October, 1988 Vol. Twenty-one, No. Four

FLUORIDE

OFFICIAL QUARTERLY JOURNAL

OF

INTERNATIONAL

SOCIETY for

FLUORIDE

RESEARCH

Vol. Twenty-one, No. Four October, 1988 Pages 163-224

FLUORIDE

Quarterly Reports

Issued by

THE INTERNATIONAL SOCIETY FOR FLUORIDE RESEARCH

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AN INVITATION TO BUDAPEST

The 17th Conference of the International Society for Fluoride Research will be held June 22-25, 1989, at the Sporthall in Budapest, Hungary. All interested scientists are welcome.

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SUBSCRIPTION RATES — Price per annum in advance, including postage: $30.00. Single copies, $8.50.

MANUSCRIPTS for publication should be submitted in English, doublespaced with generous margins. References should be arranged according to the order in which they are cited in the text, and written as follows: Author, title, journal, volume, pages and year. Each paper must contain a summary ordinarily not exceeding 15 lines. Papers are accepted for publication after favorable evaluation and recommendation by qualified reviewers.

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ENVIRONMENTAL FLUORIDE PROBLEMS IN CHINA

Through improved and greater use of industrial emission control systems, airborne fluoride pollution has been substantially reduced in many parts of the world. In China, however, as in a number of other countries, serious problems with fluoride still exist. In fact, in certain regions of China, a critical issue confronting the government is an extremely high prevalence of endemic fluorosis.

Since 1946, when Lyth (1) first reported four cases of skeletal fluorosis in the southwestern province of Guizhou, many papers dealing with different aspects of China's environmental fluoride problems have been published. According to Wang et al. (2), except for Shanghai, endemic fluorosis is widespread throughout China's primary administrative districts, including 22 provinces, 2 municipalities, and 5 autonomous regions. In all, an estimated 40 million persons out of a total population of 1.1 billion are afflicted with dental and/or skeletal fluorosis. To cope with this enormous problem, the Department of Hygiene has established an endemic disease prevention and treatment research institute in each administrative district.

The nature of endemic fluorosis in China varies with geographical regions. In the northern provinces, for example, fluorosis appears to be caused mostly by high levels of F in drinking water, as indicated by studies done in Xinjiang (2) and Inner Mongolia (3). In a survey of 4.1 million inhabitants of Inner Mongolia, 1.9 million had dental fluorosis, and 230,000 were afflicted with skeletal fluorosis (3). A high correlation was demonstrated between the prevalence and severity of the disease and F levels in the drinking water. In this region the quality of drinking water has been improved by changes in the water supplies of 1100 areas and communities and by installation of F-removal systems in more than 70,000 dwellings. Altogether, more than 1.4 million inhabitants of Inner Mongolia have now been spared the risk of fluorosis. For sucessfully undertaking such an enormous task, the government is certainly to be commended.

Whereas waterborne fluoride is the primary cause of endemic fluorosis in many northern regions of China, foodborne fluoride is apparently its principal source in some southern ones. For example, researchers at Guiyang Medical College observed in 1976 that 98% of the inhabitants of Bijie County, located in the western part of Guizhou Province, had fluorotic dental mottling (4). Subsequent radiological studies on 211 adults revealed 34 cases (16%) of skeletal fluorosis manifested by osteosclerosis, ossification of tendons, and multiple bony exostoses (5), all of which are typical clinical features of fluorosis associated with waterborne fluoride. Analysis of the drinking water, however, indicated an average F level of only 0.18 ppm thereby prompting investigation into other possible sources of F intake. Major food items customarily eaten by the inhabitants, such as rice, wheat, corn, soybeans, and cabbage, were found to contain high levels of fluoride. From the data, F intakes by the inhabitants were estimated to be as high as 7.6 mg/day.

In view of such high dietary F intakes as well as elevated urinary F levels (6.9 ppm) in these areas compared to those of controls (0.8 ppm), it was concluded that not only dental but also skeletal fluorosis can be induced by fluoride in food as well as in drinking water (5). Indeed, this investigation

represents the first detailed account of food-induced skeletal fluorosis, as reported in This Journal in 1981 (6). Subsequent studies in other parts of China have resulted in similar findings.

The high F levels in agricultural crops in Bijie County have been traced to acidic soils which, because they are less likely to convert F into insoluble forms, presumably dissolve more F, thereby making it more available to vegetation, including crops (5). Moreover, the widespread practice of treating produce harvested in the area with smoke derived from the combustion of coal having a high F content undoubtedly makes an additional contribution to the elevated F level of these crops (7).

The effect of airborne fluoride on human health in China is another area of increasing concern, especially among exposed workers in metallurgical industries (8,9). Data from a survey of 63 fluoride-emitting industries correlated closely with the health status of about 10,000 workers in them. Among those surveyed, 3.2% exhibited symptoms of industrial (skeletal) fluorosis, with the highest incidence among pot-room workers in aluminum plants (10). Unfortunately, fluoride-related health effects are also beginning to be observed among the general population living near industrial plants (11,12). Thus the introduction of effective fluoride emission control systems remains a vital challenge for various industries in China.

Finally, there is the frequently asked question concerning fluoridation of drinking water for the prevention of dental caries. In China, effective measures to prevent and deal with tooth decay are likewise an important health goal. According to a 1980 survey, 37.3% of 4.5 million inhabitants who were examined had dental caries with an average rate of 2.47 caries per person (13). In Guangzhou City, an earlier survey done from 1960 to 1966 showed that 63.8% of the elementary and middle school children had dental caries (13). Because the F concentration of the drinking water was 0.2 to 0.3 ppm, the city government appointed a study group to consider fluoridation of the water supply, which was then initiated for the first time in China in November 1965. Average F levels were set at 0.6-0.8 ppm in summer and 0.8-1.0 ppm in winter. Fluoridation continued in Guangzhou for nearly 18 years until September 1983.

As early as 1976, however, heated debate began to occur about the efficacy and other aspects of fluoridating the water supply. Although the percentage of school-age children with dental caries had decreased from 63.8% to 38.3%, the prevalence of mottled teeth had increased eightfold, from only 6.8% to 54.8%. Also noted was the fact that F intake depends not only on waterborne F but likewise on foodborne and airborne F. The total F intake by children in the city was estimated at 2.83 mg/day (16), which clearly exceeds the World Health Organization's recommended maximum of 2 mg/day for children. Moreover, it was also recognized that the observed reduction in dental caries might be due as much to improvements in oral hygiene as to fluoridation. In September 1983, following a critical assessment of both the positive and negative aspects, fluoridation was terminated in Guangzhou City.

In 1978 the Department of Hygiene appointed a special study and coordination task force of scientists from 18 provincial research institutes to evaluate

and propose fluoride standards for drinking water. On the basis of findings from a 4-year national survey, the group make the following three major recommendations: (i) reduction of F levels in drinking water from 1 mg/L (1 ppm) to 0.6 mg/L; (ii) permission to exceed the F level of 0.6 mg/L but not to exceed 1.0 mg/L in areas where the incidence of mottled teeth among inhabitants is below 15% and the total F intake is less than 3 mg/day; and (iii) abandonment of the conventional F standard of 0.5 to 1.0 mg/day in view of difficulties in conducting an appropriate national examination survey as well as possible adverse health effects that could result from it.

Obviously, these recommendations were made in recognition of the fact that, in setting fluoride standards for drinking water, one must consider not only the F concentration in the water but also the F content of foods consumed in the area.

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EDITOR'S NOTE: The Japanese language journal Fusso Kenkyu (Fluoride Research) referred to above is published, according to CASSI Quarterly Abstracts, in Japanese with English summaries, by

Fusso Kenkyukai (Japanese Society for Fluoride Research)
c/o Yanagisaun Seijinbyo Kenkyusho
403 Shibuya Roiyaru Building
3-9-2 Shibuya
Shibuya-ku, Tokyo 150, Japan

Correction: 21:162, 1988, Paragraph 5, line 1, substitute Victoria (Australia) for New Zealand.

FLUORIDE IN TOOTHPASTE: CAUSE FOR CONCERN

by

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Madras, India

SUMMARY: This study, conducted to determine whether fluoride enters the blood circulation when fluoridated toothpaste is used for brushing, reveals that, within minutes after brushing, circulatory levels of fluoride are enhanced. Experiments in rabbits by applying different quantities of fluoridated toothpaste on the abdominal surface showed that the rise in the blood circulation level of fluoride is directly related to the quantity of fluoridated toothpaste applied.

KEY WORDS: Serum fluoride; Toothpaste.

Introduction

Fluoride added to toothpaste for prevention of dental caries (cavities), a practice which started in the Western world, is widely accepted in India and in developing countries without regard for the health status of the people, climatic conditions, poor nutritional standards and fluoride contamination in drinking water and food. During the last 15 years the Indian market has been flooded with various brands of fluoridated toothpaste which contain from 1000 to 1500 ppm of fluoride, a fact that is not revealed on the carton. The maximum amount of fluoride tolerated by humans with minimum harm is said to be 1 ppm (1). One quart of water fluoridated at 1 ppm contains 1 mg, the daily amount considered safe by health officials. Most raw material used for manufacturing toothpastes namely chalk, talc and calcium carbonate, contains high amounts of fluoride as a contaminant (2). Yet, it is claimed that topical application produces no harmful side-effects.

This report aims to reveal the extent of absorption of fluoride from toothpaste and the levels of fluoride in human circulation before and after brushing with fluoride-containing toothpaste as well as whether it penetrates the skin surface of rabbits maintained under laboratory conditions.

Materials and Methods

To test the rate of absorption of fluoride from toothpaste, the hair on the abdominal surface of the skin of 3 normal, healthy, adult rabbits, was shaved after which 1, 2 and 3 g of toothpaste containing 1100 ppm fluoride was applied and the area bandaged. Serum fluoride level before and 30 min., 24 hrs., 48 hrs. and 72 hrs. after application was estimated using the method of Jardiller and Desmet (3) and Orion meter with fluoride electrode (Table 1).

In addition, 10 children, aged 5-10 years were instructed to brush their teeth once a day, in the morning, with 0.8 g of fluoride toothpaste which contained 1100 ppm of fluoride. Blood samples were drawn before brushing

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and on the 3rd, 6th and 9th day after brushing. The serum samples were analyzed for fluoride using the above-cited method (Table 2).

The third set of experiments, was carried out on 10 children, aged 10-14 years. Serum fluoride content before and 5 minutes after brushing with fluoride-containing toothpaste was estimated on the 3rd, 6th and 9th day (Table 3).

Table 1

Serum Fluoride Leven [in ppm] in Rabbits Before and After Application of Fluoride Toothpaste on the Skin

Animal	Quantity of paste applied [gm]	Serum fluoride level before application	Serum fluoride level after application			
			30 min.	24 hrs.	48 hrs.	72 hrs.
Rabbit 1	1.0	0.004	0.012	0.021	0.033	0.044
Rabbit 2	2.0	0.015	0.025	0.040	0.051	0.053
Rabbit 3	3.0	0.015	0.031	0.048	0.068	0.075

Table 2

Serum Fluoride Level [in ppm] in Children of 5-10 Years Using Toothpaste [containing fluoride] once a day

Subject	Age [Yrs.]	Serum fluoride before using fluoride paste	Serum fluoride in ppm after using paste		
			3rd day	6th day	9th day
1	5	0.014	0.029	0.038	0.037
2	8	0.014	0.045	0.045	0.054
3	8	0.013	0.015	0.038	0.043
4	9	0.013	0.017	0.038	0.038
5	9	0.013	0.028	0.034	0.063
6	9	0.013	0.048	0.075	0.070
7	9	0.012	0.036	0.037	0.057
8	10	0.012	0.008	0.005	0.027
9	10	0.010	0.007	0.005	0.012
10	10	0.013	0.028	0.030	0.034
Mean ±S.D.		0.013 ±0.0012	0.026 ±0.014	0.034 ±0.019	0.046 ±0.017
Student's 't' test			$p < 0.01$	$p < 0.005$	$p < 0.001$

Results and Discussion

After applying 1 g of fluoride toothpaste to the abdominal skin of rabbits, serum fluoride content rose from 0.004 to 0.044 ppm; 2 g caused the fluoride level to rise from 0.015 to 0.053 ppm; with application of 3 g of paste the serum fluoride content rose from 0.015 ppm to 0.075 ppm. In all three groups, even 30 minutes after application, circulating levels of fluoride increased.

Table 3

Serum Fluoride Level [in ppm] in Children of 10-14 Years, Using Toothpaste [containing 1100 ppm of Fluoride] Before Brushing and 5 Minutes After Brushing

Subject	Age (Yrs.)	1st day		3rd day		6th day		9th day	
		Before brushing	5 min. after brushing	Before brushing	5 min. after brushing	Before brushing	5 min. after brushing	Before brushing	5 min. after brushing
1	10	0.032	0.039	0.003	0.020	0.030	0.034	0.042	0.052
2	10	0.047	0.048	0.048	0.047	0.063	0.069	0.063	0.075
3	10	0.022	0.024	0.021	0.024	0.045	0.038	0.038	0.060
4	12	0.037	0.036	0.008	0.036	0.051	0.066	0.069	0.075
5	12	0.021	0.026	0.033	0.050	0.066	0.048	0.049	0.074
6	13	0.024	0.044	0.022	0.050	0.075	0.068	0.060	0.127
7	13	0.023	0.024	0.014	0.029	0.039	0.042	0.036	0.038
8	14	0.023	0.030	0.050	0.058	0.063	0.075	0.051	0.052
9	14	0.024	0.027	0.014	0.015	0.038	0.054	0.031	0.051
10	14	0.030	0.031	0.017	0.021	0.033	0.056	0.022	0.033
Mean ± S.D.		0.028 ±0.008	0.033 ±0.0085	0.023 ±0.016	0.035 ±0.015	0.053 ±0.015	0.056 ±0.012	0.046 ±0.015	0.064 ±0.027
Paired 't' test		$p < 0.05$		$p < 0.01$		NS		$p < 0.025$	

Since abdominal skin absorbs fluoride, the highly vascularized oral mucosa may also absorb fluoride and cause the circulatory fluoride level to rise following use of fluoride-containing toothpaste for brushing. This hypothesis was tested in human subjects. In children 5 to 10 years old fluoride content in serum on the 3rd, 6th and 9th day was higher than serum fluoride levels prior to brushing (Table 2).

Table 3 reveals that, except in one subject each on 1st and 3rd and 3 subjects on the 6th day, all serum fluoride levels on 3rd, 6th and 9th day were enhanced after brushing with fluoridated toothpaste. The increase in the same subject from a mean value of 0.033 ppm to 0.064 ppm was steady. The basal fluoride level ranged from 0.028 ppm to 0.046 ppm. Thus fluoride from the serum may be transported and possibly deposited in tissues which have a high affinity to bind with fluoride, or alternatively it is excreted. Thus fluoride from paste which enters the circulation constitutes an additive or cumulative effect.

