Volume 29
Number 2
Pages 57-128
May 1996

FLUORIDE

JOURNAL

of the

International

Society for

Fluoride

Research

THE INTERNATIONAL SOCIETY FOR FLUORIDE RESEARCH

Vol. 29 No. 2 May 1996 Pages 57 - 128

FLUORIDE

QUARTERLY JOURNAL OF
THE INTERNATIONAL SOCIETY FOR FLUORIDE RESEARCH

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LITERATURE REVIEWS

ABSTRACTS

NEUROTOXICITY OF FLUORIDE

The August 1995 issue of this journal contained an abstract (pages 151-152) of an interesting paper by Dr Phyllis Mullenix and her collaborators.[1] They recorded behavioral changes in rats after ingestion of fluoride, and found that the severity of the effect on behavior increased directly with plasma fluoride levels and fluoride concentration in specific brain regions. A reading of the full paper is well worthwhile. In their Introduction, after referring to the increase in dental fluorosis in humans after decades of water fluoridation, the authors comment:

"One concern that has not been fully investigated is the link between fluoride and effects on the central nervous system (CNS).... Many years of ubiquitous fluoride exposure have not resulted in obvious CNS problems such as seizures, lethargy, salivation, tremors, paralysis, or sensory deficits. Still unexplored, however, is the possibility that fluoride exposure is linked with subtle brain dysfunction."

The carefully designed animal experiment which they report revealed subtle but very real changes in behavior patterns following fluoride ingestion: hyperactivity after prenatal exposure, and cognitive deficits after weanling and adult exposure. Fluoride accumulation in important regions of the rat brain, especially the hippocampus, was found to increase as the drinking water fluoride levels increased. These effects, and the sex differences observed, corresponded to those observed in other studies of hippocampal brain damage.

The authors point out that the plasma fluoride levels recorded in the rats were the same as those sometimes recorded in humans - for example, in children one hour after receiving topical fluoride treatment of their teeth. In their conclusion calling for further rat and human studies they state:

"Experience with other developmental neurotoxicants prompt expectations that changes in behavioral function will be comparable across species, especially humans and rats. Of course behaviors per se do not extrapolate, but a generic behavioral pattern disruption as found in this rat study can be indicative of a potential for motor dysfunction, IQ deficits and/or learning disabilities in humans."

The authors draw attention to reports from Chinese investigators that high levels of fluoride in drinking water (3-11 ppm) affect the central nervous system directly without first causing the physical deformations of skeletal fluorosis.[2-4] Readers of *Fluoride* will recall the recent (November 1995) research report from China indicating adverse neurological effects on the brain from fluoride exposure.[5] This work also suggested that children with dental fluorosis are at greater risk of decreased mental acuity. One can only wonder whether the effects of fluoridated water might extend beyond the appearance of the teeth and include neurotoxicity among children afflicted with dental fluorosis.

Some of our readers may recall also pertinent early clinical findings reported by our founding editor, Dr G L Waldbott, of which Dr Mullenix and her co-workers do not appear to have been aware. These involved a wide range of reversible toxic effects of fluoridated drinking water, including diminished mental acuity and

impairment of memory.[6-8] In a separate report, Dr Waldbott even gave an account, supported by laboratory data, of a case of tetaniform convulsions induced by drinking fluoridated drinking water.[9] For decades proponents of water fluoridation have questioned the validity of these reports without, however, offering objective evidence to refute them. But in the light of the human research in China, and now the animal research in the United States, these clinical observations by Dr Waldbott on the neurotoxicity of fluoride in drinking water clearly deserve greater attention and credence.

AWB and JC

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XXIst WORLD CONFERENCE of the INTERNATIONAL SOCIETY FOR FLUORIDE RESEARCH in association with the HUNGARIAN SOCIETY FOR FLUORIDE RESEARCH, will be held in BUDAPEST, HUNGARY. AUGUST 25 - 28, 1996. Three-day **SCIENTIFIC PROGRAM** (26th, 27th, 28th) includes discussions on effects of fluoride on humans, animals, plants, and the environment. All proceedings in English. **REGISTRATION FEE:** Delegate US$300, accompanying guest US$150 (includes lunches and coffee breaks). **VENUE:** Aquincum Hotel. **ACCOMMODATION** (at Hotel) for 4 nights (25th, 26th, 27th, 28th): single room US$149 per night double room US$97 each person per night. Book direct with hotel: H-1036 Budapest, Árpád fejedelem útja 94, Hungary. (Phone 361 250 3360. Fax 361 250 4672). **SOCIAL:** Farewell Banquet US$100. Conference days will be free after 2 pm, with special programs planned. Daily and Post-Conference **TOURS** at special rates have been arranged. For costs and other information, direct enquiries to: Dr Miklós Bély, National Institute of Rheumatology, Department of Morphology, PO Box 54, H-1525 Budapest 114, Hungary (Phone 361 212 2689. Fax 361 212 2676).

THE EFFECTS OF FLUORIDE, ALONE AND IN COMBINATION WITH SELENIUM, ON THE MORPHOLOGY AND HISTOCHEMISTRY OF SKELETAL MUSCLE

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SUMMARY: The objective was to study the effect of fluoride on skeletal muscle and the protection afforded by selenium. Skeletal muscle specimens from a four month old foetus were prepared for ultrastructural study after the addition of sodium fluoride, or sodium fluoride and sodium selenite, and incubation for two hours *in vitro*. Further specimens for ultrastructural and histochemical study were also obtained from rats who had been given, for eight weeks *in vivo*, drinking water containing 221 mg/L of sodium fluoride (100 ppm of fluoride), or 221 mg/L of sodium fluoride and 16.7 mg/L of sodium selenite. The histochemical results showed a decrease in the activities of the enzymes succinate dehydrogenase, cytochrome oxidase, and Mg^{2+}-adenosine triphosphatase when fluoride had been given. The ultrastructural studies showed that the skeletal muscle cells were damaged directly by fluoride with mitochondria and myofibrils being affected. Selenium was found to protect skeletal muscle from the effects of fluoride. It was concluded that skeletal muscle cells may be damaged by fluoride with necrosis following a disruption of energy metabolism in the mitochondria with interference to the stability of the mitochondrial membrane. Selenium was found to have a protective effect which may be due to improving mitochondrial membrane stability.

Key words: Enzymes; Fluoride; Histochemistry; Selenium; Skeletal muscle; Ultrastructure.

Introduction

Skeletal muscle is sensitive to fluoride-induced muscle cell damage in chronic fluoride toxicity or fluorosis resulting in functional changes with muscle ache and weakness, and alterations to the levels of succinate dehydrogenase (SDH).[1]

The effect of selenium on fluorosis has been studied with no effect being found in one study[2] but in another selenium alleviated lipid peroxidation by fluoride and increased fluoride excretion.[3]

In the present study, using *in vitro* and *in vivo* techniques, the morphological and mitochondrial enzyme changes induced by fluoride were studied together with the protective effects of selenium on fluorosis.

Materials and Methods

In an *in vitro* study, skeletal muscle obtained from a four month old foetus was cut into small pieces and placed in incubation bottles containing 5 mL of PRMI 1640 medium. After the addition of 50 μL of 6 mg/mL sodium fluoride, 12 mg/mL sodium fluoride, or 12 mg/mL sodium fluoride and 0.22 μg/mL sodium selenite,

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the specimens were incubated for 2 h at 37°C and then placed in 3% glutaraldehyde. Control specimens were incubated in the PRMI 1640 medium or in 3% glutaraldehyde. The specimens were prepared for examination with a H-600A electron microscope.

In an *in vivo* study 21 male Wistar rats, weighing 180-200 g, obtained from the animal breeding facility of Harbin Medical University, were divided into three groups of 7 animals. The experimental groups were given drinking water containing 221 mg/L of sodium fluoride (100 ppm of F), or 221 mg/L of sodium fluoride and 16.7 mg/L of sodium selenite. The fluoride level of the drinking water for the control group was 0.38 mg/L (0.38 ppm of F). After 8 weeks the animals were sacrificed and the skeletal muscles placed in 3% glutaraldehyde prior to preparation for electron microscopy or immediately frozen in liquid nitrogen for histochemical study by slicing into sections 4 μm thick, incubating and staining. Six slices were tested for each enzyme for each rat. SDH was determined by Pearson's method, cytochrome oxidase (CCO) by Seligman's method, and Mg^{2+}-adenosine triphosphatase (Mg^{2+}-ATPase) by the method of Wachstein and Meisel.[4] The results of the enzymatic histochemistry were analysed by the Ridit test with a higher value for the mean R indicating a higher level of enzyme activity.

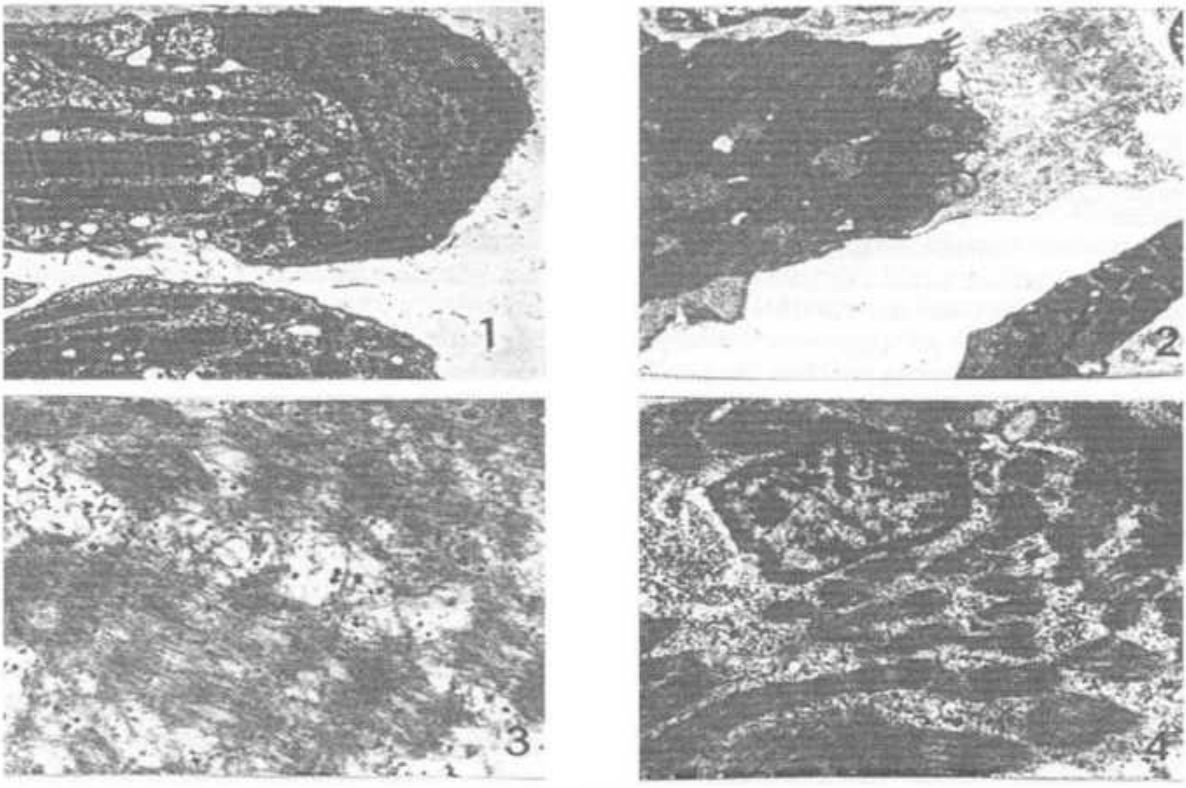
Results and Discussion

In the control skeletal muscle specimens prepared *in vitro,* the skeletal muscle cells were slim and elongated with the myofibrils arranged orderly and showing cross striations of dark and light bands. The mitochondrial cristae were discernible (Figure 1). In the specimens treated *in vitro* with fluoride, most of the cells were damaged with the arrangement of the myofibrils being disorderly and and some appearing shrunken, thin and necrotic. The mitochondrial cristae showed disintegration and the mitochondrial matrix was of low density (Figures 2 and 3). These changes were more serious and extensive in the specimens treated with the higher dose of sodium fluoride than in those treated with the lower dose. In the specimens receiving fluoride and selenium, the changes were less prominent than in those treated with fluoride alone (Figure 4).

For the group treated *in vivo,* the ultrastructure of the skeletal muscle was normal in the control group (Figure 5) but abnormal in the group treated with fluoride with localized twisting and necrosis present, together with disintegration and swelling of mitochondrial cristae (Figure 6,7). In the group treated with both fluoride and selenium, no damage to myofibrils was present but some mitochondria were swollen and hollow (Figure 8).

The Ridit test of the histochemical results showed that, when compared to the control values, sodium fluoride decreased the activities of the three enzymes studied (see Table). When selenium was present with the fluoride in the drinking water, the values for SDH and CCO were significantly higher than the values for fluoride without selenium. The value for Mg^{2+}-ATPase increased to a non-

Figures 1-4. Ultrastructural changes in skeletal muscle of foetus *in vitro*: 1 The control (x5000); 2 and 3 Fluoride group (x6000 and x17000); 4 Fluoride + selenium group (x6000).



Figures 5-8. Ultrastructural changes in skeletal muscle of rat *in vivo*: 5 The control (x12000); 6 and 7 Fluoride group (x4000 and x8000); 8 Fluoride + selenium group (x6000).

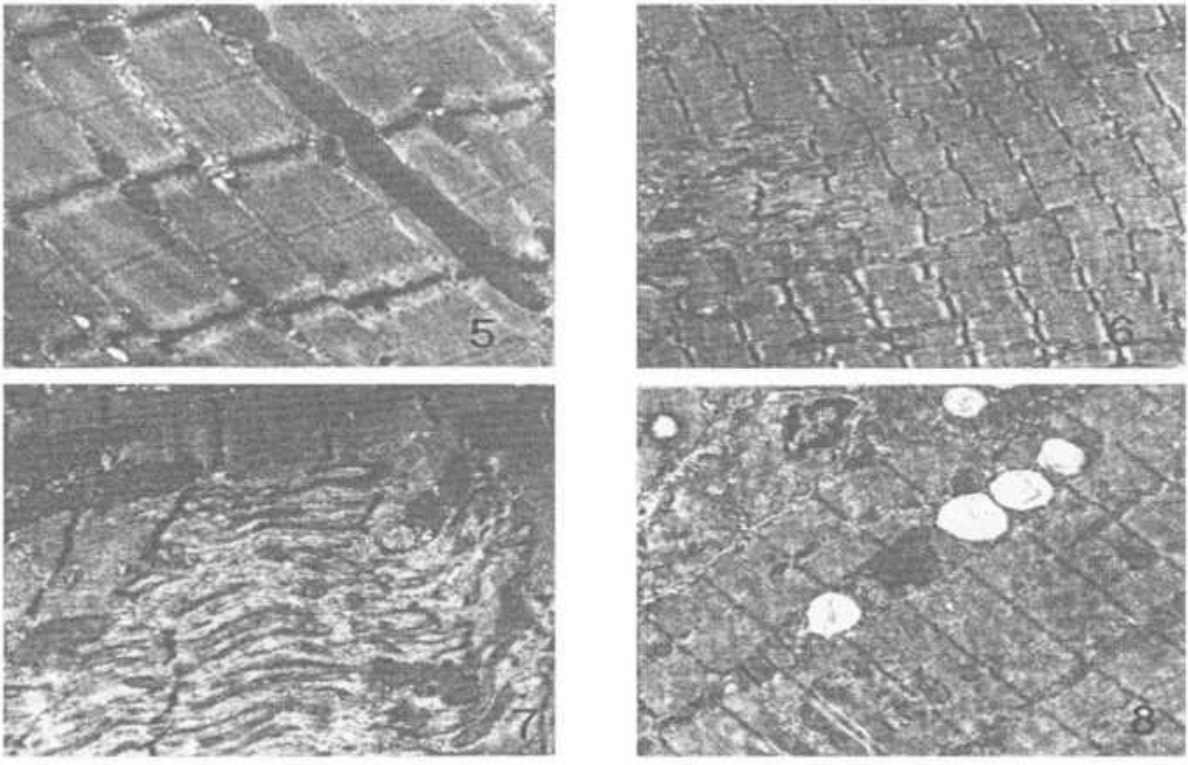


TABLE. The activities of SDH, CCO and Mg^{2+}-ATPase of skeletal muscle of rats treated *in vivo* with sodium fluoride and sodium selenite

Treatment	$\bar{R}$ Ridit test	SDH 95% confidence interval	$\bar{R}$ Ridit test	CCO 95% confidence interval	$\bar{R}$ Ridit test	Mg^{2+}-ATPase 95% confidence interval
Fluoride	0.45*	0.35-0.56	0.40*	0.29-0.50	0.47	0.37-0.58
Fluoride and Selenite	0.70	0.59-0.80	0.64	0.54-0.75	0.53	0.42-0.63
Control	0.70	0.60-0.81	0.74	0.64-0.85	0.61	0.51-0.72

* compared to the control $p<0.05$

Conclusion

The results of the *in vitro* and *in vivo* studies indicate that mitochondria and myofibrils in skeletal muscle cells can be damaged directly by fluoride. The primary function of mitochondria is to provide energy for cells by catalyzing, with a series of enzymes, the oxidation of nutrient substances. The activity levels of the marker enzymes, SDH, CCO and Mg^{2+}-ATPase, reflect the state of oxidation and energy metabolism. In conditions with a high level of fluoride present, the stability of the mitochondrial membrane was destroyed and the activities of the marker mitochondrial enzymes decreased. It is considered that the impairment of energy metabolism may lead to the skeletal muscle necrosis which may occur with fluoride. The protective effect found with selenium may be due to an improvement in the stability of the mitochondrial membrane.

