. 50 ml of the liquid diet sample was taken in a distillation flask. Sufficient AnalaR silver sulphate was added to precipitate the chlorides present. 50 ml of AnalaR 60 % perchloric acid was added and the distillate collected between 135 - 139 °C was neutralised using 0.2 N NaOH and analysed for fluoride.

TABLE 1. Utilised relationships and definitions.

Formula	Constituents	Definitions	Unit
$I_T = I_{DW} + I_D$	$I_{DW} = C_W \cdot V_W$	I_T Total daily intake per person,	$\text{mg} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
		I_D Intake through diet,	$\text{mg} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
		I_{DW} Intake through drinking water,	$\text{mg} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
		C_W Concentration of F in water,	mg/L
		V_W Volume of consumed water,	$\text{L} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
$I_D = I_{LD} + I_{SD}$	$M_D \approx V_{LD} + M_{SD}$	M_D Total amount of diet, *	$\text{kg} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
		I_{LD} Intake through liquid diet,	$\text{mg} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
		C_{LD} Conc. of F in liquid diet,	mg/L
	$I_{LD} = C_{LD} \cdot V_{LD}$	V_{LD} Volume of liquid part of diet,	$\text{L} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
		I_{SD} Intake through solid diet,	$\text{mg} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
		f_{SD} Fraction of F in solid part of diet,	mg/kg
		M_{SD} Mass of solid part of diet,	$\text{kg} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
$I_W = I_{DW} + I_{CW}$		I_W Total daily intake through water,	$\text{mg} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
		I_{DW} Intake through drinking water,	$\text{mg} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
		I_{CW} Intake through cooking water,	$\text{mg} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
$I_T = I_F + I_W$		I_F Intake through food alone,	$\text{mg} \cdot \text{c}^{-1} \cdot \text{d}^{-1}$
$I_F = I_T - I_W$			

* The water used for cooking was found to constitute 80 % of the total diet or for all practical purposes 1 litre of water per person per day.

TABLE 2. Fluoride intake through water and food/day by the selected human subjects in the control areas. Figures in columns 2- 6 are in mg F per capita per day. M ~ Male. F ~ Female. C ~ Child.

Subject No.	Intake through				Total	Water %	Food %
	Drink. Water	Cooking Water	Water	Food			
Control Area I (C-I Non-fluorotic)							
1. (M)	0.84	0.71	1.55	3.73	5.28	29.4	70.6
2. (F)	0.70	0.54	1.24	3.06	4.30	28.8	71.2
3. (C)	0.41	0.35	0.77	1.91	2.68	28.7	71.3
4. (C)	0.37	0.25	0.62	1.44	2.06	30.1	69.9
5. (M)	0.89	0.70	1.59	3.90	5.49	29.0	71.0
6. (F)	0.68	0.51	1.19	3.06	4.25	28.0	72.0
7. (C)	0.50	0.43	0.93	2.27	3.20	29.1	70.9
8. (C)	0.44	0.38	0.82	1.63	2.45	33.5	66.5
9. (M)	0.92	0.91	1.83	3.85	5.68	32.2	67.8
10. (F)	0.80	0.72	1.52	3.09	4.61	33.0	67.0
11. (C)	0.63	0.54	1.17	2.28	3.45	33.9	66.1
12. (C)	0.59	0.48	1.07	1.84	2.91	36.8	63.2
13. (M)	1.00	0.89	1.89	3.97	5.86	32.3	67.7
14. (F)	0.83	0.71	1.54	3.05	4.59	33.6	66.4
15. (C)	0.65	0.57	1.22	2.53	3.75	32.5	67.5
16. (C)	0.67	0.62	1.29	2.66	3.95	32.7	67.3
Ave	0.68	0.58	1.27	2.77	4.03	31.5	68.5
Control Area II (C-II Non-fluorotic)							
17. (M)	1.20	0.91	2.11	3.63	5.74	36.8	63.2
18. (F)	1.00	0.70	1.70	2.84	4.54	37.4	62.6
19. (C)	0.72	0.67	1.39	2.30	3.69	37.7	62.3
20. (C)	0.67	0.58	1.25	1.98	3.23	38.7	61.3
21. (M)	1.26	1.14	2.40	3.64	6.04	39.7	60.3
22. (F)	1.09	0.89	1.93	3.04	4.97	38.8	61.2
23. (C)	0.82	0.71	1.53	2.48	4.01	38.2	61.8
24. (C)	0.72	0.61	1.32	2.27	3.59	36.8	63.2
25. (M)	1.21	0.89	2.10	3.87	5.97	35.2	64.8
26. (F)	0.99	0.74	1.73	3.01	4.74	36.5	63.5
27. (C)	0.75	0.64	1.39	2.68	4.07	34.2	65.8
28. (C)	0.58	0.47	1.05	1.98	3.03	34.7	65.3
29. (M)	1.22	1.14	2.30	3.81	6.17	38.2	61.8
30. (F)	0.98	0.89	1.87	3.21	5.08	36.8	63.2
31. (C)	0.67	0.59	1.20	1.85	3.11	40.5	59.5
32. (C)	0.62	0.40	1.08	1.58	2.60	40.6	59.4
Ave	0.91	0.75	1.65	2.76	4.41	37.6	62.5