In a recent report on the salivary fluoride level after brushing with fluoride-containing toothpaste, fluoride in saliva was enhanced; the level of fluoride returned to normal within 60 min. indicating clearance of salivary fluoride through the gastro-intestinal tract (4).

Conclusion

This is one of the first reports from the Indian subcontinent to reveal, by experiments on human and animals, that fluoride from fluoridated toothpaste enters the blood circulation minutes after brushing. It is not scientifically justified to add fluoride to toothpaste in a country like India where salt and every food item is contaminated by fluoride and where a large proportion of the population, young and old, is already afflicted with dental and skeletal fluorosis and an equal number is suffering from non-skeletal manifestations due to fluoride toxicity.

Acknowledgement

Gratitude is expressed for grants-in-aid from the Department of Environment, Ministry of Environment and Forests, Government of India, and to Dr. A.K. Susheela of the All India Institute of Medical Sciences, New Delhi, for her comments, criticism and helpful suggestions in preparation of this manuscript.

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ESTIMATION OF FLUORIDE CONTENT OF TOOTHPASTE

by

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SUMMARY: Most of the toothpastes marketed in India contain fluoride either added or as an impurity in the raw material. The object of this study was to evaluate sensitivity of the ion selective electrode methods to estimate fluoride in toothpastes. Those identified as fluoridated, nonfluoridated, herbal and homeopathic and the effect of varying concentration and stirring time were evaluated by four techniques of conversion of fluoride into fluoride ions. In water suspension methods the release of fluoride is dependent on weight of the paste and volume of TISAB solution added to the sample. The composition of the paste is also related to the release of fluoride. All pastes except two showed the presence of fluoride by all four methods. The values obtained by water suspension and TISAB boiling were in good agreement with each other.

KEY WORDS: Fluoride in toothpaste; Four methods of F measurement.

Introduction

Topical application of fluoride to the tooth surface for prevention of caries (1) commenced in 1941. Some of these topical fluoride agents are sodium fluoride, stannous fluoride, acidulated phosphate fluoride, sodium monofluorophosphate and amine fluoride. Commerical preparations are mouth rinses, gels, varnishes, dentifrices and tablets. Varied geological strata and rainfall pattern in India, results in different concentrations of fluoride in foods and waters; almost every known food stuff and water source contains at least traces of fluoride. The fluoride content of the main food grains of India namely rice, wheat, jawar and bajara are 1.4-11.4 mg/L, 1.2-17.4 mg/L, 1.3-14.0 mg/L, 1.0-10.6 mg/L, respectively (2), all of which contribute to fluoride intake.

The incorporation of fluoride into toothpaste as a cariostatic agent and its commercialization on a large scale has generated concern, particularly where fluorosis is endemic. Ingredients and concentration of fluoride is not specified in most products; moreover some toothpastes, although not labelled, contain fluoride. For this reason, a study of analytical techniques for estimation of fluoride is relevant.

Analytical procedures to estimate fluoride in toothpastes are either potentiometric or gas chromatographic (3). The present study aimed to evaluate sensitivity of analytical methods. The procedures for estimation of the fluoride requires knowledge of the approximate fluoride content of toothpaste and lack of interference (4). When fluoride concentration is below 10 ppm, the

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possibility of loss of fluoride by association or formation of insoluble fluoride is minimized (5). Soluble and insoluble fluoride depend upon the composition of toothpaste, the fluoride compounds used and the additives like surfactants and glycerine (6). Fluoride that leached from toothpaste at room temperature under control experimental conditions was termed "soluble." Total fluoride was estimated by ashing, distillation and conversion into trimethylfluorosilane using GL Chromatography. The procedures of leaching at room temperature and the technique of ashing followed by distillation are two extremes and are not likely to simulate the natural conditions of use of fluoride toothpastes.

Materials and Methods

Samples of toothpaste were obtained from A.I.I.M.S., New Delhi and market. Toothpastes, identified as per carton information, were grouped as i) Fluoridated; ii) Nonfluoridated; iii) Homeopathic; and iv) Herbal. The investigated homeopathic toothpaste was labelled "natrum fluoratum" as its ingredient, not as fluoride bearing. Similarly a toothpaste containing disodium monofluorophosphate was not specified as fluoridated.

Specific ion meter (Ionalyzer, 407A, Orion Research, Ins., USA) and Fluoride Selective Electrode were used in estimations. Four methods were used in these studies: three replicates were carried out for each paste and every method used for arriving at the average fluoride concentration.

a) Water Suspension: The fluoridated and nonfluoridated toothpastes, taken in the ranges 0.1-0.3 g and 0.5-0.6 g respectively in polyethene beakers, were stirred with 25 mL of distilled water for 10 minutes and volume was made up to 100 mL volumetrically. TISAB (Total Ionic Strength Adjustment Buffer) was added in 1:1 proportion.

b) Boiling with TISAB Solution: A weight of toothpaste (0.2-0.5 g) was stirred with 1-2 mL distilled water. Fifty mL TISAB was added and boiled with stirring. The contents were allowed to cool to room temperature and volume made to 100 mL.

c) Acid Hydrolysis: A weight of the toothpaste (about 0.5 g) was dissolved in 10 mL of 1N HCl and pH was adjusted to 5.0-5.5 with 1N NaOH. The volume was made to 100 mL. TISAB was added in 1:1 proportion.

d) Distillation: Toothpaste (0.5-2.0 g) was quantitatively transferred into fluoride distillation assembly. Sixty mL sulphuric acid (24N) was added dropwise until effervescence subsided, thereafter rapidly. All distillate above 120°C was collected and the temperature of the contents in the distillation flask was maintained in the range 145-150°C. Nearly 600-700 mL of distillate was collected and the pH was adjusted to 5-6. The final volume was made to 1000 mL with distilled water and estimations were done as in a) and c) above.

Results and Discussion

Experiments were initially carried out using TISAB III (Orion Research, Inc., USA) and laboratory made TISAB solution to find out interference, if any. The results are given in Table I. The difference in estimation was 3%.

The effect of variation in stirring time on estimation was also studied

Table 1

Estimation of Fluoride in Toothpaste Using Different TISAB.

No.	Wt. of Paste (g)	CDTA TISAB (mg/g)	Sodium Citrate TISAB (mg/g)	Difference
1	0.2574	0.543	0.524	+0.019
2	0.2574	0.543	0.524	+0.019
3	0.2574	0.524	0.524	+0.000
4	0.2574	0.524	0.505	+0.019
5	0.1763	0.527	0.545	-0.018
6	0.1763	0.538	0.510	+0.028

and data are presented in Table 2. The stirring period did not show any difference but recovery was decreased with increased sample weight. Stirring period of 10 minutes was subsequently used in all estimations. The observations indicate that the estimated fluoride depends not only on the initial fluoride and complexing matter of the sample but also on the availability of adequate TISAB to release fluoride from complexation. The difference in fluoride values of filtered and unfiltered samples was large as shown in Table 2. The influence of weight of toothpaste on water leachable fluoride was determined (Table 3). Estimated fluoride decreased with increased weights of samples.

There are two possibilities: either the TISAB solution was not adequate or dispersal could not extract total fluoride. It was also observed that the

Table 2

Effect of Variation on Stirring Period on Water Soluble Fluoride

No.	Wt. of Paste (g)	Stirring Time (minutes)	Fluoride (mg/g)	
			Whole Sample	Filtered
1	0.1763	10	0.545	0.190
2	0.5792	10	0.466	0.138
3	0.5792	40	0.448	0.138
4	0.5792	60	0.466	0.138
5	0.5792	80	0.466	–
6	0.9575	10	0.480	0.167
7	0.9575	20	0.470	0.167
8	0.9575	20	0.480	0.167
9	0.9575	40	0.480	–
10	0.9575	50	0.480	–
11	0.9575	100	0.480	–

Table 3

Water Soluble Fluoride at Different Concentrations of Paste in Dispersion

(Method A)

No.	Wt of Paste (g)	F (mg/g)
1	0.1763	0.545
2	0.2574	0.52
3	0.5792	0.466
4	0.9575	0.480
5	1.2928	0.364
6	3.3159	0.157

Table 4

Fluoride by Acid Hydrolysis at Different Concentrations of Paste in Dispersion.

(Method C)

No.	Wt. of Paste (g)	F (mg/g)
1	0.2709	0.22
2	0.5363	0.237
3	0.8751	0.223
4	1.127	0.239
5	1.594	0.24
6	2.5	0.24
7	2.99	0.23
8	5.08	0.23

leaching of fluoride depends upon other ingredients of toothpaste. Instrument took longer to attain steady state (7-8 minutes) with unfiltered samples compared to filtered and treated samples. Table 4 shows fluoride by acid hydrolysis. The samples were 0.27 g to 5.08 g and the fluoride was estimated at 220 to 240 mg/kg, which revealed that acid hydrolysis released all fluoride and the values were not dependent on the quantity of toothpaste. The data in Tables 1 through 4 suggests that the sample of toothpaste for analysis should be about 0.2 g and that 10 minutes stirring time was sufficient for dispersion of toothpaste. In the presence of a large excess of TISAB the estimation of fluoride was not adversely influenced.

Table 5 shows that 18 out of 20 toothpastes leach fluoride, even under mild extraction procedures such as water suspension. The remaining two toothpastes gave 30 mg/kg fluoride by distillation method. Occurrence of fluoride in labelled and other toothpastes suggests fluoride is an impurity in the raw materials used for toothpaste. Non-fluoridated toothpastes contain 20 to 180 mg/kg fluoride by "water suspension procedure." The values were much higher with acid hydrolysis and distillation procedure. The fluoride content of fluoridated toothpaste was 200-1100 mg/kg by the water suspension method and the values were about 1.5 times higher with the distillation method.

Drastic extraction procedures such as acid treatment and distillation do not, however, simulate the condition of application of toothpaste. Methods a) and b) with water suspension and TISAB boiling gave values which almost agreed with each other, whereas the values obtained with TISAB boiling were relatively higher compared with the water suspension techniques.

Conclusion

1. Eighteen out of 20 toothpastes contained fluoride either added or an impurity in raw materials.

Table 5

Fluoride Content of Toothpastes Estimated by Four Methods

No.	Toothpaste	Fluoride Content (mg/kg) Estimated by Four Methods			
		A	B	C	D
1	F 1	625	660	990	1126
2	F 2	1100	1140	1150	1610
3	F 3	430	460	830	1270
4	F 4	200	280	560	570
5	F 5	620	630	1020	1040
6	NF 1	130	110	150	240
7	NF 2	130	120	120	140
8	NF 3	100	120	260	290
9	NF 4	170	220	250	250
10	NF 5	180	210	200	240
11	NF 6	20	20	45	80
12	NF 7	130	140	240	250
13	NF 8	40	50	80	70
14	NF 9	70	90	100	150
15	NF 10	–	–	2	30
16	NF 11	–	–	6	30
17	He 1	110	250	340	360
18	He 2	30	75	180	190
19	He 3	740	740	780	970
20	He 4	480	610	930	990

2. The fluoride content of fluoridated toothpastes ranged from 200 to 1100 mg/kg.

3. Herbal and homeopathic toothpastes, which contain high fluoride levels, are not marketed as fluoridated toothpastes.

4. The significant variation from aliquot to aliquot suggests that content was not homogeneous.

5. The TISAB boiling technique is recommended because it is simpler, accurate and reproducible for fluoride estimation in toothpaste.

Acknowledgement

Gratitude is expressed to Shri K.R. Bulusu, Deputy Director and head, Water Division, NEERI, Nagpur and Dr. A.K. Susheela, Associate Professor, Department of Anatomy, All India Institute of Medical Sciences, New Delhi for their guidance.

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COST-EFFECTIVENESS ANALYSIS: APPLICATION TO INDUSTRIAL FLUOROSIS

by

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SUMMARY: Decision analysis was applied to potroom workers of the aluminum industry, either compensated for fluorosis or surveyed for being exposed to fluoride. Controls were non-exposed workers of the same industry or workers outside the aluminum industry. Bone fluoride content was shown to be the golden standard and to display the highest sensitivity and specificity. Different strategies, with various combinations of testing procedures, were identified as more or less cost-effective, following the prevalence of the disease. It was also suggested, that some strategies are better suited for screening workers for prevention, when diagnosing fluorosis for compensation.

KEY WORDS: Aluminum industry; Compensation; Cost-effectiveness; Fluoride; Industrial fluorosis.

Introduction

In most industralized countries, the borderline between policies for preventing occupational diseases and compensation programs is not clearcut. In Switzerland, the same insurance company (CNA = Swiss National Insurance Company for Occupational Injuries) is in charge of both. For this reason, this company is in a position either to screen workers for detection of subclinical or early clinical signs, in order to introduce appropriate preventive measures, or to submit them to a clinical examination when assessing, as occupational, a disease for compensation.

Most occupational diseases share the following characteristics: they are due to a specific agent which has to be detected at the work place. This agent may also be present outside the work place. The prevalence of the disease usually increases with the intensity of the agent. Most often, the evolution of the disease is very slow, requiring several years of continuous exposure. Usually, occupational health diseases cannot be cured, although some of their symptoms can be treated.

Industrial fluorosis includes all these features; particularly, it is a slow process (according to our data, 8 to 10 years of exposure are necessary for the development of symptomatic fluorosis) and the risk increases sharply with the concentration of fluoride at the work place. Since this concentration varies with technical improvement, we may expect the prevalence of the disease in the aluminum industry around the world to range between 1 and 20%.

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Using data from potroom workers of the Swiss aluminum industry provided by CNA, as well as controls, we endeavored to determine which testing procedures would be the most appropriate for detecting fluorosis, either as an indicator for improving protection, or to diagnose fluorosis as an occupational disease for compensation. To test the cost-effectiveness of possible strategies, we referred to two methods: the decision tree of Wenstein (1) and the informative decision analysis of Eeckhoudt (2,3).

Materials and Methods

Population: We have at our disposal two sets of data. The first one is derived from 43 fluorotic potroom workers of the Swiss aluminum industry who were admitted for disability (4). The second set derives from working potroom workers who are regularly surveyed by CNA (N = 126) (5). Controls are either workers of the same industry, but not exposed to fluoride, or other persons who were never exposed to fluoride professionally and never worked in the aluminum industry (N = 77).

Testing Procedures: Exposure to fluoride was measured in different ways. Two biological determinations only are taken into account in this presentation: pre-shift urine fluoride (from a spot sample) and bone fluoride by biopsy (6). The urine fluoride content assessed, like here, 48 hours after the last exposure, measures the slowly liberated bone fluoride and is an index of the fluoride body burden.

Clinical Variables: Fluorotic workers as well as controls were examined by the same physician to establish their impairment. It was expressed in two ways: pain and stiffness of the joints and spine. The "pain index" is the sum of all painful joints and can vary from 0 to 10. Similarly, a "stiffness index" was developed by the physician from measurements of restricted movements around joints. It could be shown that pain and stiffness indices were strongly correlated.