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Published by the International Society for Fluoride Research
Editorial Office: 81A Landscape Road, Mount Eden, Auckland 4, New Zealand

INVESTIGATIONS OF SOFT TISSUE FUNCTIONS IN FLUOROTIC INDIVIDUALS OF NORTH GUJARAT

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SUMMARY: The present study was undertaken to investigate the various health problems caused by water-borne fluoride in endemic villages of Mehsana and Banaskantha districts of Gujarat. The study revealed high levels of fluoride in serum samples of the villagers. Mottling of teeth and skeletal complications were common. Intake of fluoride caused a decrease in hæmoglobin content and in the serum protein levels. Serum cholesterol levels were normal. Circulating levels of testosterone were decreased, but not significantly enough to indicate an effect on reproductive functions. The enhanced levels of serum transaminases, which are markers for liver function, indicated structural and functional changes in liver due to fluoride intake. Changes in the serum calcium, sodium and potassium levels revealed electrolyte imbalance in the fluorotic individuals. While levels of thyroid stimulating hormone (TSH) and triiodothyronine (T_3) did not vary, a significant increase in the thyroxine (T_4) levels suggested alteration in thyroid function. Thus the study revealed some harmful effects of fluoride in the soft tissue functions of the endemic population.

Key Words: Banaskantha; Mehsana; Soft tissue function; Water-borne fluoride.

Introduction

Fluorosis caused by intake of fluoride has been recognised in India for six decades. It is a slow, progressive crippling malady, affecting young and old, rural and urban populations. It has recently attained alarming dimensions. It is widespread in as many as 15 states of the Indian Republic, afflicting some 25 million people. Gujarat is one of the 15 states in India reported to have endemic fluorosis, and 18 out of the 19 districts have elevated fluoride concentrations in drinking water. The worst affected districts include Amreli, Mehsana, Banaskantha, Sabarkantha and Baroda (Chhota Udepur).

Agricultural crops, water and food are contaminated with fluoride because of the high concentrations of fluoride in the soil of those regions.

The Geological Survey of India reveals that topaz, apatite, rock phosphate, phosphate nodules and phosphorite are widespread in the earth's crust in India and contain high percentages of fluoride. As a result of the rich mineral content and high rainfall, fluoride leaches out and contaminates the water and the soil.

Fluoride is known to affect the dental and skeletal systems. In addition, studies carried out in the past few years have shown detrimental effects on soft tissue functions of various animal models.[1-7] Its effect on soft tissue functions on humans is less understood and few reports are available regarding this aspect of fluoride toxicity. We have carried out surveys in the fluoride endemic areas of Gujarat since

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1985. This paper reports our surveys during the last three years. Earlier survey results have been published.[8,9]

Materials and Methods

Five hundred individuals from fifty-two villages in Mehsana and Banaskantha of Gujarat State were initially examined. Individual proforma sheets recorded the following: Name, age, sex, address, drinking water source, depth of the well or pond, duration of stay in the village, food habits, dental changes and skeletal changes. The tests of Susheela [10] were used to assess whether or not the joints were affected.

After collection of those data, drinking water source samples, and blood collected from randomly selected fluorotic individuals, were brought to the laboratory for analysis. The serum was separated by centrifugation.

Selection of control individuals:

Water samples and blood samples were also collected from Ahmedabad city where water fluoride is below the permissible limit (Indian Bureau of Standards).

The following parameters were studied in control and fluorotic populations:

Fluoride in drinking water and serum samples were determined with an Ion selective electrode Orion. Model 701A, and were expressed as ppm.

Hæmoglobin levels, determined with a hæmometer, were expressed as gm%.

Serum protein levels were estimated by the method of Gornall *et al*,[11] and expressed as gm/100 mL serum.

Serum cholesterol levels, determined by the method of Pearson *et al*,[12] were expressed as mg/100mL.

Serum glutamate pyruvate transaminase (SGPT) levels were estimated by the method of Reitman and Frankel[13] and expressed as mU/mL serum.

Serum glutamate oxaloacetate transaminase (SGOT) levels were estimated by the method of Reitman and Frankel[13] and expressed as mU/mL serum.

Calcium, sodium and potassium levels in serum were estimated by a Flame Photometer (Systronic digital unit type 125) according to the method of Dean [14] and expressed as ppm.

Serum hormones:

Testosterone serum levels were assayed by the double antibody radioimmunoassay (RIA) technique of Peterson and Swerdloff[15] (kit obtained from Binax, USA) and were expressed as ng/mL serum.

Triiodothyronine and thyroxine (T_3 and T_4) serum levels were determined by RIA method of Peterson and Swerdloff[15] (kits obtained from BARC Bombay) and were expressed as ng/mL.

Thyroid stimulating hormone (TSH) serum levels were determined by the immunoradiometric assay method of Kemp *et al*[16] (kit supplied by BARC, Bombay) and were expressed as μU/mL serum.

Serum catecholamines levels were determined by the method of von Euler and Hamberg[17] and expressed as $\mu g/mL$ serum.

Results

Surveys conducted in 52 villages of North Gujarat revealed symptoms of fluorosis in the majority of the individuals studied. 74% of the individuals showed slight to severe mottling of teeth. 59% had stiffness of spinal cord. Other skeletal problems such as stiff hands and fingers (60%), stiffness of legs and joints (65%) were also common. 93% of the cases studied were regular tea drinkers. Tea accumulates fluoride, so may contribute to the fluoride burden of the body.

Water fluoride content: Water samples from various places of Ahmedabad city showed fluoride levels within the permissible limit (mean: 0.6 ppm). However, as before,[8,9] the samples collected from endemic villages of North Gujarat revealed high fluoride contents, ranging in this survey (Table 1) from 1.0 to 6.53 ppm. Of the 52 villages 18 (35%) had fluoride content below 2 ppm and 26 (50%) had fluoride content within the range of 2-4 ppm while 8 (15%) had fluoride levels above 4 ppm. Bore water samples had higher fluoride concentrations than well water samples.

Tables 1-4 present similar results to those of earlier surveys,[8,9] *i.e.* the fluorotic individuals, when compared to controls, had significantly increased serum levels ($P < 0.001$) of fluoride, SGOT, SGPT, sodium and potassium, and serum cholesterol levels were essentially the same in both populations.

In this survey, there was an insignificant decrease in mean serum testosterone levels in the fluorotic individuals, compared to controls.

Other new results from this survey were:

Serum fluoride: Of the 80 samples analysed, 38% had fluoride concentration < 0.2 ppm; 47% showed F^- levels in the range 0.2-0.4 ppm; while 15% showed F^- levels above 0.4 ppm (Table 1). Fluoride concentration increased with age (see Figure).

Hæmoglobin: Levels of the fluorotic group showed an insignificant decrease when compared to the control population (Table 2).

Serum cholesterol: Levels were essentially the same for both fluorotic populations and controls (Table 2).

Serum protein and calcium: Levels of the endemic population showed a highly significant decrease ($p < 0.001$) as compared to the control (Tables 3 and 4).

Serum triiodothyronine (T3) and *thyroid stimulating hormone* (T5): There was no difference in levels in the fluorotic and control groups (Table 5).

Serum thyroxine (T4): Levels showed a significant increase ($P < 0.001$) compared to control (Table 5).

Serum catecholamines: The serum adrenalin and nor-adrenalin levels increased significantly in fluorotic individuals ($P < 0.001$) compared to controls (Table 6).

TABLE 1. Water and serum fluoride levels (ppm) in control and endemic population

Parameter	Control	Endemic Population
Water fluoride	0.638 ± 0.013	2.70 ± 0.18
Range	0.56 - 0.72	1.0 - 6.53
No. of cases	15	52
Serum fluoride	0.04 ± 0.002	0.284 ± 0.032
Range	0.03 ± 0.05	0.131 ± 0.552
No. of cases	15	76

Values are Mean ± S.E.

TABLE 2. Hæmoglobin (gm%), serum cholesterol (mg/100 mL) and testosterone (ng/mL)

Parameter	Control	Endemic Population
Hæmoglobin	13.3 ± 0.339	12.89 ± 1.48
Range	11.8 - 16.4	7.8 - 16.0
No. of cases	22	75
Cholesterol	155.22 ± 7.51	148.25 ± 3.90
Range	122.5 - 200	64.0 - 192.30
No. of cases	15	40
Testosterone	6.42 ± 0.423	5.56 ± 0.49
Range	4.3 - 9.3	1.10 - 11.5
No. of cases	15	35

Values are Mean ± S.E.

TABLE 3. SGOT, SGPT (mU/mL) and serum protein (gm/100 mL) levels

Parameter	Control	Endemic Population
SGOT	16.02 ± 1.2	29.38 ± 0.83
Range	12.0 - 24.0	23 - 41
No. of cases	15	35
SGPT	11.7 ± 0.83	22.33 ± 0.73
Range	9 - 15	15 - 29
No. of cases	15	35
Protein	8.64 ± 0.144	5.76 ± 0.89
Range	7.942 - 9.42	4.15 ± 6.98
No. of cases	15	35

Values are Mean ± S.E.

TABLE 4 - Calcium, sodium and potassium levels (in ppm)

Parameter	Control	Endemic Population
Calcium	0.958 ± 0.045	0.595 ± 0.014
Range	0.71 - 1.15	0.40 - 0.79
No. of cases	15	60
Sodium	1163.68 ± 28.84	1875.59 ± 30.8
Range	861 - 1500	1320 - 2450
No. of cases	22	60
Potassium	129.35 ± 7.96	322.75 ± 42.38
Range	90 - 120	130-820
No. of cases	22	60

Values are Mean ± S.E.

TABLE 5. T_3, T_4 and TSH levels in serum

Parameter	Control	Endemic Population
T3 (ng/mL)	1.50 ± 0.135	1.528 ± 0.076
Range	0.70 - 2.1	1.0 - 3.7
No. of cases	15	40
T4 (ng/mL)	9.16 ± 0.63	14.77 ± 0.512
Range	5.4 - 13.0	7.2 - 20.0
No. of cases	15	40
TSH (μU/mL)	2.56 ± 0.36	2.55 ± 0.37
Range	0.50 - 4.4	0.30 - 6.1
No. of cases	15	55

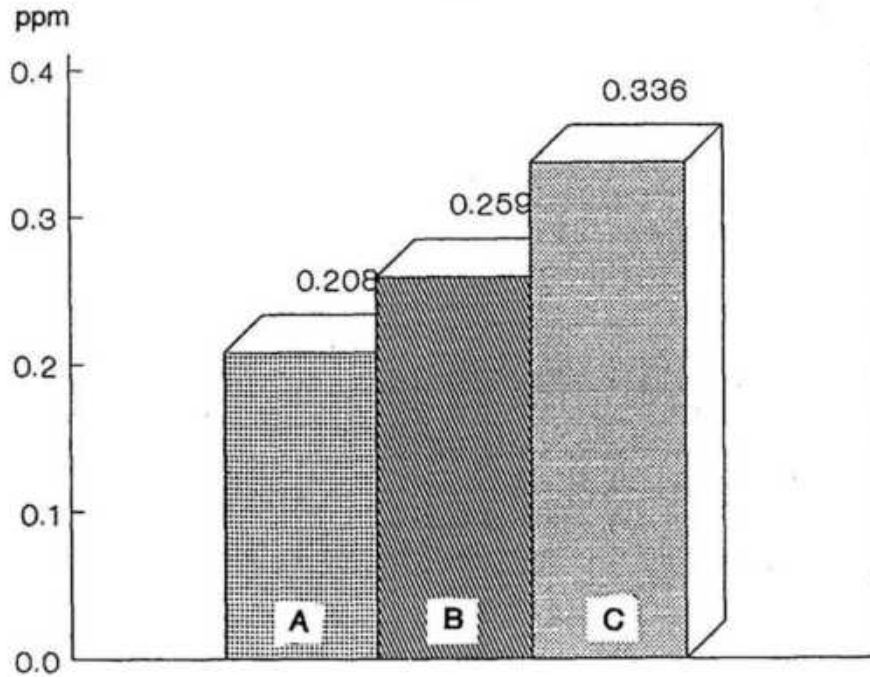
Values are Mean ± S.E.

TABLE 6. Catecholamine levels (μg/mL) in serum

Parameter	Control	Endemic Population
Adrenalin	220.67 ± 20.79	332.61 ± 20.54
Range	157.46 - 311.60	114.20 - 788.51
No. of cases	15	50
Nor-adrenalin	164.51 ± 11.19	514.87 ± 35.27
Range	118.51 - 235.0	108.64 - 1053.07
No. of cases	15	50

Values are Mean ± S.E.

FIGURE. Age dependent variation in serum fluoride concentrations among endemic population. A: below 30 yr. B: 30.- 50 yr. C: Over 50 yr.



Discussion

The study of health problems caused by water-borne fluoride in Mehsana and Banaskantha districts of North Gujarat revealed a wide occurrence of fluorosis, ranging from mild to acute.

The concentrations of fluoride ions in plasma is directly related to the fluoride content of the drinking water. This close relationship has been clearly demonstrated by several authors.[18,19] Saralakumari and Ramakrishna Rao[20] observed a correlation between fluoride toxicity and duration of stay in the village, nutritional and socio-economic status of the individuals.

In this study, when the individuals were divided into three age groups (under 30 yr, 30-50 yr, and over 50 yr), an increase in serum fluoride levels with age was observed (Figure). Ekstrand[21] showed that plasma fluoride increased with age between 10 and 38 years. This difference in serum fluoride levels could be attributed to a difference in fluoride uptake by the skeleton. The young, growing skeleton, being low in fluoride, has a greater capacity for taking it up. In older people, the bone fluoride is higher and the plasma approaches equilibrium with it, hence there occurs a rise in plasma fluoride with advancing years.[22] Experiments on dogs and puppies also revealed age-dependant increase in blood fluoride levels.[23] Thus there is a direct correlation between the age of the individual and fluoride retention.

There are only a few reports in the literature of anæmia in fluorotic individuals. Hæmoglobin levels in the endemic villages were low, compared to those in the control population. Though the difference between mean values was not significant, individual values in the endemic population showed great fluctuation. Though fluoride is capable of causing anæmia, the hæmoglobin level is also governed by the individual's nutritional status. Macuch *et al*[24] observed decreased hæmoglobin, increased erythrocytes and abnormal lymphocyte count in children living in the vicinity of an aluminium processing plant. Decreases in hæmoglobin and erythrocyte count were also reported in camels near a super-phosphate factory.[25]

Fluoride is known to inhibit protein synthesis, mainly due to impairment of peptide chain initiation[26] and by interfering with peptide chains on ribosomes.[27] In the present study protein levels in the endemic area were significantly decreased, which would adversely affect the growth of the affected individuals.

Conflicting reports have been published regarding fluoride toxicity and lipid metabolism. Saralakumari *et al* reported a decrease in plasma free fatty acids as well as total lipids, and an increase in serum cholesterol, in rats supplemented with fluoride in drinking water for sixty days,[28] but Chinoy *et al* showed no changes in serum cholesterol and various reproductive tissues of rats[2,6,7] and mice[29] exposed to NaF for 30 days. The results of the present investigation also revealed normal levels of serum cholesterol, thus ruling out the occurrence of hypo/hypercholesterolæmia among fluorotic individuals in the early stages of the disease.

The circulating levels of testosterone in fluorotic individuals were also not altered significantly in males. Chronic fluoride treatment of rats also resulted in decreased testicular cholesterol levels.[30]

Chronic cases of fluorosis need to be investigated in detail since the chances of atherosclerosis cannot be ruled out. Numerous investigators have reported calcification of arteries in association with skeletal fluorosis in high fluoride areas.[31,32] Susheela and Kharb have reported aortic calcification in rabbits subjected to chronic fluoride poisoning.[33] Fluoride also causes renal calcification in rats.[34] The decreased levels of serum calcium in the fluorotic individuals could be attributed to ectopic calcification in soft tissues. It could also be due to a decrease in the intestinal absorption of fluoride since fluoride is known to produce insoluble complexes with calcium. Further studies are necessary on endemic human populations to establish the role of fluoride atherosclerosis.

Calcium homeostasis is controlled by hormonal regulation of the thyroid and parathyroid glands.[35,36] In the present study, no significant change was observed in the levels of thyroid stimulating hormone (TSH) and T_3 in the fluorotic individuals. An enhancement was observed in the levels of T_4, which might be due to enhanced iodination to form this hormone rather than T_3 which would result in its increased synthesis/release by the gland. Demole did not find any relationship between thyroid dysfunction and fluoride toxicity.[37]

In fluorotic individuals the serum catecholamines were increased significantly, which would have a stimulatory effect on the sympathetic nervous system, thus influencing the hypothalamus gonadal axis and result in marked changes in reproductive functions. It would also affect the carbohydrate metabolism by accelerating the breakdown of glycogen.