TABLE 3. Fluoride intake through water and food/day by the selected human subjects in the fluorotic areas. Figures in columns 2- 6 are in mg F per capita per day. M ~ Male. F ~ Female. C ~ Child.

Subject No.	Drink. Water	Cooking Water	Intake through:		Total	Water %	Food %
			Water	Food			
Fluorotic Area I (F-I)							
33. (M)	1.47	1.26	2.73	8.35	11.08	24.6	75.4
34. (F)	1.18	0.97	2.15	6.95	9.10	23.6	76.4
35. (C)	1.00	0.81	1.81	5.52	7.33	21.7	75.3
36. (C)	0.83	0.70	1.53	4.42	5.95	25.7	74.3
37. (M)	2.15	1.61	3.76	7.31	11.07	34.0	66.0
38. (F)	1.77	1.21	2.98	5.36	8.34	35.7	64.3
39. (C)	1.03	0.92	1.95	3.55	5.50	35.5	64.5
40. (C)	0.98	0.64	1.62	2.80	4.42	36.7	63.3
41. (M)	2.06	1.66	3.72	8.71	12.43	29.9	70.1
42. (F)	1.69	1.30	2.99	6.76	9.75	30.7	69.3
43. (C)	1.29	1.03	2.32	5.77	8.09	28.7	71.3
44. (C)	1.14	0.94	2.08	5.06	7.14	29.1	70.9
45. (M)	1.48	1.29	2.77	8.54	11.31	24.5	75.5
46. (F)	1.15	0.94	2.01	7.14	9.23	22.6	77.4
47. (C)	0.88	0.71	1.59	4.90	6.49	24.5	75.5
48. (C)	0.74	0.57	1.31	3.64	4.95	26.5	73.5
Ave.	1.30	1.04	2.33	5.92	8.26	28.4	71.4
Fluorotic Area II (F-II)							
49. (M)	5.20	2.96	9.16	8.61	17.77	51.5	48.5
50. (F)	4.28	3.08	7.36	6.21	13.57	54.2	45.8
51. (C)	3.18	2.66	5.84	5.76	11.60	50.3	49.7
52. (C)	2.94	2.33	5.27	4.82	10.09	52.2	47.8
53. (M)	4.56	4.07	8.63	6.28	14.91	57.9	42.1
54. (F)	3.59	3.18	6.77	5.68	12.45	54.4	45.6
55. (C)	2.29	1.76	4.05	3.10	7.15	56.6	43.4
56. (C)	2.49	1.99	4.48	3.63	8.11	55.2	44.8
57. (M)	4.56	3.90	8.46	8.72	17.18	49.2	50.8
58. (F)	3.51	3.04	6.55	7.93	14.48	45.2	54.8
59. (C)	3.12	2.72	5.84	5.48	11.32	51.6	48.4
60. (C)	2.85	2.27	5.12	5.18	10.30	49.7	50.3
61. (M)	5.26	3.89	9.15	7.09	16.24	56.3	43.7
62. (F)	4.27	3.10	7.37	5.62	12.99	56.7	43.3
63. (C)	3.01	2.14	5.15	4.71	9.86	52.2	47.8
64. (C)	3.19	2.71	5.90	4.78	10.68	55.2	44.8
Ave.	3.64	2.86	6.57	5.85	12.42	53.0	47.0

TABLE 3 (continued)

Fluorotic Area III (F-III)