X-ray Index: The diagnosis of disabling fluorosis, which gives rise to compensation, relies mostly upon radiological changes of the skeleton. For this reason, we had at our disposal a great number of views in diseased and non-diseased workers of the aluminum industry. The "radiological index" is based on anteroposterior and lateral views of the cervical, dorsal and lumbar spine, as well as anteroposterior views of the forearm, hands, calcaneum, right femur and knee. The index ranges from 0 to 10.

Materials and methods are described in a previous paper (4).

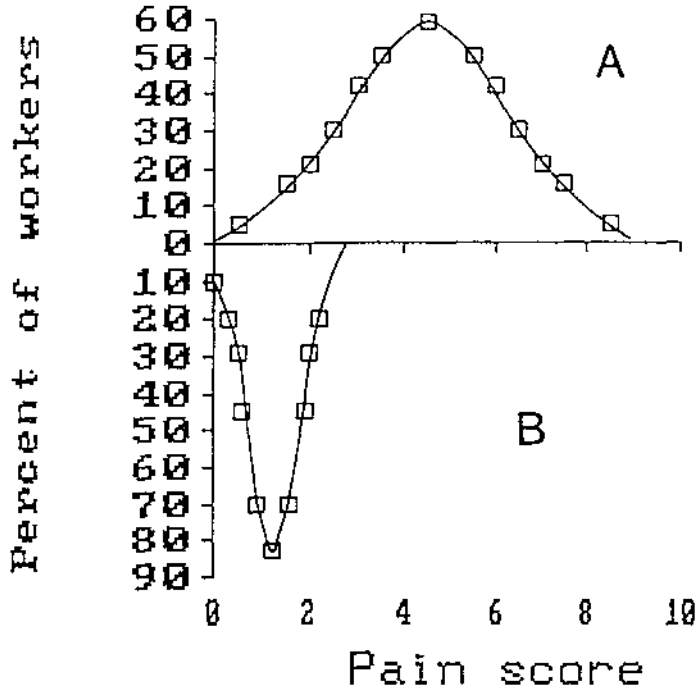
Results and Discussion

To rank the cost-effectiveness of different testing procedures and strategies, it is first necessary to define, for a continuous variable, the threshold at which the true positive rate is maximized and the false positive rate is minimized.

The normality of the distributions of the clinical and radiological variables was at first checked for fluorotics and controls. Figure 1 displays how pain scores are distributed around a mean value of 5.65 for fluorotics and of 1.30 for controls.

Figure 1

Frequency Distribution of Pain Scores
in Diseased Workers (A) and Controls (B).



The same procedure was applied to pre-shift urinary fluoride and bone fluoride concentrations.

The level of the pain index, stiffness index and X-ray index was significantly higher in the fluorotic group than in the control group ($p < .01$). Fluoride concentrations were significantly higher in the exposed, than in the control group ($p < .001$).

For each test, we established the optimal cut-off point for positivity from the so-called "receiver operating characteristics curve" or ROC-curve of Weinstein. The ROC-curves of pre-shift urinary fluoride and of bone fluoride are displayed in Figure 2. One can see that bone fluoride is superior to pre-shift urine fluoride.

Specificity and sensitivity rates were then calculated for all variables (Table 1).

Cost-Effectiveness Analysis: The computerized method by Eeckhoudt (2), which is based upon the Bayes formula and the well-known folding-back procedure of the decision tree, was applied to our data. The effective information value for different combinations of 3 sequential tests was plotted against their

Figure 2

ROC-curves Following Weinstein's Method
for Bone Fluoride (A) and Pre-shift Urine Fluoride (B).

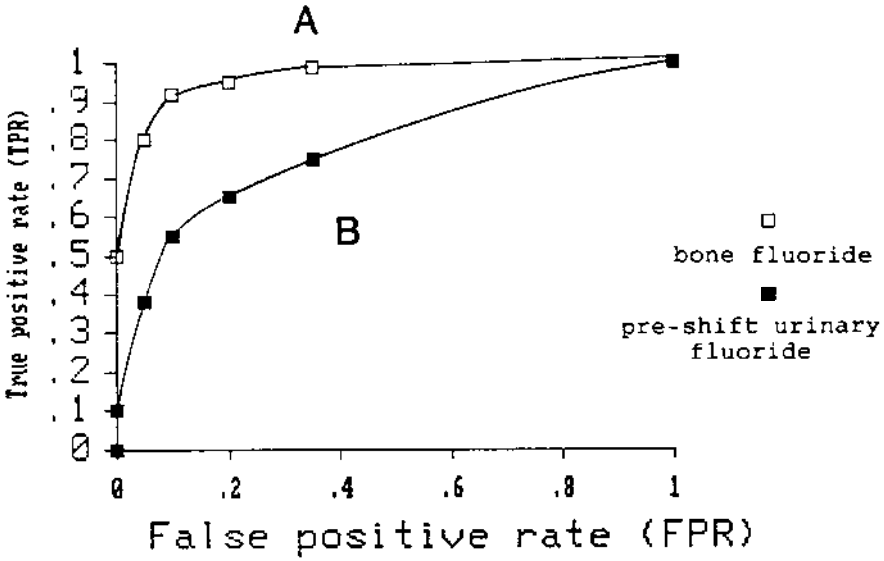


Table 1

Sensitivity and Specificity Rates of Biological (a,b) and Medical (c,d) Variables Used in the Cost-Effectiveness Analysis.

	Test	Sensitivity	Specificity
a	Pre-shift Urinary Fluoride	68%	75%
b	Bone Fluoride	95%	87%
c	Pain Index	86%	83%
d	X-ray Index	86%	60%

respective costs. With three consecutive tests, the third one being the best, the amount of combinations rises to 39 out of which, the most cost-effective can be shown to be located along a growing curve (Figure 3). This method is thus aimed to select several fair cost-effective strategies, rather than the unique best one. We verified for fluorosis what is well known in cost-effectiveness analysis, i.e., a) Testing procedures submit to the law of the decremental output, i.e. the effect of growing expenses is relatively less when the total amount of expenses is already large, and b) The cost-effectiveness of testing procedures depends upon the a priori prevalence of the disease. For example, strategy 20 (Table 2), which is cost-effective at a prevalence of 1%, loses its efficacy for higher prevalences (here 10 and 20%). As seen in Figure 3,a,b,c, strategy number 20 moves downwards from the reference curve.

Figure 3

Graph of the Relationship Between the Expected Informative Value as a Function of Cost for a 1% a priori Prevalence of Fluorosis (A), 10% (B) and 20% (C). The Most Cost-Effective Strategies are Located along this Reference Curve (cf. Table 2)

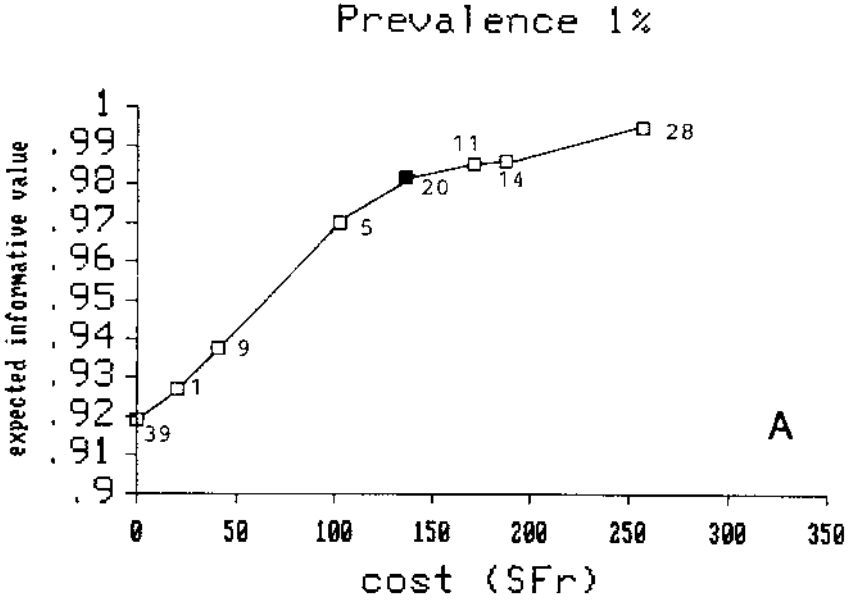
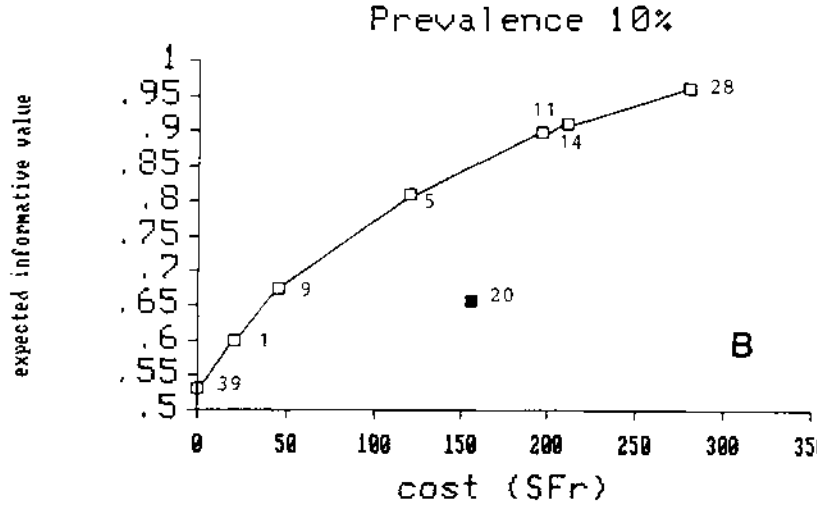


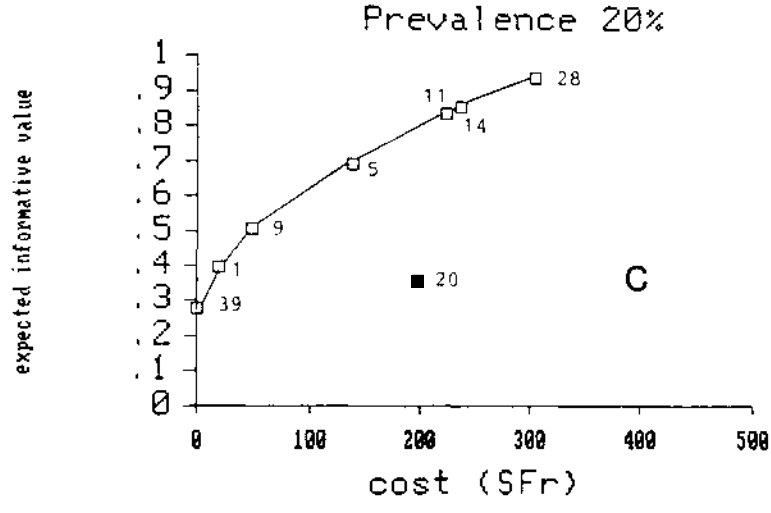
Table 2

Cost-Effective Strategies as Calculated by the Eeckhoud Method

Number	Sequential Testing Procedures
39	No Test
1	Urinary-Fluoride (F)
9	F ——> if F+ ——> Pain Index (P)
5	F ——> if F+ ——> Bone Fluoride (B)
20	F ——> if F+ ——> P ——> if P+ ——> B
11	P ——> if P+ ——> B
14	P ——> if P+ ——> B if P- ——> F
28	F and P ——> if F- and P- ——> No Test ——> if else ——> B

In cost-effectiveness analysis, one important decision may be to do nothing, since no test should be done if it does not change the treatment or the preventive action. For example, if we assume that the prevalence of fluorosis is very low, one of the most cost-effective decisions is to do nothing. For higher prevalences (Figures 3b and 3c), to do nothing remains a cost-effective procedure, (if one ignores potential medical and social costs); however, the confidence value declines considerably. Comparing the three curves, it is obvious that, at a prevalence of 10%, only 3 testing procedures provide an informative value higher than .90 and only one when the prevalence is 20% and with much higher costs than in the case of a 1% prevalence.





Conclusion

Our results allow us to propose cost-effective and realistic strategies for assessing the amount of risk of fluorisis, on one hand, and for diagnosing disabling cases on the other.

Testing Procedures to Assess Risk. When screening, tests are applied to all exposed workers, whether highly exposed or slightly exposed. In healthy and active individuals, to start a strategy with bone biopsy, because of the high validity of bone fluoride would be stupid and unethical, biopsy indeed being risky and requiring a stay in a hospital. Therefore, the choice should be done among cost-effective strategies which do not involve bone biopsy. Here, two possibilities are offered: if the working conditions are known to be fair and the a piori probability of the disease low, to do nothing remains reasonable (Strategy 39, Table 2). In other words medical examination of workers with a prolonged exposure should be preferred to screening all workers, independent of duration of exposure.

Mass screening using pre-shift urinary fluoride (Strategy 1, Table 2) is often performed; however, it is not much more cost effective than no screening, either at low or at high prevalences of the disease. For higher prevalences, Strategy 1 still remains on the reference curve and is the only acceptable one in non-diseased and asymptomatic workers. Therefore, if the a priori prevalence is not known in a particular situation and working conditions are suspected to be hazardous, we can recomend determining risk by measuring fluoride concentration in the urine 48 hours or more after exposure has ceased.

Testing Procedures for the Diagnosis of the Disease. In diseased workers, to multiply radiological pictures in order to obtain an X-ray index is not helpful. When the X-ray index is added to any other 39 strategies, an important shift to the right of the reference curve is noticable, i.e. all satrategies, even in the case of a 1% prevalence, are not more cost-effective. If we compare, for example, Strategy 11 containing clinical examination and bone fluoride with a strategy including X-rays, when the clinical test is positive, it appears that this strategy, for only a slightly higher efficacy, is between three and four times more expensive (Table 3). Moreover, since consideration should always be given to the hazardous effect of the test itself, we do not recommend such a procedure, because it would expose workers to an excess of radiation.

Table 3

Efficiency and Cost of Two Equally Shaped Strategies with X-ray (A) and without (B), Calculated for Increasing Prevalences

Prevalences	A		B	
	Efficiency (%)	Cost (SFr)	Efficiency (%)	Cost (SFr)
1%	.99	709	.98	170
10%	.96	725	.90	195
20	.93	742	.83	223

For these reasons, we believe that X-ray views of properly selected places on the skeleton should be limited to the follow-up of unclear cases.

Finally, in selected cases with a definite history of industrial exposure, a thorough clinical examination should be completed by a bone biopsy: i.e., Strategy 11, which provides a fair and informative value at a very low cost. If remodeling of the bone is observed, together with a high fluoride content, painful movement impairment should be considered mostly due to fluorosis and thus justify compensation.

Acknowledgement

We thank Prof. L. Eeckhoudt and L. Bauwens for their help in setting up the cost analysis.