The increased levels of serum transaminases in fluorotic individuals suggest alteration in liver function. These levels increase several times if cellular damage occurs in the liver, so these enzymes are markers for assessing liver function.

The fluorotic group showed marked alteration in their serum electrolyte levels. Potassium and sodium levels increased significantly, compared to controls. Differential distribution of these two cations is essential for normal membrane function and integrity. Similar augmentation in electrolyte levels was demonstrated in rats fed with sodium fluoride.[6] But Suketa and Terui observed a reduction in the serum sodium level in rats after fluoride administration, while potassium levels, on the other hand, significantly increased.[38] They attributed these changes to alteration in adrenal function. However, Das and Susheela reported low corticosteroid levels in fluorotic humans, suggesting adrenal hypofunction.[39] Serum potassium is an indicator of cell damage. Increased levels suggest cell deterioration.

Conclusion

The present study revealed wide occurrence of fluorosis in the Mehsana and Banaskantha districts of North Gujarat. Intake of high water-borne fluoride altered the normal body metabolism of the individuals. Further surveys are required in fluoride endemic areas, to reveal the magnitude of the problems caused by fluoride. The Government should take steps to supply safe drinking water in the villages affected by fluorosis.

Acknowledgements

One of the authors, Mathews Michael, wishes to thank the Council of Scientific and Industrial Research, New Delhi, for the award of a Senior Research Fellowship. Another author, Vinod V Barot, acknowledges the award of a Junior Research Fellowship by the Gujarat Hunger Project Council.

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Published by the International Society for Fluoride Research
Editorial Office: 81A Landscape Road, Mount Eden, Auckland 4, New Zealand

FLUORIDE INHIBITION OF [2-^{14}C]THYMIDINE INCORPORATION INTO DNA IN MUNG BEAN SEEDLINGS

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SUMMARY: The effect of sodium fluoride (NaF) on the incorporation of [2-^{14}C] thymidine into DNA in germinating mung bean (*Vigna radiata* cv Uthong-1) seedlings was studied. One-day-old mung bean seedlings were treated with water (control) or 1.0 mM NaF containing [2-^{14}C]thymidine for 24 h and the thymidine incorporation into various parts of the radicle was examined. Silver grains shown by the autoradiograph of the F-exposed radicle were markedly decreased compared with those of the control. Fission rates (%) exhibited by various parts of the experimental radicles were much lower than those of the control. The results indicated that NaF suppressed DNA synthesis in mung bean seedlings.

Key words: [2-^{14}C]thymidine; Autoradiography; DNA synthesis; Fluoride; Mung bean seedlings.

Introduction

Impaired root growth in germinating seeds has been known as a manifestation of phytotoxicity caused by many environmental chemicals including fluoride. The mechanism involved in the impairment is not fully understood and appears multifactorial. For example, depressed root elongation in corn seedlings exposed to 10 mM NaF was shown to be related to decreased RNA contents of 3-mm root tips,[1] and changes of RNA structure.[2] Similarly, the viability and soluble proteins of germinating wheat seeds were found to be reduced by exposure to NaF.[3] We reported that the germination of mung bean (*Vigna radiata*) was inhibited when the seeds were treated with 1.0 mM NaF and that the inhibition might be related to lipase[4] and amylase[5] activity, and reducing sugar contents.[6] In this paper, we describe experimental results showing that NaF markedly inhibited incorporation of [2-^{14}C]thymidine into radicles of germinating mung bean seedlings, thus confirming the inhibitory effect of NaF on DNA synthesis in germinating seeds.

Materials and Methods

Seed germination and effect of NaF on growth of seedlings

Mung bean (*Vigna radiata* cv Uthong-1) seeds were soaked in water for 24 h and the seedlings were placed in petri dish lined with filter paper. The seedlings were then treated with 10 mL each of H_2O (control), 0.2, 0.5, or 1.0 mM NaF and incubated at 25°C for 24 h. Fifty seedlings were randomly selected and the radicles were separated and weighed.

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Presented to the XXth Conference of the International Society for Fluoride Research, Beijing, China, September 5-9, 1994.

[2-^{14}C]thymidine treatment

To study the effect of NaF on the incorporation of [2-^{14}C]-thymidine by mung bean seedlings, one-day-old seedlings were treated with 4 mL of 1.0 mM NaF containing [2-^{14}C]-thymidine (1.85 MBq/mL) and incubated at 25°C for 24 h. Seedlings treated with 4 mL of H_2O and the same amount of [2-^{14}C]thymidine were used as control. The specific activity, radiochemical purity, and final radioactive concentration of the [2-^{14}C]thymidine were 1.96 GBq/mM, 98%, and 92.5 kBq/mL, respectively.

Autoradiography

At the end of the experiment, radicles were removed and subjected to fixation with 10% formalin, followed by dehydration with ethanol. The specimens were embedded in paraffin and sectioned to a thickness of 4 μm. The thinned sections were dipped in an autoradiographic emulsion and exposed for 20 days. The sections were developed and stained with hematoxylin and eosin. The resultant autoradiographs were then examined under a light microscope.

Fission rates

Fission rates of the largest longitudinal sections of the radicles were calculated according to the following formula:

$$\text{Fission rate (\%)} = \frac{\text{No. of dividing nuclei}}{\text{No. of observed nuclei}} \times 100$$

Analysis of data:

Data were analyzed using the *t*-test after angle transformation of percentages.

Results

Exposure to varying concentrations of NaF resulted in a progressive decrease in radicle weight within 24 h, and the decrease was NaF-concentration dependent (Table 1). A 30% decrease in fresh weight was observed in radicles treated with 1.0 mM NaF. Exposure to lower concentrations of NaF also resulted in lowered biomass, but the differences were not statistically significant.

Examination of the autoradiographs under a light microscope showed black grains of developed silver deposited in the nuclei of dividing cells of the radicles (Figures 1 and 2). These grains are considered as the sites of [2-^{14}C]thymidine incorporation into DNA in the radicle under study. As shown in the figures, the number of silver grains in the radicle from NaF-exposed seedling was much smaller than that in the control tissue.

The fission rates (%) exhibited by different tissues of the control and experimental radicles are presented in Table 2. The rates displayed by the root apical meristem, endodermis, vascular cylinder, and cortex of the experimental radicles were significantly decreased compared with those of the control.

TABLE 1. Effect of NaF on radicle growth

NaF (mM)	n	Weight of radicle (mg)	Percent of control
0	50	16.7 ± 6.76[a]	-
0.2	50	16.6 ± 4.16	99
0.5	50	14.5 ± 4.84	87
1.0	50	11.7 ± 4.81***	70

[a] Values are mean ± SD
*** $p < 0.001$

TABLE 2. Fission rates of radicles from mung bean seedlings

NaF mM	n	Root apical meristem	Endodermis cylinder	Vascular	Cortex	Root cap
0	8	98.3 ± 4.7[a]	84.2 ± 7.6	96.8 ± 3.2	90.9 ± 11.2	53.3 ±32.1
1.0	8	58.7 ±38.5*	53.8 ± 45.2*	44.0 ±43.0**	44.3 ±39.3*	40.7 ±32.1

[a] Values are means ± SD
* $p < 0.05$ ** $p < 0.01$

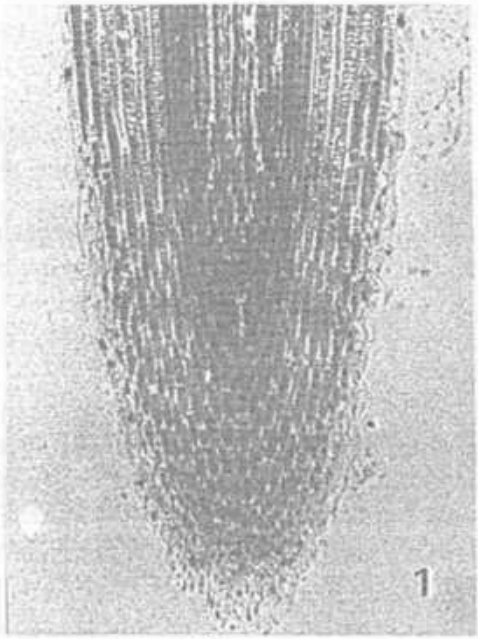

FIGURE 1. [2-^{14}C]thymidine incorporation in radicle of mung bean seedling treated with 1.0 mM NaF (80 x)

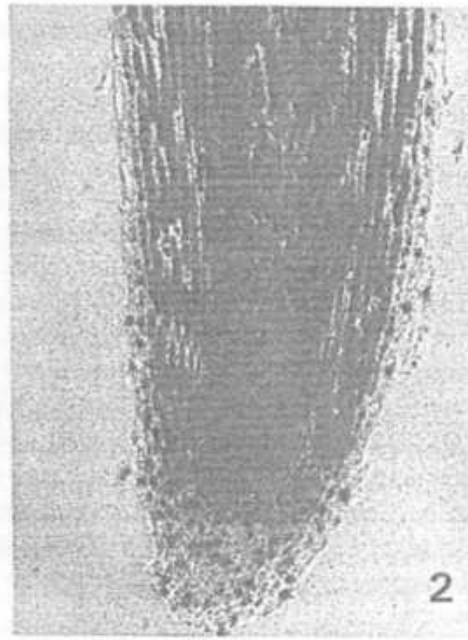

FIGURE 2. [2-^{14}C]thymidine incorporation in radicle of mung bean seedling treated with water (control) (80 x)

Discussion

Comparison of Figures 1 and 2 revealed a marked inhibition of [2-^{14}C]thymidine incorporation into the NaF-exposed radicle. In addition, the fission rates of various parts of the radicle including the root apical meristem, endodermis, vascular cylinder and cortex were all significantly decreased in the experimental seedling compared with those of the control. Because thymine and thymidine generally have no fate other than as DNA building blocks,[7] our results indicate that NaF at 1.0 mM suppressed DNA synthesis in cells of the germinating mung bean seeds. This observation supports earlier reports on different organisms.[8-10]

^{3}H-Thymidine has frequently been used in studies on DNA synthesis.[11-15] However, most of the ^{3}H-thymidine may become ^{3}H-metabolites of thymidine in the seedlings.[16] The radioactivity in the study with ^{3}H-thymidine may therefore originate mainly in the thymidine ^{3}H-metabolites. Under the experimental conditions used, it is likely that most of the [2-^{14}C]thymidine taken up by plant cells will be incorporated into DNA. The [2-^{14}C]thymidine not incorporated into DNA may be converted to $^{14}CO_2$ following metabolism[17] or be removed by the ethanol used in the dehydration of specimens for microscopic autoradiographs, as described in the Materials and Methods section.

According to Nitsan and Lang,[9] a decrease in DNA synthesis in higher plants leads to decreased RNA and protein synthesis, and to reduced cell division and cell elongation. Our results tend to support such observation. Thus, it is concluded that much of the observed inhibition of mung bean germination in the presence of NaF, such as lowered biomass or impaired root elongation, may be attributed to NaF-dependent depression of DNA synthesis.

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Published by the International Society for Fluoride Research
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FLUORINE, SELENIUM, SULPHUR AND CARBON CONTENTS OF COAL IN HUBEI PROVINCE.

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SUMMARY: Analysis of 488 coal samples in Hubei Province for content of the elements fluorine, selenium, sulphur and carbon showed that the coal is of poor quality, low in C, high in ash and S, while F and Se contents are higher than the average for our country. The coal provides low heat energy. Fluorine and selenium toxicosis in Hubei is closely related to the combustion of this coal. Prevention and control measures are recommended to decrease the fluorine content in coal, and to renovate the coal-burning stoves in the area.

Key words: Carbon; Fluorine; Fluorine toxicosis; Selenium; Selenium toxicosis; Sulphur.

Introduction

Air pollution from coal-burning causes some endemic diseases. Fluorine toxicosis in the southern and southwest parts of our country,[1,2] and the currently reported selenium toxicosis,[3,4] both have close correlations with coal-burning, including in Hubei. To further understand the geographic distribution of coal sources, and the relationship between the elements content of the coal with certain endemic diseases, we sampled coal produced in Hubei province over two years.

Material and Methods

We collected 488 coal samples to analyse the content of fluorine (F), selenium (Se), sulphur (S), and combustible organic carbon (C) in coal in Hubei Province. F analysis was with a high temperature burning ion selective electrode method; Se detection was by spectrophotometric assay; S detection was by temperature decomposition absorption iodometry; organic C detection was by weight method.

Results and Discussion

The samples had a wide range of contaminants. Most of the data presented deviation distribution, so instead of mean values, the median was taken (Table).

1. The median content of combustible organic carbon in the coal was low (50%).
2. The median content of particles (ash) in coal in was high (41.91%).
3. High content of sulphur. The median content of sulphur in all kinds of coal was 2.6%. In the bituminous type it was high - up to 4.58%.
4. Fluorine content is highest in stony coal (996.30 mg/kg) - twice that in bituminous and white coal. The median F content of coal in Hubei (531.25 mg/kg) is twice our country's average (200 mg/kg), and much higher than the world's average (80 mg/kg).[5]
5. The median content of selenium in stony coal (42.06 mg/kg) is 4-5 times more than that in bituminous and white coal. Of the 488 coal samples, 100 had selenium content over 30 mg/kg, the highest being 347 mg/kg. These selenium levels in Hubei coal are much higher than our country's average. A selenium toxicosis

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Presented to the XXth Conference of the International Society for Fluoride Research, Beijing, China, September 5-9 1994.

investigation in the western region of Hubei Province reported even higher Se contents than ours: the median in 129 stony coal samples was 143.9 mg/kg, the highest being 1150 mg/kg.[4]

TABLE. Content of 4 elements in various coals in Hubei Province

Element	Type of coal	No. of sample	Content range	Median
C (%)	stony	153	2.73 - 78.07	31.94
	bituminous	106	6.81 - 76.69	54.17
	white	229	9.01 - 82.08	57.92
	Total coal	488	2.73 - 82.08	49.67
F (mg/kg)	stony	153	79 - 3469	996.30
	bituminous	106	95 - 2021	423.81
	white	229	75 - 3658	531.25
	Total Coal	488	75 - 3858	631.25
Se (mg/kg)	stony	153	2.53 - 347	42.06
	bituminous	106	1.00 - 48.30	9.22
	white	229	0.11 - 59.30	7.82
	Total coal	488	0.11 - 347	10.15
S (%)	stony	153	0.26 - 19.81	1.86
	bituminous	106	0.46 - 14.66	4.58
	white	229	0.08 - 13.05	2.82
	Total coal	488	0.08 - 13.05	2.68

Coal plays a key role in the prevalence of fluorine and selenium toxicosis in Hubei Province. Our investigation has shown that the coal from this province is of poor quality, providing low heat energy.

To control and prevent fluorine toxicosis from combustible coal, it is important to renovate coal burning stoves, to decrease the fluorine content by new control methods, change the backward and harmful way of burning coal, enhance awareness of public health; and improve nutrition in disease areas. Such measures could radically change the environment and bring these diseases under control.

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X-RAY ANALYSIS OF 80 PATIENTS WITH SEVERE ENDEMIC FLUOROSIS CAUSED BY COAL BURNING

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SUMMARY: Radiographs of 80 patients with severe endemic fluorosis of coal-burning type [CBEF] - 49 males and 31 females aged 30 to 70 years - were analysed to examine the changes to the bone substance, peripheral structure of bone, and joints. The changes to bone substance were: 1) osteosclerosis type, 62 cases (77.5%); 2) mixed type, 16 cases (21.25%); 3) osteoporosis type, one case (1.25%); 4) osteomalacia type, one case (1.25%). The changes to the joints were: articular lesions were found in the hips and elbows in 79 cases (98.75%), and in the knees in 75 cases (93.75%). When combinations of the above three changes occur, the classification of the disease is according to the most severe one of the three. Our findings can increase the accuracy of X-ray diagnosis, making it more consistent with clinical diagnosis, thus improving prevention and treatment of CBEF.

Key words: fluoride; fluorosis; endemic X-ray diagnosis.

Introduction

CBEF is the type of endemic fluorosis caused by air and food contaminated by coal smoke, and occurs in certain mountainous regions in Sichuan, Guizhou, Hubei and Yunnan Provinces of China. To improve our knowledge of CBEF, and to improve prevention and treatment to this disease, we analysed radiographs of 80 patients with severe CBEF, examining the changes to the bone substance, the peripheral structure of the bones and joints. Relations between X-ray changes and the stages and classification of the disease were also discussed.

Materials and Methods

Radiographs were taken of 450 patients with CBEF, in the CBEF regions of Sichuan Province, China, during 1989 to 1992, and included: frontal view in pelvis and right forearm containing the elbow, and frontal and lateral views in the right tibia and fibula containing the knee. Eighty cases with severe CBEF (49 male and 31 females aged 30 to 70 years), selected from the 450, were radiographically analysed. X-ray diagnoses were according to criteria described in *The Hand Book for Prevention and Treatment of Endemic Fluorosis.*[1] With combinations of changes to bone substance, peripheral structure of bones, and joints, the classification of the disease was according to the most severe of the three changes observed.

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Presented to the XXth Conference of the International Society for Fluoride Research, Beijing, China, September 5-9 1994.