65. (M)	15.68	13.61	29.29	3.14	32.43	90.3	9.7
66. (F)	12.36	10.14	22.50	3.66	26.16	86.0	14.0
67. (F)	14.49	9.07	23.56	3.27	26.83	87.8	12.2
68. (M)	11.55	11.26	22.81	2.42	25.23	90.4	9.6
69. (F)	11.17	9.04	20.21	3.68	23.83	84.6	15.4
70. (M)	16.17	13.33	29.50	3.35	32.85	89.8	10.2
71. (F)	13.27	10.42	23.69	3.20	26.89	88.1	11.9
72. (F)	11.45	8.74	20.19	3.22	23.41	86.2	13.8
73. (C)	8.37	6.61	14.98	3.33	18.31	81.8	18.2
74. (C)	7.11	5.85	12.96	2.49	15.45	83.9	16.1
75. (C)	10.33	9.30	19.63	3.68	23.31	84.2	15.8
76. (C)	9.87	9.04	18.91	3.72	22.63	83.6	16.4
77. (C)	8.65	6.80	15.45	3.28	18.73	82.5	17.5
78. (C)	9.66	8.01	17.67	3.44	21.11	83.7	16.3
79. (C)	8.86	7.39	16.25	3.51	19.76	82.2	17.8
80. (C)	10.47	8.62	19.09	4.02	23.11	82.6	17.4
Ave.	11.22	9.20	20.42	3.34	23.75	85.5	14.5

100 g of solid diet sample was taken for analysis. The procedure for analysis was based on the classical Willard-Winter distillation method⁶ and the distillate was analysed for fluoride.

The fluoride contents of drinking water and food parts were determined using fluoride ion selective electrode and an expandable ion analyser EA 920 Orion USA⁷.

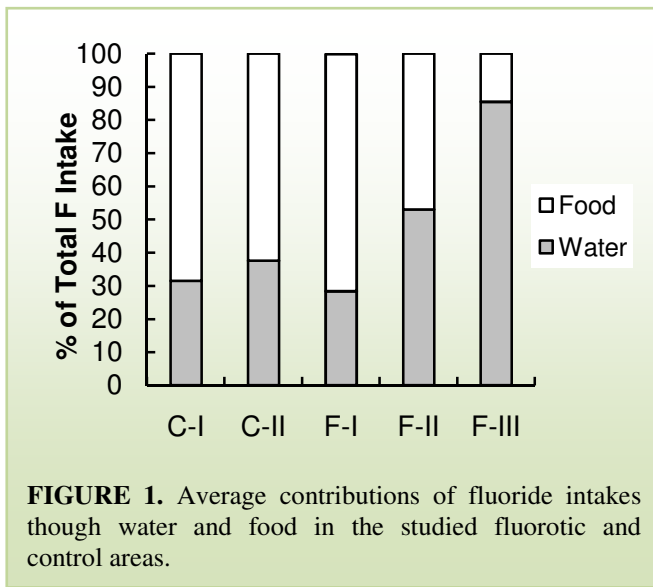
Calculation of total intake per day: The total intake of fluoride in mg per person per day, I_T , is the sum of the intakes from drinking water, I_{DW} , and from the diet, I_D . The total intake through water, I_W , is however the sum of intakes from drinking water, I_{DW} , and from cooking water I_{CW} . The intake through food, I_F , alone may be calculated as the difference between the total intake, I_T , and the intake through cooking and drinking water, I_W . The intake through diet, I_D , is the sum of intakes through liquid part of diet, I_{LD} , and solid part, I_{SD} . These relationships are indicated in table 1.

RESULTS AND DISCUSSION

The proposed methodology was utilised by the investigators to determine the fluoride intake through water and food per day by the selected human subjects of the five areas. The results obtained along with the percentage intake of fluoride through water and food separately are presented in tables 2 and 3.

From table 2 & 3 it is seen that the contribution of fluoride intake through water is on an average much less in control and low fluoride areas C-I, C-II & F-I, compared to the fluorotic areas, respectively 35 and 57 % of the total intake. Accordingly the food contribution is found to be 65 and 43 % of the total intake in the control areas and in the fluorotic areas respectively. Thus, on average basis, food fluoride contributed more towards total fluoride intake in the non-fluorotic and low fluoride areas, while water fluoride contributed more in the high fluoride areas F-II & F-III, Figure 1.

This means that the contribution of fluoride through water is, in some fluorotic areas, less than that through food. On the other hand fluorotic areas II and III are highly endemic as reported earlier by the authors⁴. The fluoride level of drinking water in area III varies between 4 to 9 mg/L. Our results show that the fluoride contribution through water varies from 82 to 90 percent while the same through food is only between 10 and 18 percent.



Thus our results confirm that people of highly endemic fluorotic areas are exposed to greater fluoride intake through water and this is responsible for the increased prevalence of fluorosis. This simple method is employed successfully to identify the dominant factor(s) causing fluoride toxicity of the areas.

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