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THE ACCUMULATION OF AIRBORNE FLUORIDES BY PERENNIAL RYEGRASS CULTURES

by

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SUMMARY: Perennial ryegrass, grown in containers provided with a semi-automatic water supply system, was exposed to ambient air fluorides in the neighborhood of a phosphate fertilizer plant. The exposure time, four weeks, was followed by clipping and harvesting.

Ambient fluorides were continually sampled by means of a dynamic single filter method. Furthermore, sampling systems were used to determine the gaseous, particulate and adsorbed fractions of ambient fluorides. At the studied area, particulates constituted a maximum 10 percent of the total ambient fluoride concentration.

Correlations between ambient fluoride concentrations and accumulation by grass are described. The last two weeks of the exposure period were responsible for 80 to 90 percent of the total fluoride level at harvest time. Rainfall during the two week period prior to harvesting failed to influence the accumulation rate.

A model was developed to calculate the average fluoride content in grass based on the average ambient fluoride concentration and rainfall.

KEY WORDS: Ambient fluoride; Grass F accumulation; Phosphate fertilizer plant; Perrennial ryegrass.

Introduction

Plants absorb and release atmospheric fluorides by their above-ground parts (1-3) because fluoride uptake is a reversible process influenced by such climatic conditions as exposure to rainfall and wind. In addition, the absorbed amount of fluoride is diluted by plant growth (increase in biomass) (3). In spite of a rather constant deposition velocity throughout the growing season (4) accumulated fluoride concentration in grass is lower in midsummer, when grass growth is very rapid. A complete model describing all possible influences on fluoride uptake and accumulation will be very complicated and difficult to apply. An extensive model will also need a whole set of measurements of fluoride compounds in ambient air and a broad spectrum of climatic, plant physiologic and soil condition parameters.

The aim of this study was to develop a model as simple as possible describing fluoride accumulation by grass. Only the most important parameters

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such as atmospheric fluoride concentration and rainfall during the exposure period have been taken into account. Plant growth conditions have been harmonized using a container system, and the proportion of particulate fluorides in ambient air has been determined. As the deposition velocity of gaseous fluorides differs from particulates, an estimate of the different fluoride components present in ambient air is necessary (5).

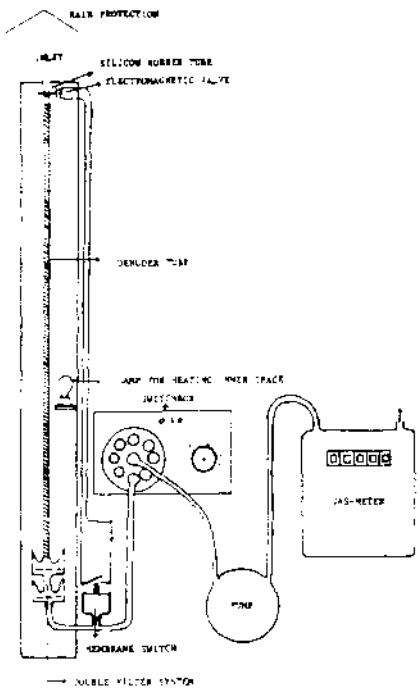
Materials and Methods

The experiments were carried out 500 m distant from a fertilizer factory, over a period of four successive years. The source of ambient air fluoride was the treatment of rough phosphates by sulphuric acid.

Perennial ryegrass, Lolium perenne cv. Melino RVP was grown in containers under standardized conditions; the containers used were 48 x 30 cm and 20 cm deep. A water reservoir was available underground and the water supply was provided by two filtercandles located in the soil substrate (peat soil) (6). The containers remained on the experimental field during the entire growing season; the grass was harvested every 28 days for 7 successive periods (April-October). Ambient air concentration of fluoride was measured by a single filter method (membrane filter impregnated with sodium formate) as described by Elfers and Decker (7) and slightly modified by Verduyn et al. (8).

Figure 1

Determination of Fluoride Fraction in Ambient Air.



A denuder system was used to measure particulate, gaseous and adsorbed gaseous components separately in ambient air (9). A system consisting of 8 denuders was constructed so that it could be operative for 7 days using a switch box. The sampling train consisted of a tubular denuder (120 cm length; 7 mm inner diameter) coated with $NaHCO_3$, a dust filter treated with citric acid and finally a membrane filter impregnated with sodium formate (Figure 1). After exposure, the filters were extracted with a 0.1 sodium citrate solution and the tubular denuder was rinsed with a TISAB buffer solution.

The fluoride concentrations were measured using an ion specific electrode. The ambient concentrations were measured at 1.50 m above ground level. Grass samples were weighed and dried. After extraction with 0.1 N

nitric acid and the addition of a buffer solution, the fluoride content was measured using an ion selective electrode (10).

Results and Discussion

Atmospheric Fluoride Measurements: The results of the ambient air concentration measurements (daily averages) are given in Table 1.

The cumulative frequency distribution of ambient fluoride concentrations is given for the year 1979 (Figure 2). The comparison between the single

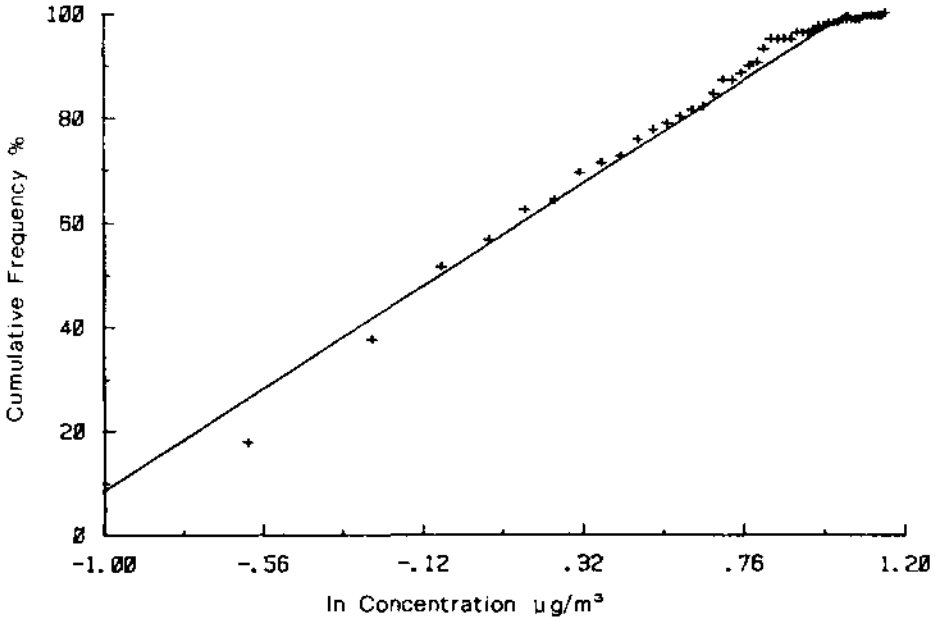
Table 1

Ambient Air Concentrations of Fluorides (µg/m³) During the Growing Season

Year	n	average	min.-max.	percentiles 50 pct	75 pct	95 pct	99 pct
1979	157	2.20	0.11-14.0	0.85	3.07	8.59	10.6
1980	195	1.51	0.11-12.4	0.50	2.07	6.47	8.1
1981	196	1.44	0.14-9.2	0.57	1.98	5.38	6.57
1982	186	0.85	0.13-3.78	0.57	1.24	2.32	2.62

Figure 2

Cumulaltive Frequency Distribution of Ambient Fluoride Concentrations in 1979.

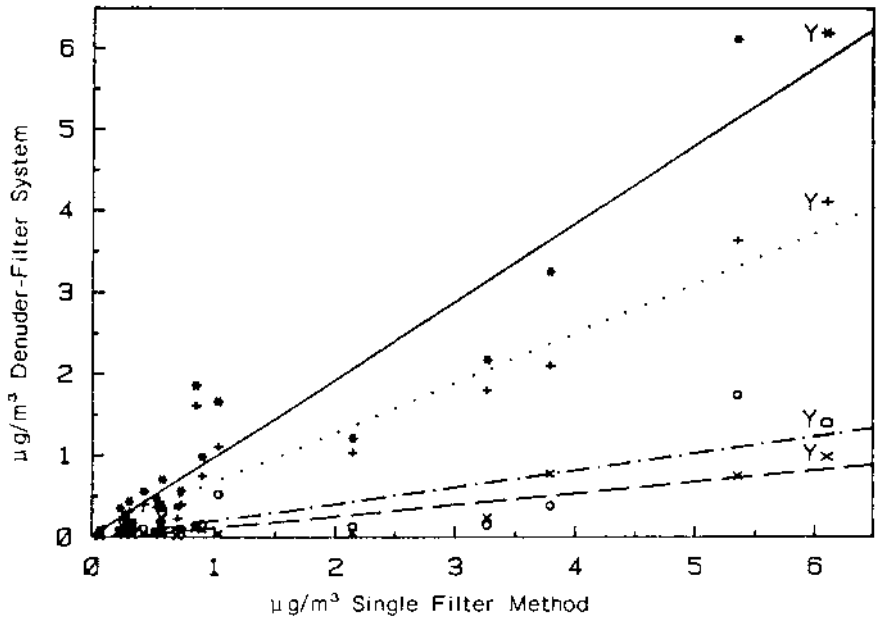


filter method and the simultaneous measurement of the different fluoride fractions in ambient air is shown (Figure 3). It is clearly demonstrated that the sum of the fractions measured with the denuder-filter system is more or less equal to the concentration measured with the single filter method. Particulate fluorides add up to about 10 percent of the total ambient fluoride concentration.

Relationship Between Ambient Fluoride Concentration and its Accumulation by Grass Culture: During the exposure period (28 days) of the grass cultures, the daily average concentration of fluorides fluctuated widely in an area

Figure 3

Fluoride Fractions as a Function of
Total Fluoride Concentrations in Ambient Air.



Sum of Fractions as a Function of Total Concentration
$Y^* = 0.96\ X + 0.015$
$R^2 = 0.88$; $n = 19$

Gaseous Fraction as a Function of Total Concentration
$Y+ = 0.61\ X + 0.06$
$R^2 = 0.88$; $n = 19$

Adsorbed Gaseous Fraction as a Function of Total Concentration
$Y_o = 0.21\ X - 0.015$
$R^2 = 0.60$; $n = 19$

Particulate Fraction as a Function of Total Concentration
$Y_x = 0.14\ X - 0.03$
$R^2 = 0.80$; $n = 19$

close to a pollution source. In such situations, where peak concentrations occur, it is not yet clear whether the average concentration is a good estimate of the environmental load of fluorides. Percentile values and especially the higher percentiles (95-99 percentiles) are determined by such peak concentrations and may be closely related to fluoride accumulations in grass. To test this hypothesis, percentile values were calculated on the basis of cumulative frequency distributions and they were correlated with the accumulated fluoride concentrations in grass (Table 2). As there were a maximum of 28 measurements per exposure period and only 14 during the last two weeks, only percentiles which were derived from regression equations with a high correlation coefficient (more than 0.9 for n = 28) were taken into account.

It can be concluded that the average ambient air concentration is correlated more closely to the accumulated concentration in grass than the peak (24 h average) concentrations (Table 2); furthermore the average concentration during the last two weeks prior to harvest is more closely related to the accumulated concentration in grass than the average concentration during the entire exposure period (Table 2).

Table 2

Correlation Coefficients of the Relationship between Atmospheric Fluoride Concentrations (Averages and Percentiles) and the Fluoride Concentration Accumulated in Grass

Ambient F^- Concentration	Correlation Coefficients for 28 days exposure	Correlation Coefficients for the last 14 days exposure
$\bar{x}$	0.64	0.79
50 pct	0.67	0.74
75 pct	0.65	0.76
90 pct	0.56	0.65
95 pct	0.53	0.58
98 pct	0.51	0.54
99 pct	0.50	0.52

All correlations are significant at the 0.01 probability level.

Taking these results into account, the entire exposure period (28 days) has been divided into four periods of 7 days each and the average ambient concentration calculated for each period. The calculated averages for the first week of exposure are indicated by C_1, for the second week by C_2, for the third week by C_3 and the fourth week by C_4. Rainfall, a very important parameter has also been included in the model. The average rainfall during the last week before clipping (R_4) two weeks before clipping R_{34}) the last three weeks of exposure period (R_{234}) and the average rainfall over the entire period of exposure (R_T) was taken into account. As the measured atmospheric concentrations show mostly a log normal distribution, all concentration data are tranformed logarithmically.

A stepwise multiple linear regression yields the following equation [1] where "F_{gr}." is the fluoride concentration in grass exposed to ambient fluorides during 4 weeks.

$$\ln F_{gr} = 4.85 + 0.13 \ln C_2 + 0.59 C_3 + 0.45 \ln C_4 - 0.0043 R_{34} \qquad [1]$$

$R^2 = 0.78$; standard deviation of the estimation: 0.42 for n = 26

The other parameters introducted in the stepwise multiple linear regression have not been used because of a low F value ($F < 2$ for $\alpha = 0.01$) too low for further steps.

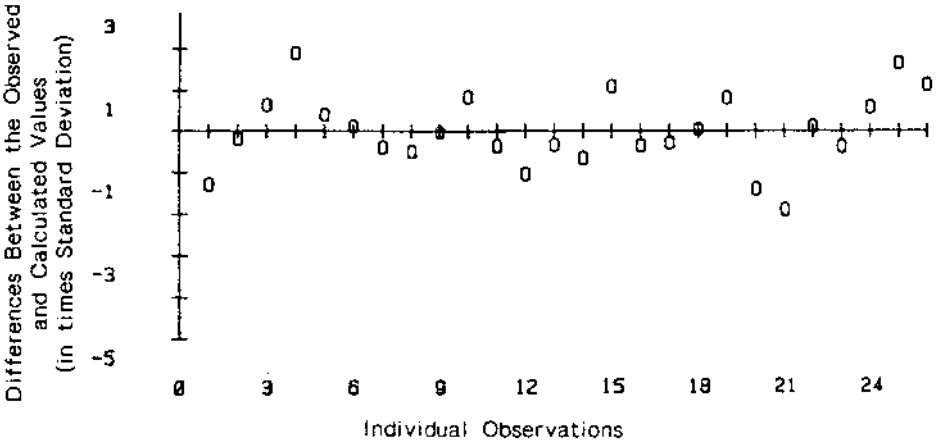
Transformation of the obtained equation gives the grass concentration as a function of atmospheric fluoride concentration in the second, third and fourth week of exposure and the average rainfall in the two weeks before clipping the grass.

$$F_{gr} = \frac{128 C_2^{0.13} \cdot C_3^{0.59} \cdot C_4^{0.45}}{e^{0.0043 R_{34}}} \qquad [2]$$

The differences between the fluoride concentration in grass, calculated with the obtained equation and the real concentrations are given (Figure 4) as standard residuals (times standard deviation, positive and negative per observation).

Figure 4

Standard Residuals of Obtained Equation



Differences between predicted (calculated) and actual values are given in the standard deviation units. Predicted value (from the equation) is subtracted from the actual value. The diffference is divided by the standard deviation. If the difference is less than 2 times the standard deviation, the equation is considered to fit the data in a satisfactory manner.