Results

Changes to bone substance and type:

1) Osteosclerosis type of CBEF occurred in 62 cases (77.25%). The density of the bone in the pelves increased, fine and compact bone striae with fusion occurred in four cases. In 46 of 58 cases, the density of the bone was lower in the extremities than in the pelves. Compact osteosclerosis in both the pelves and the extremities were observed in 16 cases, of whom 8 presented the eburnated appearance in the forearms and legs, and 11 had mild to moderate changes to the joints. The clinical diagnosis of them was: moderate degree. Their age averaged 44.4 years.

2) Mixed type of CBEF occurred in 16 cases (21.25%). The pelves all manifested compact bone sclerosis, obliteration of trabeculae, and bone transference resulting in woven bone formation. Eight of the 16 cases presented gross bone change with thin cortex. Osteoporosis of the bone cortex and sclerosis of the cancellous bone occurred in 8 cases. In 12 of 16 cases, the changes of the joints were of the severe degree, corresponding to the clinical diagnosis. Their age averaged 54.4 years.

(3) Osteoporosis type of CBEF occurred in one case (1.25%). The pelvis and extremities demonstrated obvious osteoporosis, narrowed spaces in elbows, and deformed ends of the bones. The tendons and ligaments were ossified. The lower rims of both hips showed hyperostosis embracing the femoral heads. The knees presented hyperostosis, gross ends of the bones, with calcified interosseal membranes and parietes of the blood vessels.

4) Osteomalacia type of CBEF occurred in one case (1.25%). There were multiple pseudofractures in the left tibia and fibula. radiographs after 18 months showed that the fracture lines were clearer, with margins of osteosclerosis. Although there was a little callus, the fractures were not healed because of osteomalacia. The pelvis showed compact osteosclerosis, with trabeculae obliterated as osteosclerotic osteomalacia.

Changes to the peripheral structure of the bones:

Interosseal membranes in the forearms and/or legs were ossified in 79 cases (98.75%). Intertransverse ligaments were ossified in 59 cases (74.25%). Supraspinal ligaments were ossified in 58 (72.50%), and iliolumbal ligaments in 38 (47.50%). Twenty-nine cases (36.25%) were graded as severe according to the changes of the peripheral structures of the bones.

Changes to the joints:

In all our cases, there were articular lesions in various degree, the most common site being the hips in 80 (100%) cases, main findings included: hyperostosis of the upper and lower rims of the acetabulum, embracing the femoral heads; lesions of the elbows in 79 (98.75%) manifested in ossified extensor and flexor tendons and narrowed spaces of the joints. Forty one of 80 cases were graded as severe according to the changes to the joints.

Discussion

1) Changes of bone structure of CBEF: The increase of bone density is the main roentgen finding. In 79 among 80, the pelves showed increase of bone density, and compact osteosclerosis. In 63 of these, the degree of osteosclerosis decreased from the trunk to the extremities, as described in the literatures.[2] However, in 16 cases the pelves, forearms and legs all showed compact osteosclerosis. In 8 of the 16, the articular changes were mild to moderate, consistent with the clinical diagnosis. The patients were younger and their ability to work remained. It is apparent that osteosclerosis is not parallel to the articular changes and the clinical stages. So osteosclerosis does not represent the severity of CBEF.

2) Clinical diagnosis of CBEF is based on the degree of motion of the joints. In our cases, the ossifications of the peripheral structures of the bones occurred in 98.75%. Besides the tendons and ligaments in the extremities, there were multiple ossifications of the spinal ligaments, so that the vertebral column was limited in motion, resulting in kyphosis, a stiff and rigid spine.

3) Lesions of the joints of CBEF.[3] Articular lesions in the elbows and hips occurred in 98.75% of the cases, and in the knees in 93.75%. The patients were unable to flex the knees and to squat. In 12 of 16 cases with mixed type CBEF, the articular lesions were severe, consistent with the clinical diagnosis. Their age averaged 54.4 years and they were disabled. The lesions of the peripheral structure of the bones and of the joints are closely related with the clinical symptoms and signs, and are positively related to the patient's age.

4) CBEF may cause necrosis of the articular cartilage, similar to degenerative arthropathy, from which it should be differentiated. Ossifications and osteophytes of the articular synovial, tendons and ligaments are characteristics of CBEF.[4] The main roentgen findings of CBEF are the changes to the bone substance, to the peripheral structure of the bones, and to joints. We suggest that criteria for X-ray diagnosis of CBEF should include the articular changes. Classification of the disease depends upon the most severe of the above three changes. The above considerations can make X-ray diagnosis more consistent with clinical diagnosis.

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Published by the International Society for Fluoride Research
Editorial Office: 81A Landscape Road, Mount Eden, Auckland 4, New Zealand

 Fluoride Vol.29 No.2 82-88 1996

DEVELOPMENTS IN THE ANALYSIS OF FLUORIDE 1993-1995

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This biennial review is a continuation of the previous articles[1,2] and covers the literature of the analysis of fluoride from June 1993 to May 1995.

Electroanalysis

A fluoride electrode assembly was examined in terms of potential-concentration curves and potential-time response. The behaviour of the F^- ion-selective electrode (FISE) with the studied internal contact based on a copper(II) ion-selective electrode was in good agreement with the commercial fluoride electrode.[3]

Two types of pH-ISFETs were used as the basis for F^--FETs with Si_3N_4 or Al_2O_3 as sensitive layers, respectively. Deposition of LaF_3 on the gate isolator results in pF-ISFETs. A Nernstian sensitivity was reached with both kinds of fluoride ISFETs. While the ISFETs with the Si_3N_4 interlayer were very stable, a drift of 5-10 mv/h was observed with those having Al_2O_3 in contact with the LaF_3 layer. A combination of pH- and pF-ISFETs was investigated over one order of magnitude in acid solutions. Impedance spectroscopy and tracer measurements with ^{18}F were used to identify the rate-determining step of the potential forming process.[4,5] A flow injection analytical system has been developed with a fluoride ISFET as detector and a pH-ISFET as reference. Acid solutions decrease the response time of the fluoride sensor. Optimum conditions are around pH 2, which can be met with IM acetic acid. The sample rate can be increased by a factor of 8 in this solution compared to standard TISAB. Also, concentrations as low as 1 ppb can be determined. The reason for the influence of pH on the response rate has been investigated by impedance spectroscopy and X-ray photoelectron spectrometry, which showed that chemical modification of the LaF_3 surface reduces the energy barrier for fluoride ion transfer.[6]

Three- and four-component mixtures of halides (I^-, Br^-, Cl^-, and F^-) from one titration can be analysed in aqueous and EtOH-H_2O solutions by use of different pairs of ion-selective electrodes for the end-point determination. The halide mixtures without F^- were titrated with a mixed titrant, $AgNO_3$ + $La(NO_3)_3$.[7]

Electroanalysis methods for fluoride are shown in Table 1.

Spectral Analysis

A new chemical method[8] for the determination of fluoride in samples with high fluoride content such as toothpaste has been reported. A radical complex absorbs radiation at 227.45 nm from a hollow Pt cathode lamp. The method is fast and relatively free from interference. It has been used especially for the determination of both ionic and covalently bonded fluoride in toothpaste.

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TABLE 1. Determination of fluoride by electroanalysis

Method	Application	Reference
ISE	Biological materials	*Anal. Chim. Acta 274* (2) 253-256 1993
Zirconium electrode	Flow injection system	*Anal. Chim. Acta 273 (1,2)* 267-274 1993
ISE	Industrial wastes	*Chem Anal 38* (1) 129-131 1993
Potentiometric	Environmental water	*Analyst 118* (7) 859-861 1993
Discontinuous flow potentiometry	Environmental samples	*Chem. Listy 87* (6) 443-448 1993
ISE	Soil solutions	*Commun. Soil Sci. Plant Anal. 24* (15,16) 1865-1882 1993
Gas diffusion with pre-concentration-flow injection	Water	*Talanta 41* (1) 115-123 1994
Potentiometric and spectrophotometric	Evaluation of its uptake rate by tooth enamel	*Asian J. Chem 5* (4) 1091-1098 1993.
Flow-type system for multi-element ionometric determinations	Drinking water	*Zavod Lab 60* 13-15-63 1994
ISE-masking reagents	Raw materials of fluoride glasses	*Analyst 120* (1) 167-170 1995.
ISE- with catalytic controlled current potentiometric and conventional potentio-metric titrations	In a pharmaceutical preparation	*Glas Hem Tehnol Maked 13* (2) 85-90 1994
ISE	Industrial wastes	*Chemik 47* (9) 224-226 1994
ISE	Cryolite ratio in alu-minium electrolysis cells	*Aluminium 70* (9/10) 579-582 1994
ISE	Foods	*Bromatol Chem Toksykol 27* (4) 353-357 1994
Microdiffusion-ISE	Foods	*Weisheng Yanjiu 24* (2) 111-113 1995

A rapid AAS method[8] has been proposed for the determination of fluorides by selective dissolution of lead zirconate-titanate. Procedures were developed for the flame-photometric determination of lithium and an indirect AAS determination of fluorides in treated water and in air of work areas for the production of lithium fluoride monocrystals. From 0.5 to 5.0 mg Li/L and from 2.0 to 20 mg F/L can be measured.

The determination of fluoride in urine and tap water by laser-excited molecular fluorescence spectrometry of magnesium monofluoride in a graphite tube furnace has been reported.[10] The use of barium as a chemical modifier increased the size of the signal by a factor of 100. The 1800°C vaporization temperature was lower than the 2400-2700°C reported by other workers.

Determination of fluoride by spectral analysis is summarised in Table 2.

TABLE 2. Determination of fluoride by spectral analysis

Method	Application	Reference
Auger electron spectroscopy	Barium fluoride thin films	*Appl. Surf. Sci. 70-71* (pt. A) 85-88 1993
Kinetic flow-injection spectrofluorimetric method	Tap and mineral water	*Anal. Chim. Acta 283* (1) 489-493 1993
Spectrophotmetric method	Water and biological samples	*Fenxi Huaxue 21* (10) 1202-1204 1993
Photometric	Natural water	*Zavod. Lab. 59* (7) 4-6 1993
Fluorometric using an expanded porphyrin	At the ppb level of fluoride	*Microchem. J. 49* (2-3) 136-144 1994
Spectrophotometry of arsenazo III complex of the back-extracted Th(IV)	Water	*J. Radioanal. Nucl. Chem. 188* (4) 291-298 1994

Chromatography

The determination of anions by capillary electrophoresis (CE) in combination with indirect UV detection has been reported for eight of the most common anions (F^-, Cl^-, Br^-, SO_4^{2-}, NO_3^-, NO_2^-, $S_2O_3^{2-}$, PO_4^{3-}) in drinking water, serum, and urine.[11] The ability of capillary ion electrophoresis to analyse primary and secondary anionic contaminants as well as other ions of environmental concern in drinking water, groundwater, and wastewater has been demonstrated.[12] Analytical time is less than 5 min. Electromigration sample introduction in capillary ion electrophoresis leads to on-capillary enrichment of ionic analytes at the sample-buffer interface, thereby permitting determination of low (ng/mL) levels of anions in environmental samples of moderate ionic strength.[13]

The use of high performance liquid chromatography (HPLC) for the simultaneous determination of fluoride, nitrate, phosphate, and sulfate anions in phosphate rock, nitrogen fertilizers, and phosphoric acid has been described.[14] The HPLC results for F^-, NO_3^-, PO_4^{3-}, and SO_4^{2-} agreed well with results obtained by conventional wet-chemistry methods.

A simple post-column reaction system detects fluoride by decolorization of the zirconyl xylenol orange complex. A detection limit of 0.05 μg F^-/mL was achieved with a linear calibration function up to 10 μg F^-/mL. The method is also suitable for the determination of F^- in potable water.[15]

Fluoride analysis by chromatography is summarised in Table 3.

TABLE 3. Analysis of fluoride by chromatography

Method	Application	Reference
IC (ion chromatography)	German Environmental Specimen Bank (ESB)	*Fresenius Z. Anal. Chem. 345* (2-4) 291-293 1993
IC	Urinary fluoride	*Anal. Chim. Acta 274* (2) 299- 302 1993
IC and ionexclusion chromatography	Highly pure water	*Vysokochist. Veshchestva* (2) 98-103 1993
IC	Environmental samples	*Fenxi Huaxue 21* (5) 619 1993
HPLC using lanthanum alizarin complexone reaction	Environmental samples	*Kankyo Kagaku 3* (2) 464-465 1993
Capillary ion analysis (CIA)	Nonlignocellulose polymer	*Kankyo Kagaku 3* (2) 426-427 1993
Dual cation-selective membrane tube electrodialysis/IC	Rock samples	*Bull. Chem. Soc. Jpn. 66* (3) 1664-1668 1993
IC	Inorganic anions	*Bunseki Kagaku 42* (8) 505-508 1993
IC	Industrial landfills leachates	*Fresenius Environ Bull 2* (6) 338-343 1993
IC	Anions and cations in atmospheric aerosols	*J. Chromatogr. 640* (1-2) 217-226 1993
IC	Organic samples	*J. Chromatogr. Sci. 31* (9) 366-370 1993
IC	Inorganic and organic anions	*J. Chromatogr. 640* (1.2) 27-31 1993
GC-flame ionization detection	Biological material	*Anal. Chim. Acta 282* (3) 589-601 1993
IC	Environmental samples	*Zavod. Lab. 59* (5) 1-4 1993
IC	Biological samples	*J. Liq. Chromatogr. 16* (14) 3083-3092 1993
IC	Gaseous and particulate	*Appl. Occup. Environ. Hyg. 8* (9) 775-784 1993
IC	The detection limit for F^- is 0.1 ng	*J. Chromatogr. Sci. 32* (4) 157-161 1994
Alizarine complexone photometric-IC	In gypsum	*Bunseki Kagaku 43* (3) 241-246 1994
IC	Inorganic anions	*Bunseki Kagaku 43* (3) 237-240 1994
Capillary isotachophoresis	Feed mixtures	*J. Chromatogr. A 670* (1-2) 223-228 1994
Improvement of a computer process for IC	Natural water	*J. Chromatogr. 668* (2) 385-393 1994

continued next page

Table 3 *continued*:

Method	Application	Reference
Capillary electrophoresis with different carrier electrolytes and indirect UV detection	Inorganic cations and anions	*Anulysis 22* (4) 178-187 1994
Capillary electrophoretic-separation	Inorganic anions	*Anal. Chem. 66* (13) 2110-2115 1994
Gradient IC and isocratic HPLC interfaced with conductivity and UV detection	Simultaneous determination of anions and triclosan in dentifrices	*J Chromatogr A 671* (1,2) 351-357 1994
IC	Analysis of snow from Antarctica	*Fresenius Z. Anal. Chem.* 349(4) 289-293 1994
IC using a solid.phase chemical supressor	Anions analysis	*Am. Lab. 26* (1) 28C-28D, 28F, 28H-28I 1994
IC	Inorganic anions	*J. Chromatogr. A 671* (1-2) 249-252 1994
IC	Water	*Lihua Jianyan, Huaxue Fence 29* (6) 353-354 1993
IC	Coking wastewater	*Lihua Jianyan, Huaxue Fence 29* (6) 338-339, 341 1993
Capillary zone electrophoresis	Anions	*J. Chromatogr. A 671* (1,2) 397-402 1994
Isotachophoresis	Inorganic and organic anions	*Sepu 12* (4) 241-244 1994
IC	Cooling water of nuclear power plant	*Energetik* (3) 17-18 1994
IC	Bayer liquors	*J. Chromatogr. A 678* (2) 364-369 1994
Online coupled capillary isotachophoresis-capillary zoneelectrophoresis with conductivity detection	Anions	*Anal. Chem. 66* (23) 4258-4264 1994
IC	Atmospheric samples	*Int. J. Environ. Anal. Chem. 56* (4) 317-325 1994
Capillary zone electrophoresis with indirect photometric dectection	For the optimization of F^- and PO_4^{3-} separation	*Quim. Anal. 12* (2) 63-68 1993
IC	MnO_2 sample	*Yankuang Ceshi 13* (2) 128- 130 1994
Capillary zone electrophoresis with indirect UV detection	Water samples	*J. Liq. Chromatogr. 17* (18) 3889-3910 1994
Multi-wavelength detection for the capillary electrophoresis	Mineral anions	*Fresenius Z. Anal. Chem. 349* (10,11) 776-778 1994
IC	Fumes	*J. Chromatogr. A 685* (1) 53-60 1994
HPLC	Water	*Kankyo Kagaku 4* (3) 665-670 1994

Miscellaneous methods are summarised in Table 4.

TABLE 4. Miscellaneous

Method	Application	Reference
Enhanced X-ray yields in PIXE analysis	Binary metal fluorides	*Nucl. Instrum. Methods Phys. Res. Sect. B B75* (1-4) 14-16 1993
NAA	Water	*J. Radioanal. Nucl. Chem. 172* (2) 357-362 1993
Speciation analysis	Traditional Chinese medicine	*Fenxi Shiyanshi 12* (4) 52-57 1993
Proton probe and acid etching	Determining fluoride profiles in porous porcine enamel	*J. Dent. Res. 73* (3) 644-651 1994
Speciation analysis	Traditional Chinese medicine	*Fenxi Shiyanshi 12* (4) 32-34 1993
Lead chloride fluoride gravimetry	NaF	*Bunseki Kagaku 43* (4) 355-360 1994.
Micro-nucleus technique of Tradescantia paludosa	Monitor microindustrial toxic pollution	*Huanjing Baohu* (3) 27-28,39 1993
Nuclear reaction analysis	Environmental fluoride contamination	*Lanzhou Daxue Xuebao 29* (3) 111-115 1993

Acknowledgement

The support of the Science Fund of Application and Foundation of Yunnan Province is gratefully acknowledged.