When the ambient air concentration remains constant over a period of 3 weeks without rainfall, the equation [2] can be simplified as:

$$F_{gr} = 128\ C^{1.17} \quad [3]$$

This equation is closely related to the one found by Van der Eerden (11) on the basis of fumigation experiments (exposure to a constant concentration in absence of rain).

$$F_{gr} = 129\ C^{1.01}$$

The accumulated concentration of fluorides in grass can be calculated with the simplified equation [3], using a constant concentration, but taking into account the average rainfall during the last two weeks before clipping. For obtained average concentrations with minimum and maximum see Table 3 from which it can be concluded that the ambient air concentration should exceed 0.3-0.4 $\mu g \cdot m^{-3}$ fluoride, because 30-40 ppm of fluoride in grass (12-15) is the accepted maximum safety level for cattle.

Table 3

The Average Minimum and Maximum Fluoride Concentration in Grass as a Function of the Average Ambient Air Concentration and Average Rainfall during the Two Weeks Before Harvest

$\bar{x}$ conc. F^-	No Rainfall R_{34}** = 0	10 mm Rainfall R_{34} = 10	100 mm Rainfall R_{34} = 100
0.1 μgm^{-3}	8.7 (5.7-13)	8.3 (5.5-12)	5.7 (3.8-8.7)
0.2	20 (13-30)	19 (13-28)	13 (8.4-19)
0.3	31 (20-47)	30 (20-46)	21 (14-32)
0.4	44 (29-67)	42 (28-64)	29 (19-44)
0.5	57 (38-87)	55 (36-84)	37 (24-56)
1	128 (84-195)	123 (81-187)	84 (55-128)
2	288 (189-438)	276 (182-420)	189 (124-287)

** R_{34}: Average rainfall during the two weeks before clipping

Compared to grass cultures, the fluoride content in meadow grass is 10 to 20% lower (3) due to a better exposure of the grass in containers (30 cm above ground level) compared to meadow grass.

Conclusion

The average concentration of fluorides in ambient air is a better estimation of the accumulated fluoride concentration in grass than peak concentrations (daily averages) for a limited period of time. During the last two weeks of the exposure period the average fluoride level contributes 80 to 90% of the total fluoride concentration in grass at harvest time. Of four weeks exposure, the first week has no influence; the second is of little importance

to accumulation of fluoride by grass. Rainfall has a negative influence on fluoride accumulation. To remain under the safety level for fluoride accumulated in meadow grass, the average fluoride concentration in ambient air must be lower than 0.3-0.4 $\mu g/m^3$ when the ambient air contains a maximum of 10% particulate fluoride.

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EXPERIMENTAL FLUOROSIS IN SHEEP: FLUORIDE KINETICS AND ALLEVIATING EFFECTS OF ALUMINUM SULFATE

by

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SUMMARY: For 33 months five groups of four sheep were given a daily oral dose of 0, 0.10, 0.25 mmol F^-/kg BW with or without 0.50 mmol Al/kg. In all treated animals fluoride levels increased in blood, urine, feces, bones and teeth. Aluminum sulfate decreased the digestive absorption of fluoride (about 33 to 45%) and reduced the fluoride in serum, urine, bones and teeth. Most variations were fluoride dose-related.

KEY WORDS: Aluminum sulphate; F^- in blood, urine, feces, bones, teeth; Fluorosis; Sheep.

Introduction

Bovine fluorosis has been studied from a clinical (1-5) as well as from an experimental (6-10) point of view. On the other hand, few studies have dealt with sheep fluorosis although sheep are much easier and less expensive to use in experimental studies dealing with ruminant fluorosis.

Previous results had shown that in ruminants, industrial (11) and hydrotelluric (12,13) fluorosis induced the well-known osteodental signs and a severe alteration of the general health status with increased fluoride in bones and teeth. A few reports showed that aluminum salts could reduce the digestive absorption of fluoride when given in the diet of cattle (14) and sheep (15), but their efficiency in the alleviation of fluoride toxicity remains controversial.

We designed an experiment to observe the fluoride kinetics of oral fluoride toxicity in sheep for almost 3 years, aimed at replicating the natural intoxication of the Darmous area. Meanwhile, we studied the preventive effects of simultaneous administration of aluminum sulfate for the purpose of using this salt as a prophylactic in endemic zones of hydrotelluric fluorosis.

Materials and Methods

Animals: Twenty one-year-old Sardy male sheep weighing 27 to 33 kg were supplied by the Experimental Farm of the Institut Agronomique et Vétérinaire Hassan II (Rabat, Morocco). Previously vaccinated against the main bacterial and viral infections, they were treated with an anthelmintic (Fenbendazole, 15 mg/kg). Moreover, coprologic and thorough clinical examinations were performed to assess their good health status. They were acclimated for 10 days to individual metabolism cages allowing the separation of urine and feces.

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This research is supported by International Foundation of Science, Grev Turegatan 19, S-114 38, Stockholm, Sweden.

Animals were fed hay and water ad libitum and supplement. Fluoride levels were controlled monthly and were below 0.8 ppm in water and 25 and 20 ppm of dry matter, respectively, in hay and supplement. Relying on average daily intake, mean fluoride intake in the diet was approximately 10 µmol F^-/kg body weight per day.

Treatments: Five groups of 4 sheep, randomly assigned to treatments, were given every morning at 9:00 the following fluoride doses orally as NaF in 50 mL of distilled water: Group A — 0 Controls; Group B — 0.10 mmol F^-/kg BW; Group C — 0.10 mmol F^-/kg BW + 0.50 mmol Al/kg BW; Group D — 0.25 mmol F^-/kg BW; Group E — 0.25 mmol F^-/kg + 0.50 mmol Al/kg BW.

Aluminum was added in the dietary supplement as $Al_2(SO_4)_3 \cdot 18H_2O$.

Samples: To be used as individual references, two blood urine and feces samples were taken on day -8 and -1 before fluoride dosage. Samples were then collected at the end of months 1, 2, 3, 9, 15, 21, 27, 33. All blood samples were taken from the jugular vein. A 20 mL blood sample, taken in a dry tube, was allowed to clot at room temperature for 2 hours; serum was separated and stored at +4°C in the dark until analyzed within 12 hours. Twenty-four hour urine samples were collected at room temperature. After volume measurement, they were centrifuged and stored at +4°C in the dark until analyzed within 24 hours. Feces were collected, weighed and mixed. A 20 g aliquot was then processed within 48 hours.

At the end of the experiment, all animals were sacrificed; all teeth, and some bones (mandible, metacarpus, metatarsus, lombar vertebrae, coxal and 12th rib) were collected.

Analytical Procedures: Fluoride was measured with a selective electrode[a] and digital pH meter[b] either directly in serum and urine or after mineralization, according to Singer and Armstrong (16); in feces, teeth and bones according to Jacobson and Weinstein (17).

Data Analysis: Statistical calculations were performed using Student's t- and paired tests according to Snedecor and Cochran (18).

Results

In controls, fecal fluoride was always low. It ranged from 11 to 27 ppm (ash basis) accounting for about 65% of fluoride intake. Results were similar in the other groups before the beginning of fluoride intoxication (Table 1). In all animals receiving fluoride, daily fecal fluoride showed a dose-related increase with almost no variation over the 33 months of the experiment. Animals given only fluoride showed an absorption of fluoride approximately twice higher than controls or sheep supplemented with aluminum sulfate.

A dose-related increase of serum (Figure 1) was observed for the 2 to 3 first months following which fluoride levels remained almost unchanged. In groups supplemented with aluminum sulfate, levels were about 1.5 to 2 times lower than with the same fluoride dose unsupplemented with aluminum.

[a] 96500 Fluoride Selective Electrode, Beckman Inst. Inc., Calif., USA.

[b] 4500 Digital pH Meter, Beckman Inst. Inc., Calif., USA.

Figure 1

Variations of serum fluoride in experimental fluorosis of sheep given daily oral dosage of 0, 0.10 or 0.25 mmol F^-/kg with or without 0.50 mmol Al/kg. Results are mean +SEM (n = 4). Comparisons within each group to reference values according to student's t-paired test (* : $p < 0.05$).

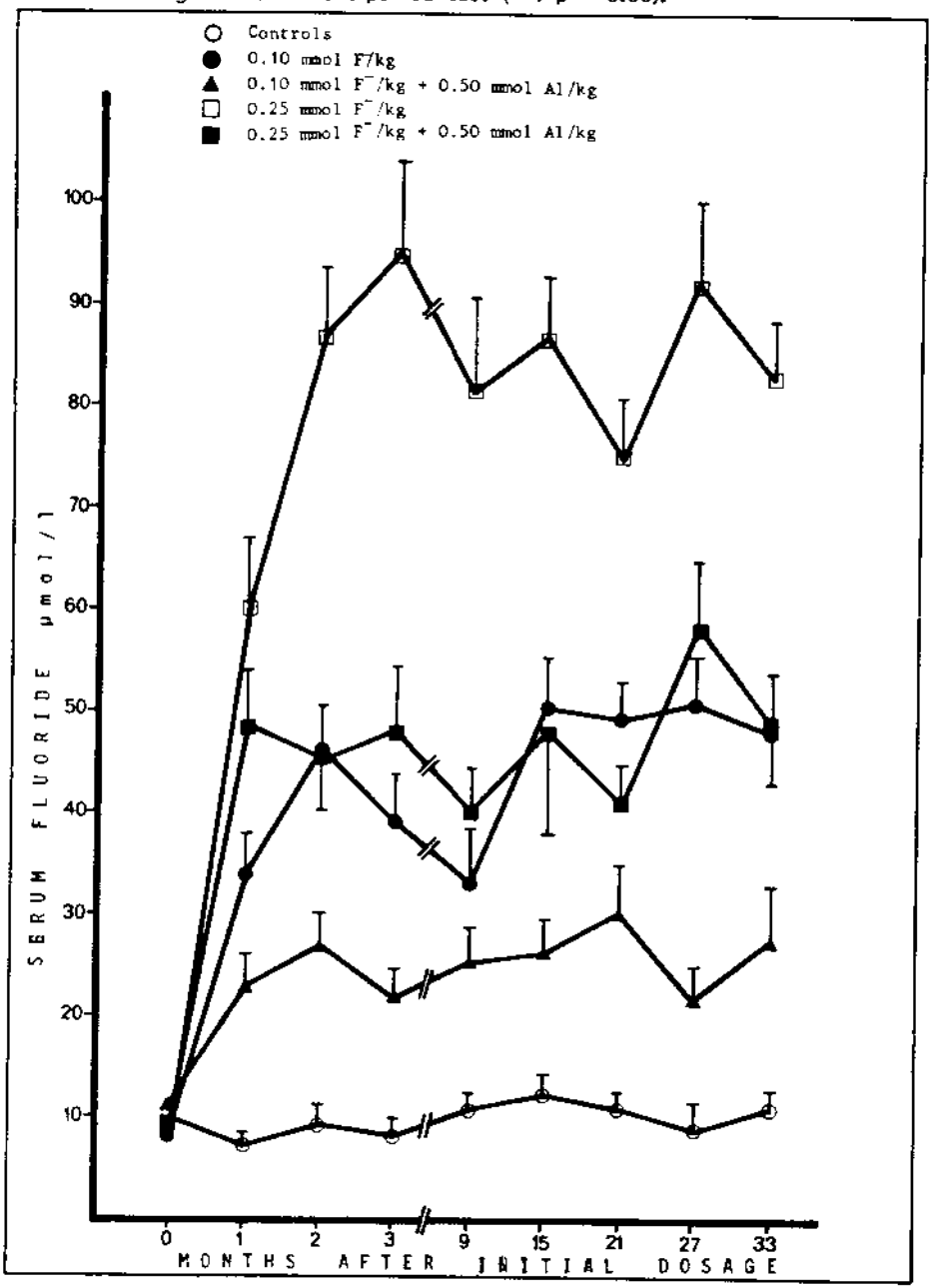
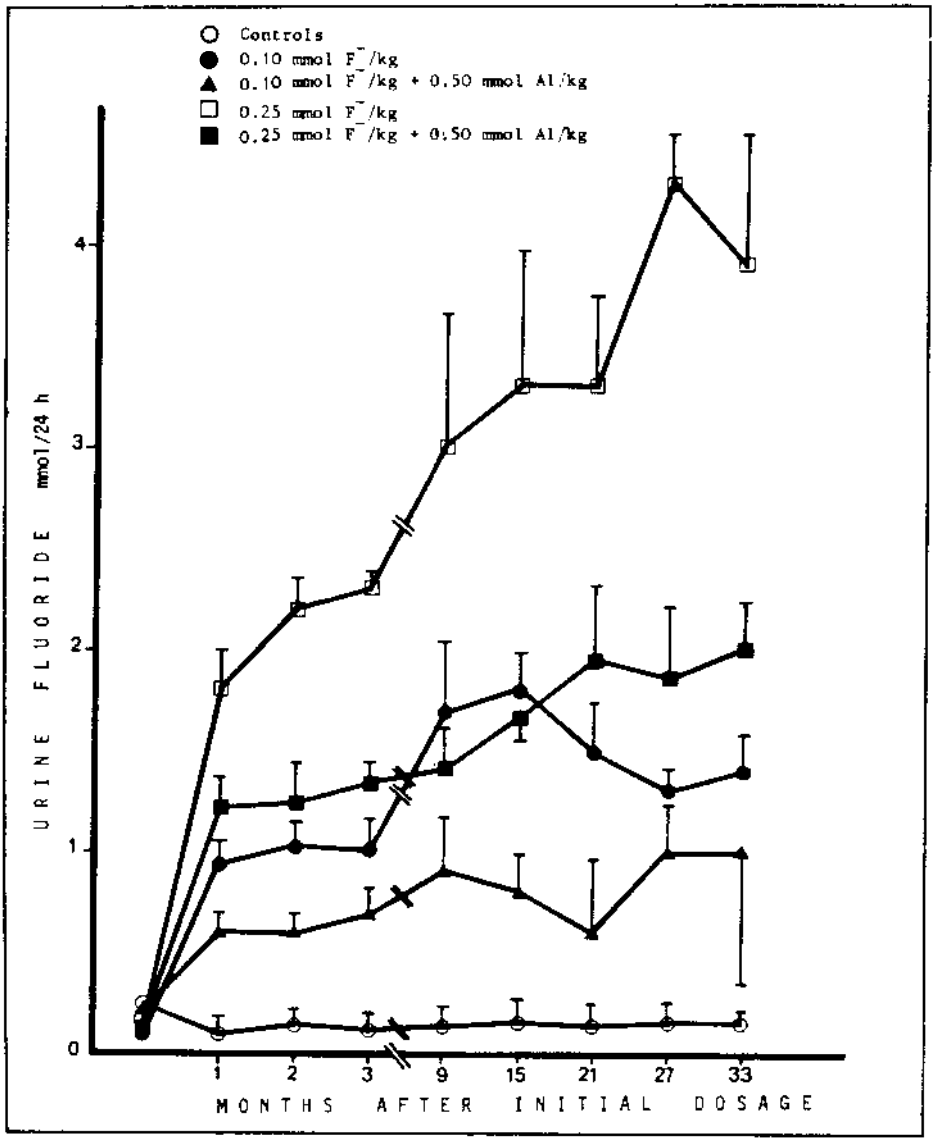


Figure 2

Variations of urine fluoride in experimental fluorosis of sheep given daily oral dose of 0, 0.10 or 0.25 mmol F^-/kg with or without 0.50 mmol Al/kg. Results are mean ±SEM (n = 4). Comparisons within each group to reference values according to student's t-paired test (* : $p < 0.05$).



As a consequence, urine fluoride levels (Figure 2) were dosage-related, aluminum having an alleviating effect. Moreover, urine volume was significantly increased in all treated sheep, but no significant difference could be observed either with dose or with aluminum sulfate treatment. (References before

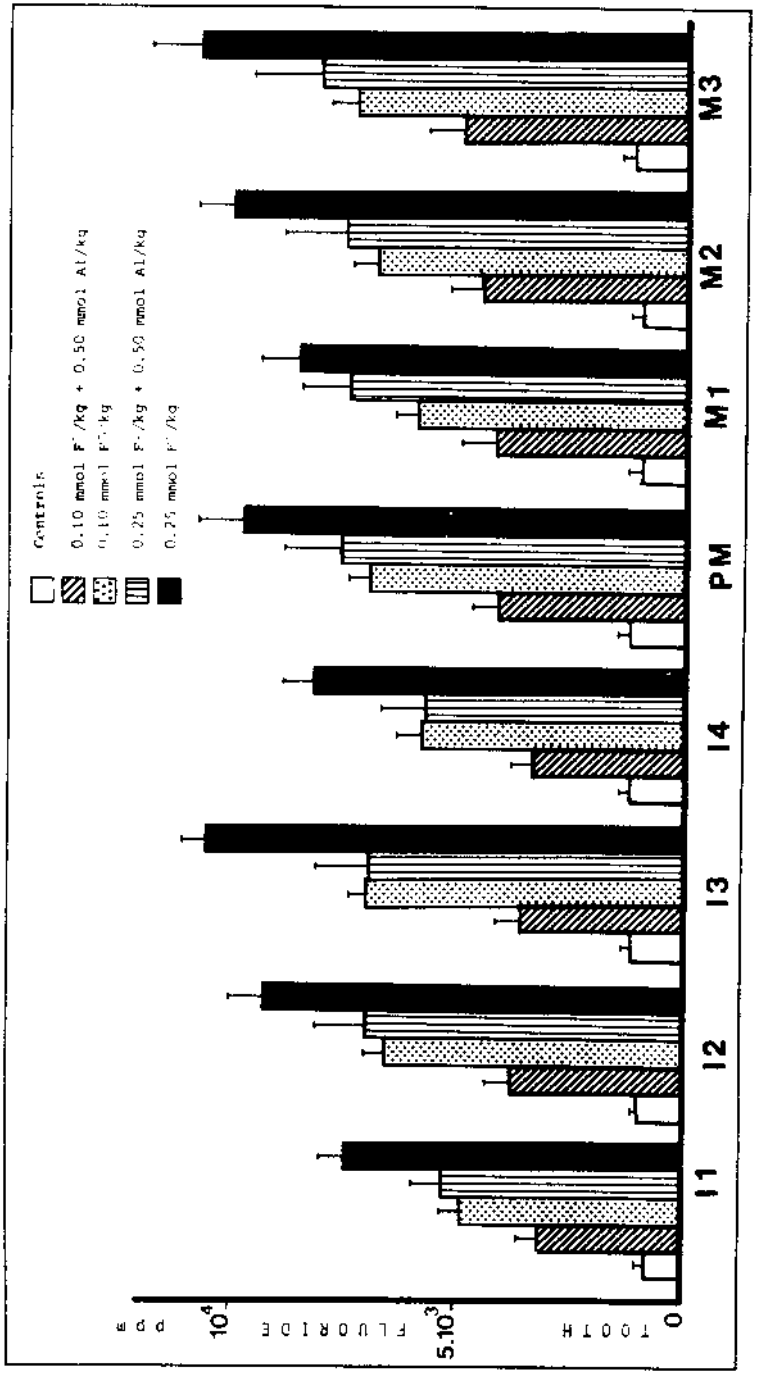


Figure 3

Fluoride levels (on ash basis) on teeth of sheep after 33 months of daily oral dosage of 0, 0.10 or 0.25 mmol F^-/kg with or without 0.50 mmol Al/kg. Values are mean ±SEM (n = 4).

Fluoride

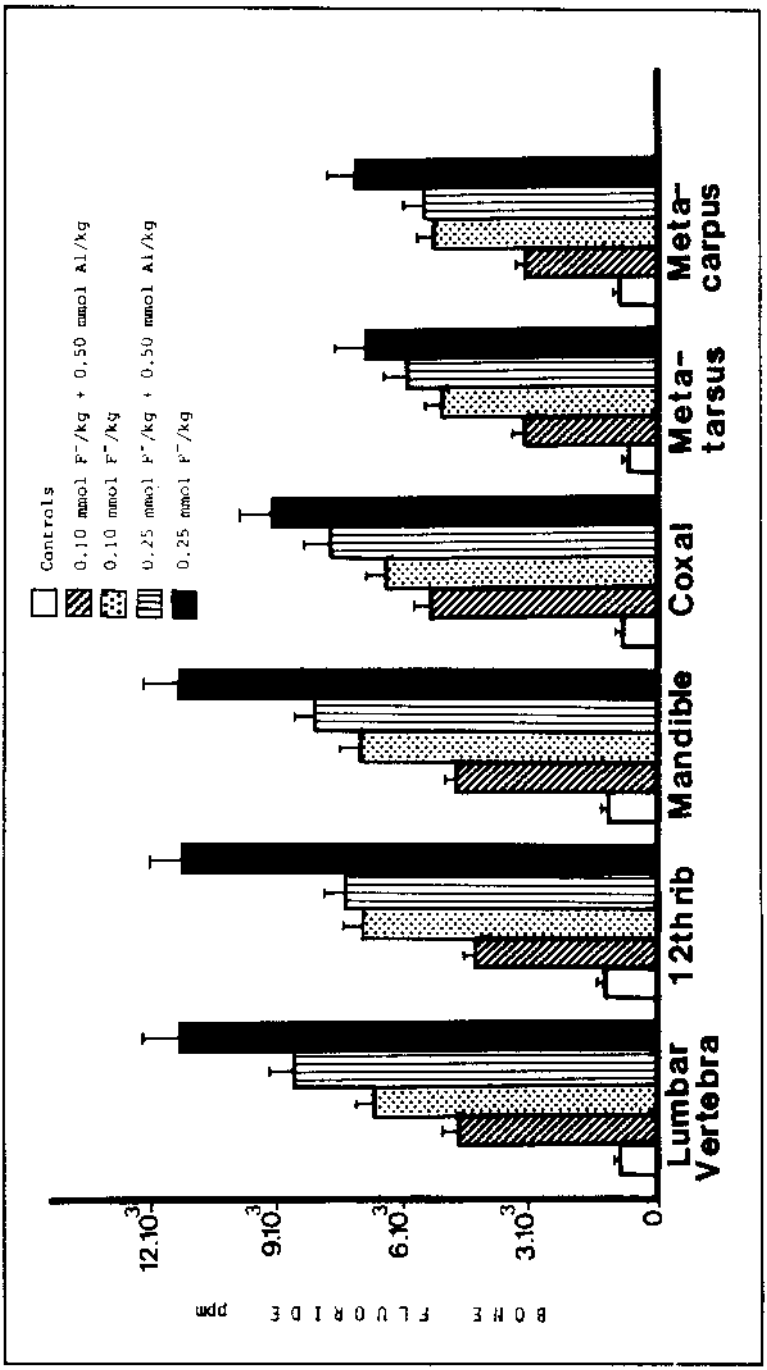


Figure 4

Fluoride levels (on ash basis) in bones of sheep after 33 months of daily oral dosage of 0, 0.10 or 0.25 mmol F^-/kg with or without 0.50 Al/kg. Values are mean ±SEM (n = 4).

treatment and in control animals were 850 ±50 mL/24 h; mean in treated animals was 1250 ±50 mL/24 h; $p < 0.50$).

Tooth (Figure 3) and bone (Figure 4) fluoride was much higher in intoxicated animals than in controls; it was about 1.5 times lower for the lower dose. Aluminum sulfate caused a significant decrease in fluoride levels. Moreover, whatever the dose, bone fluoride varied significantly according to the bone type and the location of teeth. The lowest level was observed in the first incisors and the highest level in the 2nd molar.

Discussion

Prior to fluoride dosage, blood, urine and fecal fluoride levels were within physiologic ranges (7,19). The sodium fluoride dosage induced a marked dose-related increase of those levels. Moreover, the relative absorption of sodium fluoride was much increased, confirming that fluoride naturally in water is poorly available (20). Aluminum sulfate reduced the digestive absorption of fluoride, probably through the formation of insoluble aluminum fluoride; thus blood and urine fluoride levels were reduced and fecal fluoride increased as previously described (15). High blood fluoride levels relate to the fixation of the element in teeth and bones.

When incorporated in the diet, aluminum salts (sulfate, chloride, lactate, hydroxyde) decrease the absorption of fluoride through the production of insoluble aluminum fluoride in the digestive tract as shown in cattle (21) and sheep (15). These salts were reported to alleviate the dental signs of fluoride toxicity (21); but in very severe intoxications, the aluminum effects seem to be overwhelmed. In this study, aluminum supplementation was effective in reducing fluoride digestive absorption about 33 to 45%, a rate similar to previous results. Moreover, aluminum decreased the severity of fluorosis; clinical, dental and bone effects were both less severe and delayed (22). Aluminum sulfate protection seemed to be very effective in the 0.10 mmol F^-/kg group; it was much less effective in sheep given 0.25 mmol F^-/kg. This latter lack of effect is probably due to a too high fluoride loading of sheep.

Our results demonstrate that experimental chronic fluoride toxicity in sheep is similar to field fluorosis in them. In both, dental and bone signs can be observed early and can be used as diagnostic criteria.

Conclusion

The efficacy of aluminum sulfate seems evident in experimental conditions for the lower dose, which is equivalent to the daily fluoride intake in the Darmous area of Morocco (12). Nevertheless, the efficacy remains to be demonstrated under field conditions.

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DETERMINATION OF FLUOROCARBONS OBTAINED BY THE PHOTOCHLORINATION REACTION

by

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SUMMARY: The findings in this study indicate that fluorocarbons are obtained by the photochlorination reactions of organo-fluorine compounds and the photoreactions of the HF/chloroolefin mixtures. Further we observed the production of several halocarbons such as CCl_4, $CHCl_3$, $CHCl{=}CFCl$, CH_3CCl_3, CH_3CH_2Cl, $Ch_2ClCHCl_2$, $CH_2{=}CCl_2$, $CFBr_3$, CH_3Br in our reaction systems under wavelengths of the exciting radiation (λmax. = 254 nm). For possible formation of fluorocarbons in the environment, further detailed investigation from all approaches is necessary.

KEY WORDS: Fluorocarbons; HF/chloroolefin mixtures; Organo-fluoride compounds.

Introduction

Recently, reductions in the ozone content of the upper atmosphere due to high concentrations of stratospheric halogens (1) have become the center of wide interest. Halocarbons are emitted from the production, transport, storage, end-use and disposal of industrial products, and remain as anthropogenic residues in the atmosphere (2). Rowland and Molina (3) proposed that chlorine atoms formed by the photolysis of chlorofluorocarbons ($CFCl_3$ and CF_2Cl_2) would also act catalytically to reduce the steady-state stratospheric ozone concentration. Subsequently, Crutzen et al. (4) pointed out that other relatively long-lived anthropogenic chlorocarbons such as CCl_4 and CH_3CCl_3 also represent a serious threat to the ozone layer.

Meanwhile in the human environment, hydrocarbons, HF, fluorine, organochlorine compounds, etc., are released from volcanoes, and stay in the atmosphere. Considerable research has been done concerning the distribution of concentration and behavior of fluorocarbons in the atmosphere (5-8). However, the reports on the sources and sinks, especially for origin of the halocarbons are mostly simulation which used the data of their concentrations and life times in the atmosphere and the data of production amounts; few laboratory studies have investigated the possibility of formation of these halocarbons in the environment.

The purpose of the present experiment is to show whether or not halocarbons, the fluorocarbons in particular are formed through photochemical reaction in the catalysts such as automobile exhaust, aerosol and several vapors.

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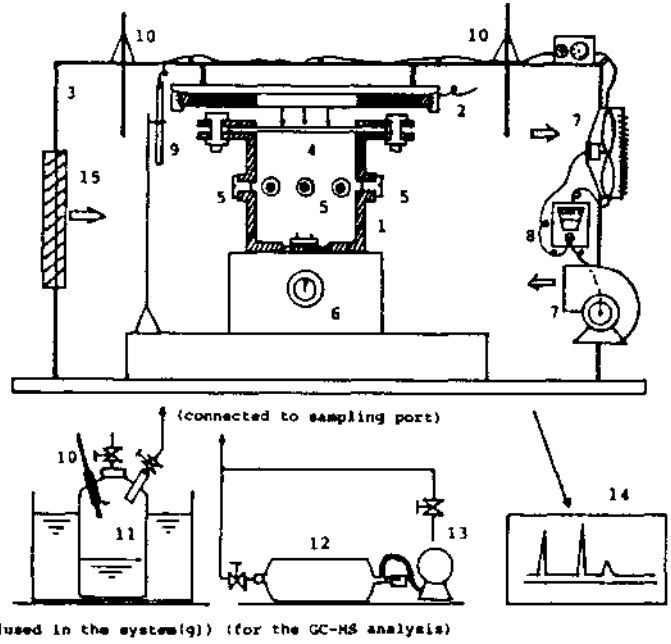
Materials and Methods

Test Chemicals: For the photochemical reactions, fluorine and chlorine compounds such as hydrogen fluoride (HF: 99.0% gas, 46.0% soln.), chlorine (Cl_2), hydrogen chloride (HCl), carbon tetrachloride (CCl_4), chloroform ($CHCl_3$), methylene chloride (CH_2Cl_2), tetrachloroethylene (CCl_2=CCl_2), trichloroethylene ($CHCl$=CCl_2), vinyl chloride (CH_2=$CHCl$), 2,2,2-trifluoroethanol (CF_3CH_2OH), fluoroacetone (FCH_2COCH_3), sodium fluoride (NaF), methylene bromide (CH_2Br_2), acetonitrile (CH_3CN) and t-butylalcohol ($(CH_3)_3COH$) were obtained in the purest available grade from the Wako Pure Chemical Company (Japan). Fluorocarbon standards for gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) were obtained from the Mitsui Fluorochemical Company (Japan) and Asahi Glass Chemical Company (Japan).