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THERMODYNAMIC ANALYSIS OF AIRBORNE FLUORIDE INDUCED DETERIORATION OF MARBLE AND PORTLAND CEMENT

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SUMMARY: Using thermodynamic data, the effect of airborne fluoride species (vapour-phase and precipitation) on the deterioration of marble and Portland cement has been estimated. Theoretically, for deterioration, the partial pressure thresholds of HF(g) and SiF_4(g) required are on the order of 10^{-13} - 10^{-19} atm and 10^{-33} - 10^{-59} atm, respectively, whereas in rain water of pH 5.6, 10^{-14} - 10^{-27} M is the range of required equilibrium activity of HF_2^-(aq). Thermodynamic calculations show that the reactions of airborne fluoride species with marble and cement are possible in the atmosphere and that deterioration is faster by the action of HF(g) than SiF_4(g). Moreover, acid deposition enhances the degree of atmospheric fluoride attack on marble and cement.

Key words: Airborne fluoride; Marble deterioration; Portland cement; Thermodynamic analysis.

Introduction

In recent years, atmospheric erosion or deterioration of buildings has been studied with great interest in Europe, North America, and Asia. Research reports deal largely with deterioration processes, mechanism, and weathering rates of marble buildings.[1-5] Sandstone, marble and granite have long been used in the construction of buildings all over the world. However, present-day buildings are generally made of concrete of which cement is an important constituent. Studies concerning deterioration of cement buildings are scanty.[6] Moreover, investigations have been done mainly on decay caused by atmospheric SO_2 and acid rain.[1,2] The role of other atmospheric pollutants causing decay of buildings is shrouded in ambiguity. Dicalcium silicate (DCS, $2CaO{\cdot}SiO_2$), tricalcium silicate (TCS, $3CaO{\cdot}SiO_2$) and tricalcium aluminate (TCA, $3CaO{\cdot}Al_2O_3$) are three main constituents of Portland cement, which form a hydrated colloidal gel of unknown composition when cement hardens. The purpose of this paper is to estimate the thermodynamic equilibrium between atmospheric fluoride species (present in vapour phase and in precipitation) and marble, DCS, TCS, and TCA, and to present a thermodynamic analysis of the effect of airborne fluoride on marble and cement.

Deterioration of marble and cement by atmospheric fluoride

1. *Reaction of vapour-phase fluoride species with marble and cement*

The main vapour-phase species of fluoride existing in the atmosphere are hydrogen fluoride (HF) and silicon tetrafluoride (SiF_4). Damage to buildings appears to be caused by the action of HF and SiF_4 gases deposited on or in the building surfaces and building constituents. High relative humidity and the presence of catalysts in the atmosphere enhance the rate of attack. In the presence of water vapour, calcium fluoride (CaF_2) is mainly formed from the attack on marble, DCS, and TCS, whereas TCA generates CaF_2 and AlF_3 (aluminium

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fluoride). Both CaF_2 and AlF_3 are insoluble compounds with high thermodynamic stability.[7] Some representative reactions are given below (Reactions I and II).

2. *Reaction of aqueous-phase fluoride species with marble and cement*

In water HF dissolves readily and generates HF_2^- species due to preferential coordination of F^- ion by HF. Similarly SiF_4 on dissolution in water is mainly converted into fluorosilicic acid which ionizes to SiF_6^{2-} and H^+ ions.[7] In dilute aqueous solution, SiF_6^{2-} anion is not stable and breaks down ultimately to HF or F^- and SiO_2. Both marble and cement interact with HF_2^- and fluorides of calcium and aluminium are produced. Some representative reactions are given below.

$$\underset{\text{marble}}{CaCO_3} \xrightarrow{HF/SiF_4/HF_2^-} CaF_2 + CO_2 \qquad \text{(I)}$$

$$\begin{matrix} 2CaO{\cdot}SiO_2 \\ 3CaO{\cdot}SiO_2 \\ 3CaO{\cdot}Al_2O_3 \end{matrix} \xrightarrow{HF/SiF_4/HF_2^-} CaF_2 + AlF_3 \qquad \text{(II)}$$

Thermodynamic Calculations

Under thermodynamic equilibrium conditions, the standard Gibbs free energy depends on the equilibrium constant (K).

$$\Delta G^\circ = -RT \ln K \qquad (1)$$

where T is temperature and R is the gas constant (1.987 cal mol^{-1} K^{-1}). At 298 K, equation (1) becomes:

$$\Delta G^\circ(\text{kcal mol}^{-1}) = -1.36 \times 10^3 \log K \qquad (2)$$

1. *Determination of ΔG° and K*

The mass balance equations for the reaction of marble with HF vapour, SiF_4 vapour and HF_2^- can be written from reaction I. Similarly, reaction II helps in the formulation of specific balanced equations for the interactions of HF vapour, SiF_4 vapour and HF_2^- with DCS, TCS, and TCA. These equations are as follows:

$$CaCO_3(s) + 2HF(g) \rightarrow CaF_2(s) + H_2O(l) + CO_2(g) \qquad (3)$$
$$2CaO{\cdot}SiO_2(s) + 4HF(g) \rightarrow 2CaF_2(s) + 2H_2O(l) + SiO_2(s) \qquad (4)$$
$$3CaO{\cdot}SiO_2(s) + 6HF(g) \rightarrow 3CaF_2(s) + 3\,H_2O(l) + SiO_2(s) \qquad (5)$$
$$3CaO{\cdot}Al_2O_3(s) + 12HF(g) \rightarrow 3CaF_2(s) + 2AlF_3(s) + 6\,H_2O(l) \qquad (6)$$
$$CaCO_3(s) + 1/2SiF_4(g) \rightarrow CaF_2(s) + 1/2SiO_2(s) + CO_2(g) \qquad (7)$$
$$2CaO{\cdot}SiO_2(s) + SiF_4(g) \rightarrow 2CaF_2(s) + 2SiO_2(s) \qquad (8)$$
$$3CaO{\cdot}SiO_2(s) + 3/2SiF_4(g) \rightarrow 3CaF_2(s) + 5/2SiO_2(s) \qquad (9)$$
$$3CaO{\cdot}Al_2O_3(s) + 3SiF_4(g) \rightarrow 3CaF_2(s) + 2AlF_3(s) + 3SiO_2(s) \qquad (10)$$
$$CaCO_3(s) + HF_2^-(aq) \rightarrow CaF_2(s) + CO_2(g) + OH^-(aq) \qquad (11)$$
$$2CaO{\cdot}SiO_2(s) + 2HF_2^-(aq) \rightarrow 2CaF_2(s) + 2OH^-(aq) + SiO_2(s) \qquad (12)$$
$$3CaO{\cdot}SiO_2(s) + 3HF_2^-(aq) \rightarrow 3CaF_2(s) + 3OH^-(aq) + SiO_2(s) \qquad (13)$$
$$3CaO{\cdot}Al_2O_3(s) + 6HF_2^-(aq) \rightarrow 3CaF_2(s) + 2AlF_3(s) + 6OH^-(aq) \qquad (14)$$

Using thermodynamic data[8] (Table 1) and equation (15) below, the standard free energies of the reactions (3)-(14) above can be calculated. Values obtained are shown in Table 3.

$$\Delta G^\circ = \Delta G_f^\circ \text{ (products)} - \Delta G_f^\circ \text{ (reactants)} \quad (15)$$

Table 2 lists the equilibrium constants (K) derived from equations (3) to (14). Values of the equilibrium constants (K) under standard thermodynamic condition (298 K, 1 atm) can be calculated from equation (2), employing ΔG° data presented in Table 3. These results are also given in Table 2.

2. *Determination of* $P(HF)$ *and* $P(SiF_4)$

The partial pressure P of CO_2 in atmosphere has been reported to be 325×10^{-6} atm.[9] Hence, using expressions and values of the equilibrium constant (K) (Table 2), required equilibrium partial pressures of HF vapour ($P(HF)$) and SiF_4 vapour ($P(SiF_4)$), in the atmosphere, for their interaction with marble, DCS, TCS, and TCA can be calculated. Results are shown in Table 3.

3. *Determination of* pH

For the reaction of HF_2^- with marble, under thermodynamic equilibrium, the following equation can be written from the expression of the equilibrium constant shown in Table 2:

$$\log (K) = \log P(CO_2) + \log a\,(OH^-) - \log a(HF_2^-) \quad (16)$$

where $a(OH^-)$ and $a(HF_2^-)$ are activities of OH^- and HF_2^- ions, respectively.

Using equation (2) and taking $\Delta G^\circ = -2.87$ kcal mol^{-1} (Table 3) and $P(CO_2) = 325 \times 10^{-6}$ atm, equation (16) can be written as:

$$\log a(HF_2^-) = -5.60 + \log a(OH^-) \quad (17)$$

or,

$$\log a(HF_2^-) = -5.60 - pOH \quad (18)$$

(since, $pOH = -\log a(OH^-)$)

Further, since the sum of pH and pOH values of a solution equals 14 at 298 K, equation (18) can also be written, in terms of pH, as equation (19).

$$pH = 19.60 + \log a(HF_2^-) \quad (19)$$

Similar equations for pH, obtained while considering interactions of HF_2^- with DCS, TCS and TCA are written below:

$$pH = 27.67 + \log a(HF_2^-) \quad (20)$$

$$pH = 32.21 + \log a(HF_2^-) \quad (21)$$

$$pH = 26.17 + \log a(HF_2^-) \quad (22)$$

For the interaction of HF_2^- with marble, DCS, TCS, and TCA, equations (19)-(22), respectively, give the relationship between pH and $a(HF_2^-)$

TABLE 1. Some $\Delta G°$ values (kcal mol^{-1}) at 298 K and 1 atm

Substance	$CaCO_3(s)$	$CaF_2(s)$	$AlF_3(s)$	$H_2O(l)$	$CO_2(g)$	$SiO_2(s)$
$\Delta G°$	-269.80	-279.00	-340.60	-56.69	-94.26	-204.46
Substance	$HF(g)$	$SiF_4(g)$	$HF_2^-(aq)$	$H^+(aq)$	$OH^-(aq)$	
$\Delta G°$	-65.30	-375.88	-138.18	0	-37.59	
Substance	$2CaO{\cdot}SiO_2$	$3CaO{\cdot}SiO_2$	$3CaO{\cdot}Al_2O_3$			
$\Delta G°$	-524.10	-665.40	-815.40			

TABLE 2. Equilibrium Constant (K) for the reactions of marble DCS, TCS, and TCA with HF, SiF_4 and HF_2^-

Reacting Surface		K	log K (at 298 K and 1 atm)
Marble	(i)	$P(CO_2)/P^2(HF)$	21.73
	(ii)	$P(CO_2)/P^{1/2}(SiF_4)$	13.05
	(iii)	$P(CO_2){\cdot}a(OH^-)/a(HF_2^-)$	2.11
DCS	(i)	$1/P^4(HF)$	66.57
	(ii)	$1/P(SiF_4)$	49.22
	(iii)	$a^2(OH^-)/a^2(HF_2^-)$	27.35
TCS	(i)	$1/P^6(HF)$	113.48
	(ii)	$1/P^{3/2}(SiF_4)$	87.45
	(iii)	$a^3(OH^-)/a^3(HF_2^-)$	54.63
TCA	(i)	$1/P^{12}(HF)$	192.75
	(ii)	$1/P^3(SiF_4)$	140.69
	(iii)	$a^6(OH^-)/a^6(HF_2^-)$	73.00

Interactions with HF (i), SiF_4 (ii) and HF_2^- (iii)
P: partial pressure a: activity

TABLE 3. $\Delta G°$, $P(HF)$, and $P(SiF_4)$ values at 298 K and 1 atm for reactions of marble, DCS, TCS, and TCA with HF, SiF_4 and HF_2^-

Reacting surface		$\Delta G°$ (kcal mol^{-1})	$P(HF)$ (atm)	$P(SiF_4)$ (atm)
Marble	(i)	-29.55	2.46×10^{-13}	
	(ii)	-17.75		8.33×10^{-34}
	(iii)	-2.87		
DCS	(i)	-90.54	2.27×10^{-17}	
	(ii)	-66.94		6.02×10^{-50}
	(iii)	-37.19		
TCS	(i)	-154.33	1.22×10^{-19}	
	(ii)	-118.93		5.02×10^{-59}
	(iii)	-74.30		
TCA	(i)	-262.14	8.66×10^{-17}	
	(ii)	-191.34		1.27×10^{-47}
	(iii)	-99.28		

Discussion and Conclusions

The negative values of Gibbs free energy for the reactions of marble, DCS, TCS, and TCA with vapour-phase fluoride (HF and SiF_4) and aqueous-phase HF_2^- indicate that these reactions are thermodynamically feasible. For reactions to occur, the required equilibrium partial pressure of HF vapour and SiF_4 vapour are on the order of 10^{-13} - 10^{-19} atm and 10^{-34} - 10^{-59} atm, respectively. Although nothing much is known about the concentrations of various fluoride species in the atmosphere, vapour-phase concentrations of total fluoride have been reported[10-14] to be on the order of 10^{-12} atm, which is many fold higher than the required equilibrium pressures of HF and SiF_4 for their reactions with marble and cement. Considering the fact that HF and SiF_4 are two major fluoride species in the atmosphere, it can be concluded that the above mentioned reactions are likely to occur spontaneously in the atmosphere. In a polluted atmosphere, fluoride concentration is increased, thus $\Delta G^\circ_{polluted} < \Delta G^\circ_{normal} < 0$; hence, deterioration of buildings due to interaction with vapour-phase fluoride is accelerated.

A pH of 5.6 is often regarded as pH of natural rain water, whereas fluoride concentrations in precipitation have been reported[11-15] to be as high as 2.1×10^{-6} - 4.0×10^{-6} M (40 - 75 μg/L) in some parts of the world. Calculations show that for reaction with marble and cement, the required equilibrium activity of HF_2^- in rain water (pH = 5.6) is on the order of 10^{-14} - 10^{-27} M. Depending on the ionic strength of rain water, which varies from place to place, the activity of HF_2^- will be less than its concentration, but the presence of fluoride in precipitation far in excess than required for the reaction of HF_2^- (most abundant fluoride species in rain water) with cement and marble suggests these reactions are spontaneous under natural conditions. A decrease in the required fluoride concentrations in rain water with fall in pH is also evident. Further, Gibbs free energies for reactions of HF being more negative than for SiF_4, deterioration of buildings is likely to be faster due to the action of HF than SiF_4.

Both CaF_2 and AlF_3, the end products of fluoride interaction with marble and cement, are insoluble compounds, but lack in mechanical strength and cannot substitute for marble and cement as building construction material. Moreover, their interaction with atmospheric SO_2 and H^+ ions of rain water, resulting in the formation of some water-soluble species,[6] cannot be ruled out. Such reactions will accelerate decay processes and simultaneously make the reactions of fluoride with building surfaces more severe.

Thermodynamic calculations thus show: 1) reactions of airborne fluoride species with marble and cement are possible in the atmosphere; 2) both marble and cement deteriorate faster by reacting with SiF_4 and HF than HF_2^-; 3) with the fall in rain water pH, the rate of fluoride interaction with building surfaces increases.

Atmospheric deterioration of building/stone surfaces is a worldwide phenomenon,[1-3,16-18] despite the fact that some ancient structures have survived the onslaught of atmospheric corrosion until now. Most studies deal with decay of buildings caused by atmospheric SO_2, HCl, and NO_x, completely ignoring contributions from other atmospheric constituents, which are present in smaller amounts. It is not easy to distinguish and quantify the role of HF/SiF_4, in building corrosion,

from that of major pollutants. However, perhaps this aspect can be explored separately only under controlled laboratory conditions. The present study clearly shows, theoretically, the feasibility of atmospheric fluoride interaction with marble and cement under natural conditions. We expect our results will be supported by laboratory controlled experimental kinetic data, which we hope to obtain soon.

Acknowledgements

We are grateful to Professor P S Satsangi, Director, Dayalbagh Educational Institute, Agra, for moral support and encouragement. We also thank our colleagues Dr Satya Prakash, Dr S S Shrivastav, and Dr Sahab Das for useful suggestions.

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REPORT OF 15th SEMINAR OF THE JAPANESE SOCIETY FOR FLUORIDE RESEARCH, SENDAI, JAPAN, NOVEMBER 14, 1995

Kenji Akiniwa
Tokyo, Japan

Since the founding of the Japanese Society for Fluoride research by Professor Fumiyoshi Yanagisawa in 1981 (*Fluoride 28* (1) 1-2 1995) the Society has arranged 15 seminars. The latest, held in Sendai, northern Japan, in November last year, was another successful function. The seminar was organized by Dr Hidetoshi Fuji of Sendai and was attended by over 50 researchers and health professionals from Japan and abroad. Many attending the seminar were school health workers, who had attended a meeting the previous day about the safety of the compulsory introduction into schools of fluoride mouth rinsing programs.

The seminar program comprised five presentations. The first was by Dr Kosei Takahashi (formerly of Tokyo University, and now retired): "Fluoride turning point after 50 years - little effect but serious damage." He discussed the fluoride-related increase in prevalence of osteosarcoma in teenage males, and critically analysed the attempt of Hoover and associates to dismiss the evidence. He discussed the evidence that fluoride is related to increases in Down's Syndrome, and presented evidence of that relationship from the records of three groups of young mothers. He also reviewed the recent evidence from Britain, USA and France that hip fractures in the aged are increased by low water fluoride intakes. He critically examined the WHO technical report of 1994 which recommended water fluoridation to a level between 0.5 and 1.0 mg/L (ppm). He pointed out that in many oriental cultures food contained fluoride in amounts which meant extra fluoride from drinking water was unnecessary and hazardous. He drew attention, also, to the dangers of fluoride gels and other topical uses of fluoride, especially for children under six years of age.

Dr K Chujou reported on successful reductions in tooth decay achieved without the use of fluoride in schools. He explained that education and nutrition were more effective procedures than administration of fluoride.

Dr N Hotta presented information on combined fluoride and arsenic pollution in areas of China. There were three main sources: drinking water, food (especially when dried in air), and air.

A government employee, Yoshikatsu Miki, reported on the fluoride mouth-rinsing program introduced in Niigata prefecture. The program had been virtually forced on schools by the local government. He seriously questioned its safety.

continued next page

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The final presentation was by the guest speaker, Dr John Colquhoun of New Zealand. His lecture was in two parts. First, he reviewed the new evidence of harm from water fluoridation, especially to the bones of the elderly resulting in increased hip fractures. In the second part Dr Colquhoun showed slides of examples of dental fluorosis in school children in Auckland, New Zealand, when the water was fluoridated to the level of 1 mg/L. In the discussion which followed, Dr Colquhoun explained that in New Zealand information on tooth decay was available for all children, and it did not support the claims made for water fluoridation, which depended upon statistical claims from small samples of children from selected areas.

There is increasing interest in the work of the Japanese Society for Fluoride Research, and further seminars are planned.

Published by the International Society for Fluoride Research
Editorial Office: 81A Landscape Road, Mount Eden, Auckland 4, New Zealand

PLAGUED NO MORE: HOW 50 YEARS OF FLUORIDES HAVE REDUCED CARIES DRAMATICALLY IN THE WEST

(Lead article in *Oral Health Care Report Vol. 6* No. 1 1996)

Reviewed by L H R Brett*
Whangarei, New Zealand

This anonymously authored "Feature Story" in the latest issue of a commercially-sponsored publication for dentists, reviews 50 years of fluoridation and improvement in dental health.

1) Its long list of references does not include a single non-blind study using randomly selected experimental and control groups. As Diesendorf and Colquhoun have pointed out (*Fluoride 28* (2) 87-106 1995), such a study cannot be found.

2) Although it opens with a quotation of Professor B A Burt, it omits to mention in its main text that Burt, Fejerskov and others have affirmed that the anti-caries effect of fluoride is a local (topical) one on tooth surfaces, not a systemic (dietary) one. However, a boxed insert does describe "How and Why Fluoride Works" in purely topical terms: "When present in dental plaque and saliva, even in concentrations as low as 0.1 to 0.2 ppm, fluoride achieves both ends" (*i.e.* minimizes demineralization and maximizes remineralization of carious enamel). This downgrading of a systemic benefit is, however, implied in the main text, which admits that tooth decay has declined also in non-fluoridated places and countries, and states: "In the past 30 years, toothpaste has become a far greater source of fluoride in the world than fluoridated water."

3) The article admits that both water fluoridation and fluoride toothpastes have caused dental fluorosis, and states: "Because children in the fluorosis-prone age group swallow about a third of the toothpaste they use, practitioners are now urging parents to restrict the amount of toothpaste to a 'pea-sized' portion and to supervise brushing."

4) The article does not explain why, if 1 ppm fluoridated water (which causes 0.1 ppm in saliva) has the same topical effect as fluoride toothpaste, it is necessaary for the fluoride content of toothpaste to be so much higher. The article recommends lowering the fluoride content of toothpaste - to around 400 ppm instead of the present 1000 ppm - but nowhere explains how fluoridated water, with only 1 ppm or less of fluoride, can have the same local effect on plaque and saliva.

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Oral Health Care Report is published quarterly by Colgate-Palmolive Canada, printed in Hong Kong and distributed free to dentists throughout the Asia-Pacific Region. Address: 8th Floor Pacific Plaza, 410 Des Voeux Road West, Hong Kong. The Editor-in-Chief is Gordon Nikiforuk DDS MSc FRCD FICD, Dean Emeritus, University of Toronto.

5) Another boxed insert gives the recommended "daily intake" of fluoride supplements, for children in non-fluoridated places, in UK, Europe, Canada, and USA. It is not explained why the recommended intake in Canada is a half that in the other countries.

6) In fact, it is not explained why any "intake" of fluoride is needed at all if its mode of action is purely a local, topical one on tooth surfaces - *i.e.* one does not need to swallow the toxin to gain its benefit.

7) The article insists that fluoride has caused the western world's decline in tooth decay, but omits to mention (and omits from its references) the studies showing that only a minority of the children in non-fluoridated areas, whose tooth decay has also declined, had actually used fluoride toothpaste.

8) Nowhere mentioned, also, is the change in dietary patterns which followed the introduction of household refrigerators - which many believe is a more rational explanation for the decline in tooth decay, along with greater parental awareness and interest in dental health.

9) The publication's sponsor is a leading seller of fluoride. What the article really highlights is the common interest of the sellers of a toxic industrial waste and a profession stubbornly refusing to admit a 50-year-old mistake.

Philip Richard Neville Sutton
1914-1995

FLUORIDE IN DENTISTRY (2nd Edition)

Ole Fejerskov, Jan Ekstrand and Brian A Burt (Editors)
(Munksgaard, Copenhagen 1996)

THE GREATEST FRAUD: FLUORIDATION

Philip R N Sutton
(Susan Sutton, Lorne 1996)

Reviewed by John Colquhoun

The above two books by dental scientists have been received by this editor for review. The first is intended for use by dentists and dental students, as was the first edition. Many dental researchers have contributed to this updated survey of dental uses of fluoride.

What is remarkable about *Fluoride in Dentistry* (2nd Edition), especially to anyone concerned with a more interdisciplinary approach to fluoride research, is its extreme selectivity of evidence. For example, the first chapter of the Section "Clinical uses of fluoride", on the subject of water fluoridation, starts and ends with the view, usual in dental literature, that fluoridation is both effective and safe. Totally omitted from its lengthy list of references are comprehensive recent studies and reviews which indicate little or no effectiveness and seriously question the safety of fluoridation. Similarly, the three chapters on fluoride and bones, including a piece headed "Concentration of fluoride in bone", do not cite the important research of Finnish scientists Alhava and Arnala, who actually measured and reported very high fluoride concentrations in human bone after 10 or more years residence in a fluoridated city. Even more disappointing is the chapter "Fluoride toxicology and health effects," wherein only acute fluoride toxicity is discussed. A brief piece at its end, headed "Sublethal toxic effects of fluoride", considers only dental fluorosis. The extensive early studies by Waldbott and others, as well as more recent investigations reporting skeletal and non-skeletal toxic effects of fluoride, published in this and other journals, are completely ignored.

The chapters on dental fluorosis, the only toxic effect which the authors seem to acknowledge, are by contrast very good. Most interesting is the critique of the much-used Dean classification of dental fluorosis, as well as other early North American dental fluorosis studies. The authors conclude, from more recent evidence, that "*... even with very low fluoride intake from water, a certain level of dental fluorosis will be found*" and "*... there exists no 'critical' value for the fluoride intake below which the effect on dental enamel will not be manifest.* The conclusion reached by Hodge that dental fluorosis will not occur at a water fluoride content below 1 ppm is therefore not tenable" (emphases in the original). The oft-repeated claim that "it is very difficult or almost impossible to discriminate between dental fluorosis and other enamel disturbances" is also firmly repudiated, and evidence is presented that, when a sensitive scoring system for dental fluorosis was used, "the only etiologic factor which could be identified as associated with any of the enamel changes recorded was fluoride."

However, in spite of these admissions about the widespread dental sign of fluoride toxicity, the book's omissions of evidence of other toxic effects of fluoride convey a misleading conclusion that fluoride in low doses is a wonderful elixir rather than a dangerous toxin.

The book states in the first paragraph of its Preface: "Over the last generation, the extent and severity of dental caries in the economically developed world has declined to an extent that was unimaginable in the days when many of today's dental practitioners attended dental school, and most indicators are that this trend is still in progress. Fluoride, in the different ways it is used today, is universally agreed to have been the principal influence in this major public health phenomenon" (which reveals, perhaps, the limited universe of dentists). The possibility that improved nutrition, rather than increased fluoride intake, has been a major factor is not seriously considered.

Later chapters present strong evidence that the tooth decay-arresting effect of fluoride is a local ("topical") one, not a systemic one. The earlier claimed systemic benefit is held to be "uncertain" - negligible if any, and possibly non-existent. The concluding chapter on "Rational use of fluorides in caries control" vigorously advocates increased topical uses, and plays down systemic uses, emphasizing the need to avoid the toxic consequence (dental fluorosis - the only one the authors admit occurs at low levels of fluoride intake).

Not adequately addressed is the question: how can water fluoridated to 1 ppm provide the same or greater topical benefit as fluoride toothpaste at a thousand times higher concentration? Fluoridated water and beverages, like toothpastes, do not have long periods of contact with the teeth.

The other book, by the late Philip Sutton, is of quite a different character. Far from selecting and omitting research studies to suit his case, Sutton subjects every report which purports to prove a dental benfit from fluoridation to intense critical examination. Published after his death by his daughter-in-law, the book is, in effect, an updated version of his earlier classic, *Fluoridation: Errors and Omissions in Experimental Trials.* Indeed, Chapter 19 is a reprint of that earlier edition, which critically examined the first North American fluoridation trials and is still relevant today, having stood the test of time. A later chapter makes further observations on those trials, while earlier chapters critically analyse and assess all succeeding pro-fluoridation studies, as well as criticisms of his analyses by proponents. Sutton's book will justify to many of his readers the change in title from the sedate "errors and omissions" to "the greatest fraud." It has become very apparent that, as Diesendorf and others have pointed out in this journal, not a single study has ever been published which actually proves that fluoridation works.

The book is modestly priced (Australian $14 plus $11 postage, from the publisher, PO Box 22, Lorne, Victoria 3232, Australia).

GEOCHEMICAL RISK FACTORS FOR MENTAL FUNCTIONING, BASED ON THE ONTARIO LONGITUDINAL STUDY OF AGING (LSA)

Comparisons of the results, relevant to aluminum water concentrations, obtained from the LSA and from death certificates mentioning dementia

W F Forbes, S Lessard and J F Gentleman
Ottawa, Canada

Abstract from *Canadian Journal on Aging 14* (4) 642-656 1995

Previous studies in this series of papers investigated the associations between aluminum (Al) water concentrations and relatively high risks of a measure of mental impairment and also various possible other drinking water characteristics, particularly pH, turbidity, fluoride and silica. The results were based on one measure of mental impairment, which would not be expected to give the same results as the more definitive endpoint (outcome variable) of a record of Alzheimer's Disease (AD) as the underlying cause of death on a death certificate. The present paper therefore investigates the relevant associations, based both on the measure of mental impairment and on death certificates in which AD and presenile dementia are listed as the underlying causes of death. As expected, the associations were not identical, but they were similar. More specifically, Al water concentrations were strongly associated with the recording of AD on death certificates, as were pH, fluoride, and silica concentrations. The implications of these results are discussed, and it is suggested that the evidence is sufficiently strong for methods of water purification to be modified, at least on a trial basis, because of the likelihood that this will reduce the incidence of AD.

Key words: Aluminum; Alzheimer's disease; Dementia; Fluoride; pH; Silica.

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ENVIRONMENT AND THE GENITOURINARY TRACT

M J Droller
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Abstract from *Otolaryngology and Head and Neck Surgery 114* (2) 248-252 1996

A variety of environmental factors have been associated with conditions that affect the genitourinary system. Chronic lead exposure and halogenated hydrocarbons have been found to affect sperm production and fertility. Heavy metals such as mercury and cadmium have been associated with renal tubular toxicity and kidney failure. Aromatic amines, used in a number of industrial processes and most commonly found in the dye industry, have been associated with development of bladder cancer. The same substances that are metabolites in cigarette smoke have been found to explain the strong association between bladder cancer and cigarette smoking. Chlorination and fluoridation have recently been associated with bladder cancer. In

each of these associations, host factors may contribute to the toxicity of these substances either by detoxifying them or by converting them to more active agents. Education and regulation are needed to decrease the environmental risk they create.

Key words: Bladder cancer; Chlorination; Environment; Fluoridation; Genitourinary tract.
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DEVELOPMENTAL TOXICITY OF SODIUM FLUORIDE IN RATS

T F X Collins, R L Sprando, M E Shackelford, T N Black, M J Ames, J J Welsh, M F Balmer, N Olejnik and D I Ruggles
Laurel, Maryland, USA

Abstract from *Food and Chemical Toxicology 33* (11) 951-960 1995

Despite the chronic exposure of the US population to fluoridated drinking water since the 1940s, existing studies have been judged inadequate to determine any potential reproductive or developmental hazard. This study was conducted to determine the effects of sodium fluoride (NaF) on foetal development. Sperm-positive female rats were given 0, 10, 25, 100, 175 or 250 ppm NaF daily throughout gestation. They were dosed by drinking water to mimic human exposure to fluoridated water. No dose-related behavioural changes or maternal clinical signs were noted. Fluid consumption by females in the 175- and 250-ppm groups was significantly less than that of the control females. Because of this decreased fluid consumption, the daily amount of NaF ingested (0, 1.4, 3.9, 15.6, 24.7 and 25.1 mg/kg body weight) was less than expected at the two high levels. Feed consumption decreased significantly at 250 ppm, and body weights of pregnant females reflected feed consumption trends. The mean number of viable foetuses per female in all treated groups was similar to that of the control group. The significant decrease in the mean number of implants per litter in the 250-ppm group is probably linked to the lower mean number of *corpora lutea* in this group. The occurrence of *in utero* deaths was similar in the control and treated groups. Foetal growth (in terms of foetal body weight and crown-rump length) was not affected by NaF, despite the fact that the darns in the 250-ppm group ate significantly less feed and drank significantly less fluid. There was no dose-related increase in the number of external anomalies in foetuses due to NaF ingestion. At the doses given, NaF had no effect on the development of specific bones, including sternebrae. A significant increase was seen in the average number of foetuses with three or more skeletal variations in the 250-ppm group; the number of litters with foetuses with three or more skeletal variations was increased in the 250-ppm group also, but the increase was not significant. There was no dose-related effect of NaF an the incidence of soft tissue variations.

Key words: Fluoridated water; Foetal development; Plasma fluoride; Rats; Reproduction; Sodium fluoride.
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HISTORICAL COHORT STUDY OF SPONTANEOUS ABORTION AMONG FABRICATION WORKERS IN THE SEMICONDUCTOR HEALTH STUDY - AGENT-LEVEL ANALYSIS

S H Swan, J J Beaumont, S K Hammond, J Vonbehren, R S Green, M F Hallock, S R Woskie, C J Hines and M B Schenker
Berkeley, California, USA

Abstract from *American Journal of Industrial Medicine 28* (6) 751-769 1995

Risk of spontaneous abortion (SAB) was examined in relation to chemical and physical agents in a retrospective study of employees of 14 seminconductor manufacturers: After screening over 6,000 employees, 506 current and 385 former workers were eligible. If a woman had multiple eligible pregnancies, one was selected at random. Telephone interviews provided data on demographics and occupational. and other exposures during the first trimester. Two groups of chemicals accounted for the 45% excess risk of SAB among fabrication-room (fab) workers: photoresist and developed solvents (PDS), including glycol ethers, and fluoride compounds used in etching. Women exposed to high levels of both these agents were at greater risk (RR = 3.21, 95% confidence interval [CI] = 1.29-5.96). In fab workers without these exposures, SAB rates were not elevated (adjusted relative risk [RR] = 0.98, 95% CI = 0.55-1.69). An association was seen with workplace stress, which was not limited to women exposed to PDS or fluoride, nor did stress explain the associations between these chemicals and SAB.

Key words: Glycol ethers; Industrial fluorosis; Miscarriage; Semiconductor manufacturing; Spontaneous abortion; Stress.

Reprints: S H Swan, University of California, Berkeley, School of Public Health, Department of Epidemiology, Berkeley, CA 94720, USA.

HYDROFLUORIC ACID-INDUCED SKIN NECROSIS [French]

V Saada, M Patarin, S Sans and P Saiag
Boulogne, France

Abstract from *Annales de Dermatologie et de Venereologie 122* (8) 512-513 1995

Introduction. Hydrofluoric acid is a fluoride-substituted compound used in the chemical industry. Burns and hypocalcaemia result from ingestion or contact with the skin or mucosal membranes. We observed burns and skin necrosis on the hands after home use of low-concentration hydrofluoric acid.