Experimental Procedure: The external view of the photochemical reactor used for the experiments is shown in Figure 1. The size of the reactor is 785 mL and it is made of Teflon. Two-way valves were provided on both sides of the reactor so that the air can be replaced by the nitrogen gas using the two-way valves at each stage. An irradiation window at the top of reactor

Figure 1

External View of Photochemical Reaction Apparatus



1. Photoreactor (made of Teflon, 785 mL; 2. Low pressure mercury lamp (λ_{main} = 254 nm); 3. Chamber; 4. Quartz glass plate or Teflon film; 5. Sampling port (Teflon-Silicon septum); 6. Magnetic stirrer; 7. Fan; 8. Thermocontroller; 9. Thermosensor; 10. Thermometer; 11. Reactor (made of Teflon, 500 mL); 12. Vacuum bottle; 13. Vacuum pump; 14. FID-GC; 15. Vent.

was fitted with a film of Teflon R (0.05-0.1 mm) or quartz plate (2 mm). Ultraviolet rays used in these photoreactions were obtained from a low-pressure mercury lamp ($\lambda_{max.}$=254 nm, Toshiba GL-15). The lamp was cooled by fans during irradiation, so that the reaction temperature was maintained at 25-30°C.

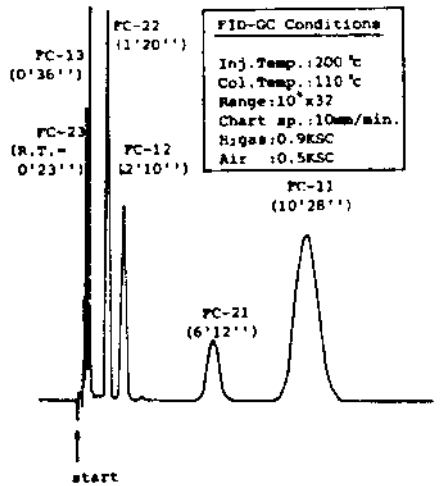
Test chemicals were injected into the reactor and irradiated for 24 hr. Injected volumes of test chemicals were 50-200 1/785 mL-reactor for vapor phase systems and 5-20 mL/785 mL for vapor-liquid phase systems. At the end of irradiation, the vapor products in the reactor were transferred to "Pyrex" or "Teflon" bottle samplers (200 mL) evacuated in advance. These samplers were used for the GC-MS analyses as shown in Figure 1. Sampling volumes of 0.1-2 mL of vapor products were injected directly into the GC and GC-MS with a gas-tight syringe.

Analytical Methods: Fluorocarbons were identified by use of a GC, GC-MS, and Mass fragmentography. The conditions of analysis were as follow:

Model	Shimadzu GC-MS 6020	Hitachi MS-70
Column	Glass, 3 mm-i.d. x 3 m	Sus, 3 mm-i.d. x 2 m
Packing	25% Silicone DC 550 Chromasorb W, 60/80 mesh	Porapack Q, 60/80 mesh
Column Temp.	55-130°C (Temp. Rate 4°C/min.)	60-120°C (Temp. Rate 3°C/min.)
Carrier Gas	He, 30 mL/min.	He, 30 mL/min.
Electric Energy	40 eV	20 eV
Ion Source	EI	EI

Figure 2

Gas Chromatograms of Standard Fluorocarbon Mixtures



Results and Discussion

The results are summarized in Table 1. The mark of + in the table indicates that fluorocarbons are determined by FID-GC and GC-MS. The gas chromatograms of standard fluorocarbons are shown in Figure 2. As the table shows, the reaction systems were classified as vapor phase and vapor-liquid phase photoreactions. The photochlorination of organofluorine compounds and photosensitized effects of mercury were examined in the vapor phase reactions. In the vapor-liquid phase reactions, we observed the reaction products appearing in the vapor phase and conjectured that the liquid phase photoreactions of HF with chloroolefins are the main reactions. When outside air, room air and/or automobile exhaust gas were used in the atmosphere of the reactor in

Table 1

Fluorocarbons (FC) obtained by the photochlorination reaction of organofluorine compounds and the photoreaction of the HF/olefins mixtures.

Reaction Systems and Test Chemicals \ Products			FC-32 (CH_2F_2)	FC-23 (CHF_3)	FC-22 (CHF_2Cl)	FC-21 ($CHFCl_2$)	FC-13 (CF_3Cl)	FC-12 (CF_2Cl_2)	FC-11 ($CFCl_3$)
Vapor Phase	(a)	CF_3CH_2OH(vapor)/Cl_2(gas)/N_2(gas)		+			+		
	(b)	CH_2F_2(gas)/Cl_2(gas)/N_2(gas)			+			+	
	(c)	FCH_2COCH_3(vapor)/Cl_2(gas)/Outside air				+			+
	(d)	CH_2F_2(gas)/HCl(gas)/Outside air		+			+		
	(e)	HF(99.0%,gas)/CH_2=CCl_2(vapor)/Metallic mercury (vapor)/Automobile exhaust gas/Room air	+		+				
	(f)	HF(99.0%,gas)/CH_2=CHCl(vapor)/EtOH(vapor)/Room air							+
	(g)	(S(powder)/NaF(soln.)/CH_3CN(soln.)/Cl_2(gas)/Room air)-Vapor products/CH_2Cl_2(vapor)/Room air	(by-products:S=CFCl,etc.)						+
Vapor-Liquid Phase	(h)	HF(46.0%,soln.)/CCl_2=CCl_2(soln.)/CHCl=CCl_2(soln.)/CH_2=CCl_2(soln.)/CH_2Br_2(soln.)/EtOH(soln.)/Room air	(by-products:CHCl=CFCl,$CFBr_3$,etc.)			+			+
	(i)	HF(46.0%,soln.)/NaF(soln.)/$(CH_3)_3COH$(soln.)/Cl_2(gas)/Room air							+

the reaction systems (c)-(i), the fluorocarbons, as indicated in Table 1, were not detected. In the reaction system (g), the non-photoreaction of the S(powder)/NaF(soln.)/CH_3CN(soln.)/Cl_2(gas)/room air mixtures was carried out in another reactor (500 mL) made of Teflon (see Figure 1) to produce the reactive S-F compounds (9) in advance. Subsequently, the vapor phase products of this reaction were introduced into the photoreactor with the CH_2Cl_2 (vapor)/room air mixtures.

Many kinds of fluorocarbons were produced in these systems (a)-(d) by the apparent photochlorination of organofluorine compounds. The initial concentration of chlorine was much higher than that of organofluorine compounds. The ultraviolet absorption bands of test chemicals which are about 250-400 nm for the Cl_2 (10), 140-220 nm for the HCl (11), ca. 120-200 nm for the fluorocarbons including CH_2F_2 (12), and further, for CF_3CH_2OH and FCH_2COCH_3, are shorter than those of ethyl alcohol (ca. < 190 nm) (13) and acetone (ca. < 350 nm) (14), respectively. The chlorine in system (a)-(c) plays a part of the initiator and the radical such as CF_3·, CH_2F·, CHF_2·, may be produced in the generation reactions, leading to the production of fluorocarbons in the table.

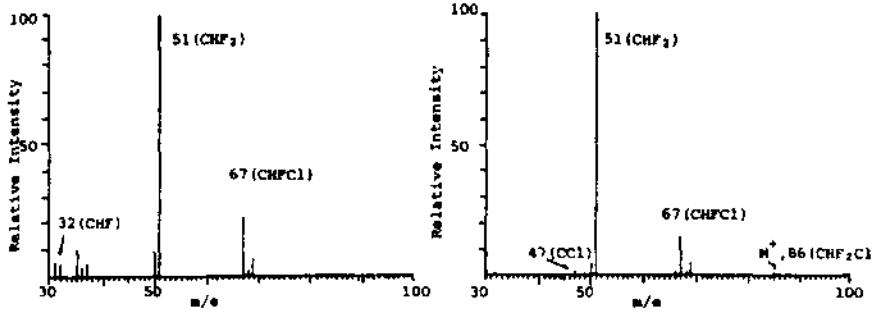
When nitrogen gas was used as the atmosphere of the reaction in the systems (a) and (b), the production ratios of fluorocarbons indicated by the gas chromatograms were generally higher than the systems (c)-(i), possibly as a consequence of the oxygen-free conditions. In the system (d), it may

be possible that small amounts of fluorocarbons were produced either by the direct photolysis of CH_2F_2 or as a result of the photoreaction of CH_2F_2 with the radicals such as OH and O_3. Therefore further detailed study is necessary.

It is known that the direct photolysis of HF rarely occurs in the ultraviolet bands of 200-400 nm (15) and the vigor of fluorination as estimated from the heats of reaction with organochloric methane (i.e. tetrachloromethane) is relatively low (16). However, addition reactions of HF towards olefins in the liquid phase have been reported (17). We performed the photoexperiments for the HF/chloroolefins reactions in the systems (e), (f) and (h), in the vapor phase and/or the liquid phase. Figure 3 shows the mass spectra of FC-22 produced by the reaction system (e) and that of standard FC-22. We considered the photosensitized reactions with mercury as the mechanism for formation of fluorocarbons in this system. The automobile exhaust gas used in our experiment was tested for fluorocarbons and none were detected by the FID-GC.

Figure 3

Mass spectra of FC-22 formed by the photochemical reaction in vapor phase of the HF (99.0% gas)/CH_2=CCl_2 (vapor)/metallic Mercury (vapor)/Automobile exhaust gas/Room air mixtures and standard sample of FC-22.



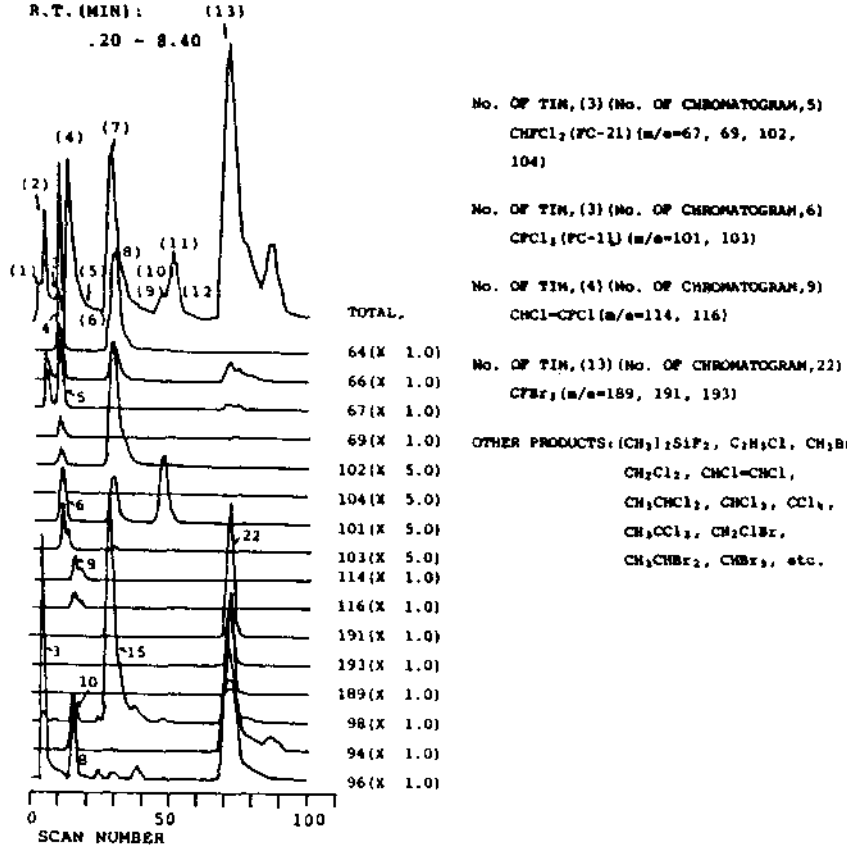
In system (h), FC-11 and FC-21 were identified from the peak numbers, 5 and 6 of mass chromatograms (the peak [3]) of Total Ion Monitor (TIM) as shown in Figure 4). When FID-GC analyses of the gaseous samples in the reactor were carried out before irradiation in system (h), as well as in other systems, we observed no fluorocarbon peaks. Further, it was shown that the peak numbers of mass chromatograms, 9 and 22 (numbers of TIM are [4] and [13], respectively) in Figure 4 indicated CHCl=CFCl and $CFBr_3$, and in system (i), the by-product CHCl=CFCl also appeared as a reaction product.

Because this compound containing the C=C double bond was not produced from the system (f) of the vapor phase reaction, it was inferred that it was formed by photoreaction and/or non-photoreaction in the liquid phase, and may have played the part of the reaction intermediate in the formation process of fluorocarbons in the photoreactions.

The only S-F compound that has been detected in the atmosphere is SF_6(18). In the experiment in system (g), we used reactants which are often

Figure 4

Mass chromatograms of FC-11, FC-21, CHCl=CFCl and $CFBR_3$ formed by the photochemical reaction of the HF (46% solution)/CCl_2=CCl_2 (solution)/ CHCl=CCl_2 (solution)/CH_2=CCl_2 (solution)/CH_2Br_2 (solution)/EtOH (solution)/ Room air mixtures.

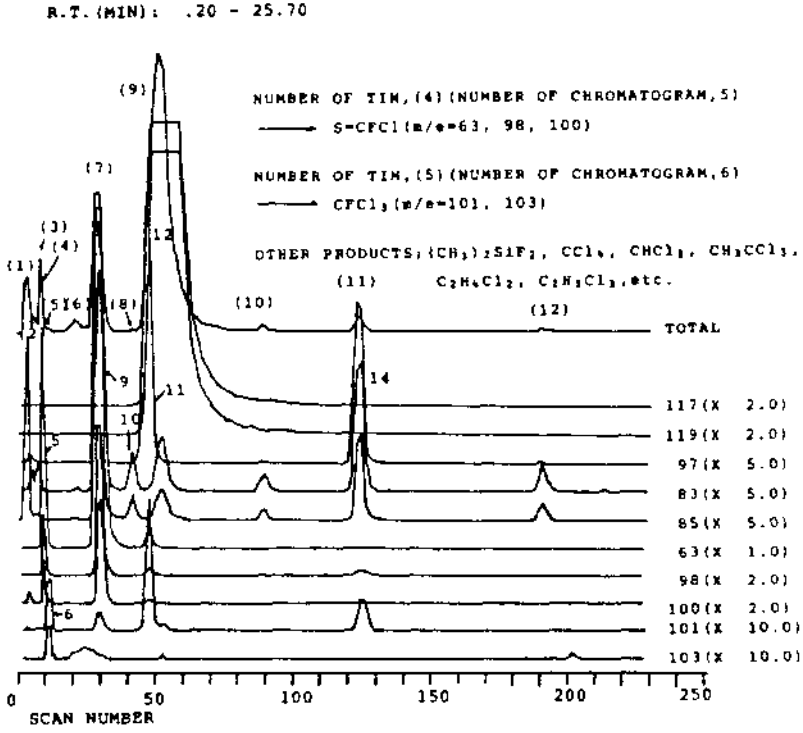


used in the laboratory synthesis of S-F compounds. The mass chromatograms of FC-11 and S=CFCl are shown in Figure 5. Considering that we would have produced the S-F compounds and carried out the vapor phase photoreaction using the products obtained from the non-photoreaction, the non-photoreaction was conducted in another reactor (500 mL). The identification of products resulting from this reaction has not been done; therefore, it is not clear whether or not the formation of S=CFCl was a result of the non-photolysis of an intermediate such as S=CFCl, because the existence of fluorocarbons was at least not detectable before irradiation.