Case report. A 57-year-old woman consulted in February 1994 for oedema, erythema and very painful burns of the palms of both hands. The day before, she had used a home-made furniture cleanser containing 5 p. 100 hydrofluoric acid. At admission, cal calcium and radiography of the two hands were normal. She was given a topical application of 5 p. 100 calcium chloride. The clinical course was favourable with squamation of both palms then necrotic lesions of the pulp on the 1 st, 2 nd and 3 rd fingers.

Discussion. Such exposure in a household situation is unusual. Hydrofluoric acid has two dangerous mechanisms of action. First it is a caustic substance producing late-onset burns and secondly hypocalcaemia results from precipitation of

insoluble calcium fluoride. The risk of hypocalcaemia is greatest when a large aera of the skin is exposed. Prognosis depends on early treatment based on prevention of hypocalcaemia by abundant washing of the teguments and permanent application of a 5 p. 100 calcium gluconate solution associated with local skin treatments. Careful follow-up is required with regular calcium chemistries.

Key words: Hydrofluoric acid; Industrial fluorosis; Skin necrosis.

Reprints: V Saada, Chu Ambroise Pare Service Dermatologie, 9 Ave Charles De Gaulle F-92104 Boulogne, France.

APOPTOTIC CELL DEATH FOLLOWING EXPOSURE TO FLUORIDE IN RAT ALVEOLAR MACROPHAGES

S Hirano and M Ando
Ibaraki, Japan

Abstract from *Archives of Toxicology 70* (3-4) 249-251 1996

Since inhaled fluoride is implicated in the acute respiratory failure, cytotoxic effects of fluoride on alveolar macrophages, primary target cells of inhaled toxicants, were investigated. The LC(50) of sodium fluoride was estimated to be 0.41 mM, while 1 mM sodium chloride, bromide and iodide had virtually no effects on the viability of alveolar macrophages. Photomicroscopic observation revealed that nuclei of the fluoride-exposed alveolar macrophages were fragmented. The ladder formation was observed when DNA isolated from fluoride-exposed alveolar macrophages was electrophoresed in agarose gel. These results suggest that cytotoxicity of fluoride is associated with apoptosis in rat alveolar macrophages.

Key words: Alveolar macrophages; Apoptosis; Cytotoxicity; DNA fragmentation; Fluoride; Rat.

Reprints: S Hirano, National Institute of Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305, Japan.

BRONCHIAL RESPONSIVENESS, EOSINOPHILIA, AND SHORT TERM EXPOSURE TO AIR POLLUTION

V Soyseth, J Kongerud, P Broen, P Lilleng and J Boe
Lillehammer and Oslo, Norway

Abstract from *Archives of Disease in Childhood 73* (5) 418-422 1995

The number of capillary blood eosinophils and the prevalence of bronchial hyperresponsiveness (BHR) were compared between schoolchildren living in a polluted area (Ardal) and unpolluted area (Laerdal).

In Ardal there is an aluminium smelter emitting sulphur dioxide and fluoride to the environment. Daily measurements of these pollutants in ambient air were available. The mean number of eosinophils in Ardal was 220 x 10(6)/l compared with 106 x 10^6/L in Laerdal. The prevalence of BHR was 15.9% in Ardal and 11.8% in Laerdal. The odds ratio of having BHR in relation to these pollutants during the last 24 hours were: 1.12 (95% confidence interval (CI) 1.01 to 1.24) by increasing sulphur dioxide with 10 μ g/m^3, and 1.31 (95% CI 1.07 to 1.60) when fluoride

exposure increased with 1 μ g/m^3. Similarly, these exposures were associated with a decrease in eosinophils of -21 x 10^6/L (95% CI -36 to -6) and -52 x 10^6/L (95% CI -98 to -8), respectively, in atopics.

It is hypothesised that recent exposure to irritants induces changes in the airways leading to BHR in addition to recruitment of eosinophils to the airways in atopic subjects.

Key words: Air pollution; Bronchial provocation tests; Eosinophils; Epidemiology.
Reprints: V Soyseth, Lillehammer Hospital, Department of Medicine, N-2600 Lillehammer, Norway.

SEVOFLURANE

A number of papers have been published (see list below) relevant to the very high plasma fluoride levels in patients following use of halogenated anesthetics, especially sevoflurane. Opinions differ about the resulting danger to patients. Most of the papers in the anesthesiology literature conclude that the high fluoride levels are "unlikely" to be of clinical significance.

THE SAFETY OF SEVOFLURANE HAS NOT BEEN ADEQUATELY ESTABLISHED by E I Eger, J L Martin and J H Tinker in *Anesthesia and Analgesia 82* (2) 431-432 1996. Reprints: E I Eger, University of California San Francisco, Department of Anesthesia, San Francisco, CA 94143, USA.

PLASMA INORGANIC FLUORIDE CONCENTRATIONS AFTER SEVOFLURANE ANESTHESIA IN CHILDREN by M F Levine, J Sarner, J Lerman *et al* in *Anesthesiology 84* (2) 348-353 1996. Reprints: J Lerman, University of Toronto Hospital for Sick Children, Department of Anaesthesia, 555 University Avenue, Toronto, ON M5G 1X8, Canada.

FLUORIDE ION TOXICITY IN HUMAN KIDNEY COLLECTING DUCT CELLS by M L Cittanova, B Lelongt, M C Verpont *et al* in *Anesthesiology 84* (2) 428-435 1996. Reprints: M L Cittanova, Hospital Pitie Salpetriere, Department Anesthesie Reanimat, 47 Blvd Hop, F-75651 Paris 13, France.

SEVOFLURANE [Review] [French] by I Murat, M C Dubois and V Piat in *Annales Francaises d Anesthesie et de Reanimation 14* (6) 489-501 1995. Reprints: I Murat, Hop Enfants Armand Trousseau, Service Anesthesie Reanimat, 26 Ave Dr Arnold Netter, F-75571 Paris 12, France.

FLUORIDE - INDUCED NEPHROTOXICITY - FACT OR FICTION [German] by M Nuscheler, P Conzen, D Schwender and K Peter in Anaesthesist 45 (Suppl 1) S 32-S 40 1996. Reprints: M Nuscheler, University of Munich, Klinikum Grosshadern, Institute of Anesthesiology, Marchioninistr 15, D-81377 Munich, Germany.

ANAESTHETIC QUALITY AND SERUM-FLUORIDE IN CHILDREN DURING INHALATIONAL INDUCTION AND ANAESTHESIA WITH SEVOFLURANE OR HALOTHANE [German] by W Funk, J Moldaschl, Y Fujita *et al* in *Anaesthesist 45* (1) 22-30 1996. Reprints: W Funk, University of Regensburg Anesthesiology Clinic, D-93042, Regensburg, Germany.

SEVOFLURANE FOR OUTPATIENT ANAESTHESIA - COMPARISON WITH ISOFLURANE [German] by J Scholz, P Bischoff, W Szafarczyk *et al* in *Anaesthesist 45* (Suppl 1) S63-S70 1996. Reprints: J Scholz, University of Hamburg, Krankenhaus Eppendorf, Department of Anesthesiology, Martinistr 52, D-20246 Hamburg, Germany.

FLUORIDE AND RENAL TOXICITY - A NEPHROLOGISTS VIEWPOINT [German] by T Bosch in *Anaesthesist 45* (Suppl 1) S41-S45 1996. Reprints: T Bosch, University of Munich, Klinikum Grosshadern, Marchioninistr 15, D-81377 Munich, Germany.

VALIDATION OF AN ION SELECTIVE ELECTRODE SYSTEM FOR THE ANALYSIS OF SERUM FLUORIDE ION

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Ballyclare and Antrim, Northern Ireland

Abstract from *Journal of Automatic Chemistry 17* (6) 219-223 1995

A high impedance unit was developed for use with a fluoride/pH electrode system for the measurement of serum fluoride. The linearity, accuracy, precision and detection limit of the system is reported. At a pH of 1.55, the system was linear over a range of serum fluoride concentrations up to 100 μmol L^{-1}, with a lower limit of detection of 0.3 μmol L^{-1}. Recoveries at this PH were 94-105% in the range 2.6-100μ mol L^{-1}. Within-run CVs ranged from 4.2% at a level of 2.3 μmol L^{-1} to 1.2% at a level of 55.7 μmol L^{-1}, while day-to-day CVs ranged from 12.8% at a level of 2.2 μmol L^{-1} to 4.6% at a level of 51.7 μmol L^{-1}. The system demonstrated a rapid response time and has the potential for a smaller sample size requirement with alternative electrode shape. Continued development of this unit into an automated fluoride ion selective electrode system is recommended, since the measurement of serial serum fluoride samples is of greatest importance in assessing the impact of new anaesthetic agents on renal function.

Key words: Fluoride analysis; Ion selective anode; Serum fluoride.
Reprints: S R Luney, 14 Huntingdale, Ballyclare BT9 9XB, Northern Ireland.

CRITICAL STUDY OF FLUORIDE WATER INTERACTIONS

S S Xantheas and L X Dang
Richland, Washington, USA

Abstract from *Journal of Physical Chemistry 100* (10) 3989-3995 1996

A new parameterization of the fluoride-water interaction within a polarizable water model is presented. Because of the absence of accurate experimental data for the enthalpy of formation of the $F^-(H_2O)$ cluster, the results of *ab-initio* calculations were used to parameterize the ion-water interaction. The *ab-initio* results suggest that this interaction is 10% stronger than what was previously thought. The accuracy of the present parameterization was evaluated by comparing the model potential with the *ab-initio* results along the minimum energy profile for the fluoride-water interaction for various F^-O separations. The energetic and structural properties of the clusters $F^-(H_2O)(n)$, $n = 1^{-10}$, as well as of aqueous fluoride solution are studied using molecular dynamics simulation techniques. The stronger ion-water interaction results in the appearance of interior states (configurations in which the ion is "solvated" by water molecules) for finite clusters with six or more water molecules. The results of the aqueous ionic solution simulations provide a reasonable description of many structural and thermodynamic properties of the solvated ion such as the solvation enthalpy, the radial distribution function, and the hydration number.

Key words: Aqueous fluoride solvation; Fluoride-water interactions; Solvation energy.
Reprints: S S Xantheas, Battelle Memorial Institute, Pacific Northwest Laboratories, POB 999 Richland, WA 99352, USA.

CALCIUM DEFICIENCY IN FLUORIDE-TREATED OSTEOPOROTIC PATIENTS DESPITE CALCIUM SUPPLEMENTATION

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J R Farley and D J Baylink
Loma Linda, California, USA

Abstract from *Journal of Clinical Endocrinology and Metabolism 81* (1) 269-275 1996

To test the hypothesis that the osteogenic response to fluoride can increase the skeletal requirement for calcium, resulting in a general state of calcium deficiency and secondary hyperparathyroidism, we assessed calcium deficiency, spinal bone density by quantitative computed tomography, and serum PTH in three groups of osteoporotic subjects. Two of the three groups had been treated with fluoride and calcium (at least 1500 mg/day) for 32 ± 19 months. Group I consisted of 16 fluoride-treated subjects who had shown rapid increases in spinal bone density (+3.8 ± 2.6 mg/cm^3 month), group II consisted of 10 fluoride-treated subjects who had shown decreases or only slow increases in spinal bone density (-0.05 ± 0.6 mg/cm^3 month), and group III consisted of 10 age-matched untreated osteoporotic controls. Calcium deficiency was assessed by measurement of calcium retention after calcium infusion. The results of our studies showed that 1) 94% of the subjects in Group I were calcium deficient compared with only 30% in groups II and III ($P < 0.01$ for each); 2) the subjects in group I retained more calcium (79%) than the subjects in group II (60%, $P < 0.001$) or the subjects in group III (64%, $P < 0.005$); 3) calcium retention was proportional to serum PTH ($r = 0.37$, $n = 36$, $P < 0.03$); and 4) calcium retention was proportional to the (previous) fluoride-dependent increase in quantitative computed tomography spinal bone density (in groups I and II, $r = 0.48$, $n = 26$, $P < 0.02$). To test the hypothesis that the calcium deficiency and the secondary hyperparathyroidism that were associated with the positive response to fluoride would respond to concomitant calcitriol treatment, a subgroup of 7 calcium-deficient subjects were selected from group I and treated with calcitriol (plus fluoride and calcium) for an average of 7 months. The calcitriol therapy reduced the calcium deficit in all 7 subjects, decreasing calcium retention from 80% to 62% ($P < 0.02$), and decreasing PTH from 50 to 28 pg/mL ($P < 0.02$). Together, these data indicate that fluoride-treated osteoporotic subjects may develop calcium deficiency in proportion to the effect of fluoride to increase bone formation, and this calcium deficit is responsive to calcitriol therapy.

Key words: Calcium deficiency; Calcium supplementation; Fluoride therapy; Osteoporosis.

Reprints: D J Baylink, Jerry L Pettis Memorial Medical Center, 11201 Benton St, Loma Linda CA 92357 USA.

EFFECTS OF LOW-DOSE LONG-TERM SODIUM FLUORIDE PREVENTIVE TREATMENT ON RAT BONE MASS AND BIOMECHANICAL PROPERTIES

Y Jiang, J Zhao, R Vanaudekercke, J Dequeker and P Geusens
Pellenberg, Belgium

Abstract from *Calcified Tissue International 58* (1) 30-39, 1996

Effects of fluoride on bone strength and cortical bone mass remain controversial. We compared 9-month, low-dose sodium fluoride (NaF) treatment with estrogen replacement therapy. Female Wistar rats 4.5 months old were divided into baseline, sham-operated (sham), sham-treated with NaF at 0.5 mg NaF/kg/day in drinking water, and ovariectomy (OVX), OVX treated with NaF and with estrogen. Bone mass was measured by dual X-ray absorptiometry (DXA) *in vitro*. Dimensions of the first lumbar vertebral body (L1) were determined by radiogrammetry. The right femur was processed undecalcified to obtain a midshaft cross-section to determine cross-sectional moments of inertia (CSMIs). L1 compressive test and left femoral torsional test were performed. OVX induced significant bone loss in L1 and femoral midshaft. Bone mass was increased to a greater extent in NaF-treated rats than in rats receiving estrogen replacement therapy. Femoral CSMIs in OVX rats, both L1 sizes and femoral CSMIs in NaF-treated rats, were significantly increased. Estrogen treatment had the least dimension expansion. OVX significantly decreased L1 compressive variables. There was no statistical difference in compressive parameters between NaF-treated groups and controls. OVX significantly increased femoral torsional strength but NaF treatment did not. Bone fluoride content was significantly increased after treatment with NaF. No significant difference in bone mineralization degree (ash and calcium) was found between treated and control rats. The discrepancy that an increase in bonemass and geometric properties in both trabecular and cortical bones by low-dose, long-term NaF treatment did not increase vertebral strength nor proportionally improve femoral strength indicated that the bone intrinsic biomechanical properties could be changed by NaF treatment.

Key words: Bone geometry; Bone mass; Compressive and torsional tests; Sodium fluoride; Trabecular and cortical bone.

Reprints: Y Jiang, Catholic University Leuven Hospital, Pellenberg Arthritis and Metabolic Bone Diseases Research Unit, B-3212 Pellenberg, Belgium.

EFFECTS OF SODIUM FLUORIDE AND ALENDRONATE ON THE BONE MINERAL IN MINIPIGS

A small-angle X-ray scattering and backscattered electron imaging study

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West Point, Pennsylvania, USA

Abstract from *Journal of Bone and Mineral Research 11* (2) 248-253 1996

Sodium fluoride (NaF), which stimulates bone formation, and bisphosphonates, which reduce bone resorption, are both used in the treatment of osteoporosis, and are binding to bone mineral, In this study, using small-angle X-ray, scattering and backscattered electron imaging, we analyzed the bone mineral in the vertebrae of

minipigs treated with fluoride, with the bisphosphonate alendronate (ALN), or with vehicle, All specimens were investigated blindly. A slight increase in the average thickness of the mineral crystals as well as changes in the structure of the mineral/collagen composite were found in the case of fluoride-treated animals. No differences were found between ALN-treated animals and controls, The changes produced by fluoride are in the same direction as seen in bones from patients treated with NaF, albeit much smaller. They also correlate quantitatively with the reduction in biomechanical properties of bone in fluoride-treated minipigs found in an earlier study with the same animals. These findings suggest that small changes in the structure of the mineral/collagen composite in bone may considerably affect its biomechanical properties. It also emphasizes the delicate balance between the increase of bone mass and deterioration of bone material properties for the effect of fluoride on the biomechanical properties of bone.

Key words: Alendronate; Bone; Electron imaging; Minipigs; Sodium fluoride; X-ray.
Reprints: G Rodan, Merck Sharp And Dohme Ltd Laboratories, West Point, PA 19486 USA.