As above, it was shown that the fluorocarbons were formed in these systems (a)-(i) using a low pressure mercury light source ($\lambda_{max.}$ = 254 nm), and also the by products CHCl=CFCl, S=CFCl and $CFBr_3$ were produced under our experimental conditions. If we continue the irradiation for a long time,

Figure 5

Mass chromatograms of FC-11 and S=CFCl formed by the photochemical reaction of the (S (powder)/NaF (solution)/CH_3CN (solution)/Cl_2 (gas)/Room air)-Vapor products/CH_2Cl_2 (vapor)/Room air mixtures.



FC-23 are newly recognized by the photodegredation of CF_3CH_2OH in the prolonged process. This indicates the possibility of transformation to FC-23 from an equation, $CHF_3 + Cl\cdot$. As reported by Clyne and Coxan (19), a reaction of Cl radical with O_3 and O may be very strong and rapid. The process of photochemical analysis for the reaction of Cl_2-CH_2F_2 may be viewed according to the following scheme.

$$Cl_2 \rightarrow 2Cl$$

$$Cl\cdot + CH_2F_2 \rightarrow CHF_2Cl + \cdot H \quad \text{(FC-22)}$$

$$\rightarrow CH_2FCl + \cdot F \quad \text{(FC-31)}$$

$$Cl\cdot + CHF_2Cl \rightarrow CF_2Cl_2 + \cdot H \quad \text{(FC-12)}$$

The reaction of Cl_2-RCH_2COCH_3 can also be explained as follows:

$$FCH_2COXH_3 \rightarrow CH_2F\cdot + \cdot COCH_3$$

$$2CH_2F\cdot \rightarrow C_2H_4F_2$$

$$\cdot COCH_3 \rightarrow \cdot CH_3 + CO$$

$$CH_2F\cdot + FCH_2COCH_3 \rightarrow CH_3F + \cdot CHFCOCH_3$$

Penkett et al. (20) stated that FC-21 in the troposphere was produced by photodegredation of FC-11.

Along with the investigation of reaction mechanisms and quantitative experiments on the formation of fluorocarbons, the selection of light sources, reaction systems and photosensitized effects are also under study. It should be noted that the wavelength of the exciting radiation ($\lambda_{max.}$ = 254 nm) is much lower than the cut-off in the solar spectrum at low altitudes (λ < 290 nm). It is more unlikely that free chlorine is present in the atmosphere at any altitude, and aerosols derived from motor vehicle exhaust are not found in the stratosphere at altitudes where the solar radiation contains UV light at wave lengths approaching 254 nm. The compounds which are observed to be produced in our photolytic experiments (FC-21, 22 and 13) are all present in the atmosphere.

Summary

The findings in this study indicate that fluorocarbons are obtained by the photochlorination reactions of organofluorine compounds and the photoreactions of the HF/chloroolefin mixtures. Further we observed the production of several halocarbons such as CCl_4, $CHCl_3$, $CHCl{=}CFCl$, CH_3CCl_3, CH_3CH_2Cl, $CH_2ClCHCl_2$, $CH_2{=}CCl_2$, $CFBr_3$, CH_3Br in our reaction systems under wavelength of the exciting radiation ($\lambda_{max.}$ = 254 nm). For possible formation of fluorocarbons in the environment, further detailed investigation from all approaches is necessary.

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TOOTH DAMAGE IN FIELD VOLES, WOOD MICE AND MOLES IN AREAS POLLUTED BY FLUORIDE FROM AN ALUMINIUM REDUCTION PLANT

by

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(Abstracted from The Science of the Total Environment, 65:257-260, 1987)

Aluminum production, a major cause of fluoride contamination of the environment, orginates from cryolite, or its equivalent, used as a flux in the electrolytic reduction of alumina. Fluoride is emitted from aluminum plants in particulate and gaseous forms; both are dispersed by prevailing winds. During an investigation into fluoride in ecosystem components around an aluminum reduction plant at Holyhead, Anglesey, in North Wales, small mammals were collected during 1977-85 (200 field voles Microtus agrestis, 303 wood mice Apodemus sylvaticus, 80 moles Talpa europaea and 240 common shrews Sorex araneus). Tooth damage was caused by high concentrations of skeletal fluoride in the first three species.

Severe tooth damage was observed only in those animals caught within a very short distance of the reduction plant, 200-300 m downwind (NE, the direction to which the prevailing SW winds blow) in the case of field voles (n = 13) and wood mice (n = 7), and 500 m downwind in the case of one mole. In addition, a significant increase in tooth wear was noted in moles between 4 and 15 km from the reduction plant, compared with moles from beyond 15 km, associated with increased bone fluoride content. Gross changes in teeth were seen in all three species.

Tooth wear and skeletal fluoride content were compared for two groups of moles, one group from within 15 km of the reduction plant (n = 76), the other from outside this area (n = 40). Frequency distribution for fluoride content and tooth wear differed markedly between the two groups of moles. The tooth wear index in the polluted group was roughly twice that in the unpolluted group.

It is not known whether the rodents in the area studied have constant dental disabilities, but still live long enough to breed; or whether the area is constantly re-colonized from outside by animals which subsequently succumb to high fluoride levels, but are sometimes caught by the investigator.

KEY WORDS: Anglesey; Aluminum plant; Mice; Moles; Tooth damage.

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****

EXTRACTION OF FLUORIDE FROM SOIL WITH WATER, AND WITH HYDROCHLORIC ACID SOLUTIONS SIMULATING PREDATOR GASTRIC JUICES

by

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(Abstracted from The Science of the Total Environment, 65:247-256, 1987)

Previous investigations by the author have indicated that the exceptionally high levels of fluoride in the skeletons of moles and shrews living in fluoride-polluted areas may result from the ingestion of earthworms containing fluoride-contaminated soil in their gut tracts. In the present study, fluoride was extracted from five different soils: two from unpolluted garden plots and three from polluted areas near an aluminum reduction plant at Holyhead, Anglesey, North Wales. For the extractions, various combinations of soil weight, pH and extractant (water or hydrochloric acid) were used. With unpolluted soils, equilibrium concentrations of fluoride were rapidly reached at a soil/water ratio of 10:1 and with polluted soils at ratios of 2:5 to 3:2. When the soils were shaken with different concentrations of HCl, maximum amounts of fluoride were released from polluted soils at pH 1.4 (near that of gastric secretions of mammals) and from one of the polluted soils at pH 1.0. The amount of fluoride and changes in pH obtained from the action of 1.0 M HCl on different soil weights could be correlated with the amount of extractable calcium present.

Results of these studies confirm the likelihood of the uptake of fluoride — as well as other pollutants, such as heavy metals — from soil by predatory animals. Because mammals can secrete more acid into their gastric contents as it is required, shrews and moles can probably extract fluoride very efficiently from soil contained in earthworm, accounting for the high fluoride concentrations found in their skeletons, even in relatively unpolluted areas.

KEY WORDS: Anglesey; Aluminum plant; Fluoride extraction; Gastric juices; Hydrochloric acid; Moles; Shrews; Soil fluoride.

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ENDEMIC FLUOROSIS IN THE ETHIOPIAN RIFT VALLEY

by

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(Abstracted from Trop. Geogr. Med., 39:209-217, 1987)

The volcanic Rift Valley, from north to south of Ethiopia divides the highland regions. Many of the major settlements with high population density are located in the Rift Valley.

The fluoride content of water samples taken at different points in the Rift Valley ranged from 1.0 mg/L to 36 mg/L (or parts per million = ppm); the drinking-water source was mainly boreholes with a depth of from 10 to 100 m; the majority were deep boreholes. In the sugar estates, with the highest population densities, fluoride levels are particularly high: Wonji-Shoa, 3.7-17.0 ppm; and Metahara, 2.4-7.0 ppm.

The prevalence of dental fluorosis in children in the groups sampled ranged from 69% to 98% (mean 84%). Of these subjects, 32.5% had a severe degree of dental fluorosis. The overall prevalence was higher among young males (741/881; 82.5%) than among young females (470/595; 81.7%), in 10-14 year olds (89%) ($p < 0.001$) compared to other age-groups. A 1977 survey of 2279 children 10-14 yrs old on the estates revealed an 80% prevalence rate of dental fluorosis.

Skeletal fluorosis was clinically manifested in only three areas namely Wonji-Shoa, Alem Tena and Sami Berta. Wonji-Shoa sugar estates had the highest prevalence. A few proven cases of skeletal fluorosis were discovered in 1985 at Alem Tena and Sami Berta. Between 1978 and 1984, 530 workers were retired from Wonji-Shoa aged 45-50 because of inability to perform their physically strenuous jobs; skeletal fluorosis was observed in 46% of these workers; the diagnosis was based on the usual radiological criteria. Radiological evidence of skeletal fluorosis was found in 65% of the 300 persons examined; 30 (10%) had crippling fluorosis. Cervical myelopathy and radiculomyelopathy were seen in 15 of the 30 persons, the commonest neurological complication; dorso-lumbar radiculomyelopathy was detected in 10.

Ten persons were completely incapacitated and bedridden, the majority with paraplegia in flexion. Spasm of muscles in the lower limbs and the abdomen was extremely painful in some patients. Sphincter disturbance was seen in 5 patients. Wasting and atrophy of muscles of the hands, especially the thenar eminence, and hypotonia in the upper limbs were seen in the advanced cases. Twelve patients of the 30 had sensory disturbance, predominately a severe affection of the vibration sensation in the lower limbs.

Dental fluorosis of varying severity is a universal finding in the Rift Valley in children born and brought up in the region. Crippling fluorosis was discovered by Jolly in a village in India with a mean fluoride concentration of 3 ppm, but not in another village where a similar concentration had been consumed for the same period.

Although the content of fluoride in drinking-water and the period of consumption of that water are important factors for the development of fluorosis, other factors such as sex, occupation, climatic conditions, the chemical composition of drinking water, diet and nutrition may also play significant contributory roles.

Because of the gravity of the fluoride problem in the Rift Valley, the Ethiopian Government is intensifying its efforts and resources to find and provide alternative sources of drinking-water with low fluoride concentration.

KEY WORDS: Crippling fluorosis; Dental fluorosis; Endemic fluorosis; Ethiopia; Rift Valley.

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****

ENHANCEMENT OF THE TWITCH OF BULL FROG SARTORIUS MUSCLE BY FLUORIDES

by

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(Abstracted from Japan J. Pharmacol. 40:191-193, 1986)

Effects of five kinds of fluoride on the twitch of the sartorius muscle of the bull frog were investigated. All of the fluorides (0.1-2.0 mM) enhanced the twitch evoked by nerve stimulation. The extent of enhancement at 2.0 mM was according to the following: stannous fluoride > potassium fluoride > sodium silicofluoride > sodium fluoride > diammine silver fluoride. The extent of each enhancement was larger than that in the case of direct stimulation of the muscle. These findings show that fluorides commonly enhance the twitch of skeletal muscle and that the extent of enhancement is related to the properties of cations included in the fluoride.

The minimal concentration of fluoride which caused the enhancement was as follows: 0.5 mM for $Ag(NH_3)_2F$, KF or Na_2SiF_6, and 0.1 mM for SnF_2, which were all higher than that in the case of nerve stimulation.

Thus, fluorides commonly enhance the twitch of skeletal muscle, and the extent of enhancement is related to the properties of cations included in the fluoride.

KEY WORDS: Bull frog; Muscle-twitch enhancement; Sartorius muscle.

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BIOAVAILABILITY OF FLUORIDE FROM SOME HEALTH FOOD PRODUCTS IN MAN

by

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(Abstracted from Caries Res. 20:518-524, 1986)

In 22 health food items — bone meal, calcium, and siliceous earth tablets — some of which are recommended especially for children for formation of bones and teeth, the fluoride content varies between 100 and 850 mg/kg. However, no declaration of the fluoride content was given for any product. Intake of fluoride from these products is between 0.9 and 2.9 mg/day. Absorption of fluoride from bone meal tablets is poor because simultaneous ingestion of calcium decreases fluoride availability.

Fluoride bioavailability was determined by measuring surplus urinary fluoride output following administration of three health food items. The term "bioavailability," according to Ritschel is the rate and extent to which fluoride is absorbed from a product and reaches systemic circulation. NaF tablets were used as reference substances.

Six healthy subjects, 3 boys and 3 girls aged 15-16 yers, participated in the study. Administration of health food products caused and increase of the urinary fluoride above normal values in 81 of a total of 84 experiments. With siliceous earth tablets no surplus fluoride excretion was obtained. The mean availability of fluoride was highest from calcium tablets (30.9-100%; mean 64.8%) lowest from siliceous earth tablets (0-74.1%; mean 38.9%). For bone meal tablets the figures were 15.9-91.5%; mean 53.9%. Since the quantity of fluoride ingested is dependent to a large extent on intake of fluids, daily urinary excretion and urinary fluoride output were closely correlated; fluoride lost with sweat is unknown. All subjects found taste and consistence of siliceous earth tablets unpleasant compared to other substances.

The findings presented here stress the need for a declaration of the fluoride content of health food products, especially when recommended for children, as well as for the estimation of fluoride bioavailability of the respective products. Such data should be considered in the recommendations of fluoride supplements for caries prevention.

KEY WORDS: Fluoride bioavailability; Health food; Urinary fluoride excretion.

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CORRECTIONS

July, 1988, p. 136. Footnote referring to publication of Fluoride in Australia – A Case to Answer by Wendy Varney was accidently omitted in the printing:

- Published by Hale and Iremonger Pty, Ltd., GPO Box 2552, Sydney 2001, NSW, Australia, Nov., 1986, ($12.95 p/b; $25.95 h/b, Australian dollars).

October, 1988, p. 166. 21:162, Paragraph 5, line 1, substitute Victoria (Australia) for New Zealand.

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INSTRUCTIONS TO AUTHORS

Fluoride, the official journal of the International Society for Fluoride Research (ISFR) is published quarterly (January, April, July, October). Its scope is the publication of papers and reports on the biological, chemical, ecological, industrial, toxicological and clinical aspects of inorganic and organic fluoride compounds. Papers presented at the annual ISFR conference are published in *Fluoride*. Submission of a paper implies that it presents original investigations and relevant bio-medical observations. Review papers are also accepted.

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