GENERALIZED OSTEOPATHY WITH PATHOLOGICAL FRACTURES IN A PATIENT WITH LONGTERM EXPOSURE TO FLUORINE-CONTAINING PLASTICS [in German]

W Rhomberg, F Bohler, A Vith and G Breitfellner
Feldkirch, Austria

Abstract from *Schweizerische Medizinische Wochenschrift, Journal Suisse de Medecine 125* (48) 2330-2337 1995

In a 68-year-old man with a painful syndrome of the lower extremities which began at the age of 64 years, workup revealed a generalized osteopathy with sclerosis of the axial skeleton and osteopenia at the extremities associated with pathologic fractures. The occupational history showed exposure to several synthetics such as vinyl chloride, polyethylene, delrine and polyamides over 30 years. However, a presumptive connection between the skeletal disorder and the occupational exposurecould not initially be substantiated. In a later analysis of the bone biopsies from 1991, a significant increase of fluorine in the tibia and fibula of the patient was detected and thus the diagnosis of industrial fluorosis established. The fluorine presumably originated from the workup of polytetrafluorethylene plates. A detailed analysis of the workplace is ongoing. The fluorosis may obviously appear as a variable skeletal disease. The clinical picture of fluorosis is incompletely described in most of the German textbooks. It calls for an extended description of the X-ray findings associated with fluorosis and a new definition of the disease.

Key words: Endemic fluorosis; Biocompatibility; Osteoporosis; Skeletal Delrin.
Reprints: W Rhomberg, Landeskrankenhaus Feldkirch, Radioonkol Abt, Carinagasse 47, A-6800 Feldkirch, Austria.

SKELETAL FLUOROSIS IN BONE INJURY CASE

S L Choubisa and R Verma
Dungarpur, India

Abstract from *Journal of Environmental Biology 17* (1) 17-20, 1996

A hospitalised bone injury case was studied clinically and radiologically for the evidence of skeletal fluorosis. Clinical findings, diffused dental fluorosis, gastro-intestinal disturbances, vague aches and rigidity and pain of the neck region, back, knee and shoulder joints, and moderate crippling have been observed. Radiographs revealed increased bone mass and density and calcified ligaments. On the basis of these findings, this case was of the third grade (very advanced) of skeletal fluorosis. Detailed clinical and radiological findings have also been discussed.

Key words: Accident; Chronic fluoride intoxication; Radiological changes; Skeletal fluorosis.

Reprints: S L Choubisa, M L Sukhadia University, Department of Zoology, Dungarpur 314001 India.

PRE-TREATMENT OF TITANIUM IMPLANTS WITH FLUORIDE IMPROVES THEIR RETENTION IN BONE

J E Ellingsen
Oslo, Norway

Abstract from *Journal of Materials Science - Materials in Medicine 6* (12) 749-753 1995

Fluoride pre-treatment of titanium improved the bone response to this material in the present study. Fluoride pre-treated titanium implants had a four times increased retention in rabbits ulna after four and eight weeks healing periods as measured by a push out technique. Scanning electron microscopic evaluation of the implants revealed that the F-treated implants were partly covered with bone after the push out procedure indicating that an internal fracture had occurred in the bone rather than between the bone and the implant. This was not observed in the titanium control group. It is suggested that the presence of a fluoride coat on the surface of titanium implants stimulates the bone response leading to a connection between titanium and phosphate from tissue fluids. Free fluoride ions will catalyse this reaction and induce the formation of fluoridated hydroxyapatite and fluorapatite in the surrounding bone.

Key words: Bone; Fluoride coating; Titanium implants.

Reprints: J E Ellingsen, University of Oslo Faculty of Dentistry, PO Box 1109, N-0317 Oslo, Norway.

ALUMINUM POTENTIATES THE EFFECT OF FLUORIDE ON TYROSINE PHOSPHORYLATION AND OSTEOBLAST REPLICATION *IN VITRO* AND BONE MASS *IN VIVO*

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D Burgener and J P Bonjour
Geneva, Switzerland

Abstract from *Calcified Tissue International 58* (1) 30-39 1996

Osteoporosis in workers exposed to fluoride (F) and aluminum (Al) (industrial fluorosis) led to the use of F as a treatment to increase bone mass in osteoporosis patients. Because the influence of traces of Al on the effects of F on bone formation is heretofore unknown, we have investigated this issue both *in vitro* and *in vivo*. We have found that minute amounts of Al (less than or equal to 10^{-5} M) potentiate the effects of F *in vitro* such that osteoblast proliferation increased by 15 ± 2.7% at 50 μM ($p < 0.001$) and by 117.6 ± 5.1% at 750 μM ($p < 0.001$), concentrations of F with no mitogenic effect alone, F + Al time-dependently modulated a growth factor signaling pathway(s) associated with enhanced tyrosine phosphorylation (TyrP) of several proteins (p90 [2.9x], p77 [4.9x], p68 [9.6x], and mitogen activated protein kinases [3x]). TyrP was only slightly or not at all changed by F and Al alone, respectively. The effects of F + Al on TyrP and cell proliferation were markedly reduced by 100 μM tyrphostin-51, a tyrosine kinase inhibitor. Protein kinase A (PKA) and protein kinase C (PKC) pathways were not involved in this response. *In vivo*, F + Al administered for 8 months, at doses that had no effect when the minerals were administered individually, significantly enhanced proximal tibia bone mineral density (BRID) by 6.3 ± 1% compared with initial values and by 2-fold compared with control ovariectomized rats ($p < 0.0001$). These effects are consistent with a crucial role of Al in osteosclerosis observed in industrial fluorosis. The results suggest that the combination of F + Al modulates a growth factor-dependent TyrP pathway enhancing mitogen-activated protein kinase and osteoblast proliferation and bone mass.

Key words: Aluminum; Bone; Fluoride; Osteoblast replication; Tyrosine phosphorylation.

Reprints: J Caverzasio, University Hospital of Geneva Department of Medicine, 24 Rue Micheli Crest, CH-1211 Geneva 14, Switzerland.

The following have also been published.

COMPARISON OF NONRANDOMIZED TRIALS WITH SLOW-RELEASE SODIUM FLUORIDE WITH A RANDOMIZED PLACEBO-CONTROLLED TRIAL IN POST-MENOPAUSAL OSTEOPOROSIS by C Y C Pak, K Sakhaee, N H Bell *et al*, in *Journal of Bone and Mineral Research 11* (2) 160-168 1996. Reprints: C Y C Pak, University of Texas, Southwest Medical Center, 5323 Harry Hines Blvd, Dallas TX 75235, USA.

This study reiterates the authors' earlier findings (see abstracts and critical reviews in *Fluoride 27* (3) 172-173 (4) 227-228, and *29* (1) 36-38) and concludes: "The similarity of response of nonrandomized trials with that of the randomized controlled trial and the resultant combined analysis further validate the efficacy and safety of slow-release sodium fluoride in the treatment of postmenopausal osteoporosis."

BIPHASIC SODIUM FLUORIDE EFFECTS ON BONE AND BONE MINERAL. A REVIEW by P T Cheng, S M Bader and M D Grynpas, in *Cells and Materials 5* (3) 271-282 1995. Reprints: P T Cheng, University of Toronto, Mt Sinai Hospital, Department of Pathology, 600 University Avenue, Toronto ON M5G 1X5 Canada.

Reviews the effect of sodium fluoride on animal and human bone strength and concludes: "These findings are in agreement with the clinical observations that high NaF dose does not help reduce vertebral fracture rate but low dose seems to help."

TREATMENT OF POSTMENOPAUSAL VERTEBRAL OSTEOPENIA WITH MONO-FLUOROPHOSPHATE - A LONG-TERM CALCIUM-CONTROLLED STUDY by M Gambacciani, A Spinetti, F Taponeco *et al* in *Osteoporosis International 5* (6) 467-471 1995. Reprints: M Gambacciani, University of Pisa, Departtment of Obstetrics and Gynecology, Piero Fioretti Via Roma 67, I-56100 Pisa, Italy.

Tested a new drug and concluded: "Present results suggest that, in osteopenic post-menopausal women, monofluorophosphate administration induces a significant increase in vertebral bone mineral density without impairment of cortical bone, with a reduction in bone resorption and an increase in bone formation rate."

EFFECTS OF FLUORIDATED DRINKING WATER ON BONE MASS AND FRACTURES: THE STUDY OF OSTEOPOROTIC FRACTURES by J A Cauley, P A Murphy, T J Riley and A M Buhari in *Journal of Bone and Mineral Research 10* (7) 1076-1086 1995. Reprints: J A Cauley, Department of Epidemiology, Graduate School of Public Health, University of Pittsburg, Pennsylvania, USA.

Compared bone mineral density and length of exposure to fluoridated drinking water in 2076 women and concluded: "Our results do not support the findings from recent ecological studies which showed an increased risk of hip fracture among individuals exposed to fluoridated public water."

FLUORIDE IN DRINKING WATER AND THE BONE MINERAL DENSITY OF WOMEN IN TAIWAN by C F Lan, I F Lin and S J Wang in *International Journal of Epidemiology 24* (6) 1182-1187 1995. Reprints: C F Lan, Nationall Yang Ming Medical College, Graduate Institute of Public Health, 155 Li Long St, Pei Tou, Taipei 112 Taiwan.

Compared bone mineral density of 248 women and level of naturally occurring fluoride in their drinking water and concluded: "There is no significant association between bone mineral density and fluoride for postmenopausal women in Taiwan."

The first of our abstracts from the dental literature is interesting for its acknowledgement: "The optimal level of fluoride intake has never been determined scientifically and has been used only in general terms." The authors observe also: "Local and regional studies in the United States and Canada have found the prevalence of mostly mild dental fluorosis to range from about 20 to 80 percent." In their concluding discussion they state: "With the majority of children having much less decay than in the past, with diverse sources and variable quantities of ingested fluoride and with the role of systemic fluoride understood to be less important than previously believed, decisions about use of dietary fluoride supplements are more complex than they were in the past." Nonetheless, the continued advocacy in the dental literature of slow-release fluoride from dental filling materials (to achieve a topical effect), and of salt and milk fluoridation, indicate tardy professional recognition of the need to reduce systemic fluoride intake to avoid toxic consequences. JC

INFANTS FLUORIDE INGESTION FROM WATER, SUPPLEMENTS AND DENTIFRICE

S M Levy, F J Kohout, M C Kiritsy, J R Heilman and J S Wefel
Iowa City, Iowa, USA

Abstract from *Journal of the American Dental Association 126* (12) 1625-1632 1995

Concerns about dental fluorosis and the paucity of detailed fluoride intake data prompted this longitudinal study of fluoride intake in infants from birth to 9 months of age. On average, water fluoride intake greatly exceeded that from dietary fluoride supplements or fluoride dentifrice. However, fluoride supplements and dentifrice contributed substantial proportions of fluoride intake among children using them. Some children had estimated fluoride intake from water, supplements and dentifrice that exceeded the recommended "optimal" intake (a level that has yet to be determined scientifically). Practitioners should estimate fluoride ingestion from all these sources if considering systemic fluoride supplementation.

Key words: Dental fluorosis; Dentifrice; Fluoride ingestion; Infants; Optimal Intake; Toothpaste; Water fluoride.

Reprints: S M Levy, University of Iowa, Collegee of Dentistry, Department of Preventive and Community Dentistry, Iowa City, IA 52242, USA.

Also published:

INFANTS' FLUORIDE INTAKE FROM DRINKING WATER ALONE, AND FROM WATER ADDED TO FORMULA, BEVERAGES, AND FOOD by S M Levy, F J Kohout, N Guha *et al* in *Journal of Dental Research 74* (7) 1399-1407 1995. Reprints: S M Levy, University of Iowa, College of Dentistry, Department of Preventive and Community Dentistry, Iowa City, IA 52242, USA.

SURVEY OF LEAD, CADMIUM, FLUORIDE, NICKEL, AND COBALT IN FOOD COMPOSITES AND ESTIMATION OF DIETARY INTAKES OF THESE ELEMENTS BY CANADIANS IN 1986-1988 by R W Dabeka and A D Mckenzie in *Journal of AOAC International 78* (4) 897-909 1995. Reprints: R W Dabeka, Department of Health and Welfare, Health Protection Branch, Food Directorate, Bureau of Chemical Safety, Division of Food Research, Ottawa, ON K1A 0L2, Canada.

RISK OF FLUOROSIS IN A FLUORIDATED POPULATION - IMPLICATIONS FOR THE DENTIST AND HYGIENIST

D G Pendrys
Farmington, Connecticut, USA

Abstract from *Journal of the American Dental Association 126* (12) 1617-1624 1995

The prevalence of enamel fluorosis has increased in optimally fluoridated areas in recent years. This has led to efforts to identify the cause or causes and to make recommendations that seek to maintain the caries-preventive effectiveness of fluoride use while minimizing the risk of fluorosis. In this study, the author estimated the potential direct impact that dental practitioners could have on reducing the amount of enamel fluorosis in U.S. children. The findings suggest that dental practitioners could have an important impact on reducing the prevalence of enamel fluorosis by guiding the public toward the most appropriate use of fluoride products.

Key words: Dental caries; Dental fluorosis; Fluoridation; Supplements; Toothpaste.

Reprints: D G Pendrys, Department of Behavioral Sciences and Community Health, School of Dental Medicine, University of Connecticut Health Center, Farmington 06030, USA.

FLUORIDE SUPPLEMENT USE BY CHILDREN IN FLUORIDATED COMMUNITIES.

D G Pendrys and D E Morse
Farmington, Connecticut, USA

Abstract from *Journal of Public Health Dentistry 55* (3) 160-164 1995

OBJECTIVES: The purpose of this study is to describe patterns of inappropriate fluoride supplementation among a sample of Connecticut schoolchildren living in optimally fluoridated areas. METHODS: Fluoride exposure histories were obtained via a written questionnaire with a response rate of 89 percent and an overall reliability of 87 percent agreement. RESULTS: A total of 575 subjects lived the entire first eight years of life in a fluoridated community. Of these, 26.1 percent had a history of inappropriate supplementation sometime during that period, including 31.8 percent of subjects with mild to moderate fluorosis and 22.8 percent of subjects without fluorosis. There were no significant supplement history differences related to current age, sex, or socioeconomic status. Overall, 71 percent of these subjects used only vitamins with fluoride, while only 14 percent were reported to have used fluoride supplements alone. Sixty-eight percent of the subjects who were supplemented while breast feeding, continued supplementation after cessation of breast feeding. CONCLUSIONS: These findings reinforce the need for health professionals to be targeted more aggressively at the school, residency, and private practice levels to better promote a full understanding of the proper utilization of fluoride supplements.

Key words: Dental fluorosis; Fluoridation; Supplements.

Reprints: D G Pendrys, Department of Behavioral Sciences and Community Health, School of Dental Medicine, University of Connecticut Health Center, Farmington 06030, USA.

RISK FACTORS FOR DENTAL FLUOROSIS IN PEDIATRIC DENTAL PATIENTS.

M C Skotowski, R J Hunt and S M Levy
Iowa City, Iowa, USA

Abstract from *Journal of Public Health Dentistry 55* (3) 154-159 1995

OBJECTIVES: Concerns have been raised recently about whether a substantial amount of dental fluorosis is resulting from the increased use of fluoride from various sources. The purposes of this study were to determine the prevalence and severity of dental fluorosis in a sample of pediatric patients seeking dental treatment in a university pediatric dental clinic and to evaluate sources of fluoride as risk factors for dental fluorosis. METHODS: A convenience sample of 157 children aged 8 to 17 years were examined for dental fluorosis using the Tooth Surface Index of Fluorosis (TSIF). Fluoride history questionnaires assessing previous exposure to fluoride during the first eight years of life were completed by the children's parents. Fluoride exposures were compared among 54 cases and 54 matched controls using a case-control retrospective design. RESULTS: Fluorosis was found in 72 percent of the children, but was generally quite mild. The risk of fluorosis was significantly greater for children who had greater exposure to fluoridated water and who used larger amounts of fluoridated toothpaste up to age eight. CONCLUSIONS: This study provided evidence that increased use of fluoride toothpaste may be a risk factor for dental fluorosis. The results suggest prudent use of dentifrice by young children to minimize the risk of fluorosis.

Key words: Dental fluorosis; Pediatric patients; Toothpaste.

Reprints: M C Skotowski, Department of Pediatric Dentistry, College of Dentistry, University of Iowa, Iowa City 52242-1001, USA.

FLUORIDE CONTENT OF INFANT FORMULAE IN AUSTRALIA

M Silva and E C Reynolds
Melbourne, Australia

Abstract from *Australian Dental Journal 41* (1) 37-42 1996

The prevalence of dental fluorosis in Australia and the United States of America has increased in both optimally fluoridated and non-fluoridated areas. This has been attributed to an increase in the fluoride level of food and beverages through processing with fluoridated water, inadvertent ingestion of fluoride toothpaste, and the inappropriate use of dietary supplements. A major source of fluoride in infancy is considered to be infant formula which has been implicated as a risk factor for fluorosis in a number of studies. In this study the fluoride content of the infant formulae commonly used in Australia was determined. The acid diffusible fluoride of each powdered formula was isolated by microdiffusion and measured using a fluoride ion-specific electrode. The fluoride content of milk-based formulae ranged from 0.23 to 3.71 μg F/g and for soy-based formulae from 1.08 to 2.86 μg F/g. When reconstituted, according to the manufacturer's directions, with water not containing fluoride, the formulae ranged in fluoride content from 0.031 to

0.532 ppm, with the average fluoride content 0.240 ppm. Using average infant body masses and suggested volumes of formula consumption for infants 1-12 months of age, possible fluoride ingestion per kg body mass was estimated. None of the formulae, if reconstituted using water containing up to 0.1 ppm F, should provide a daily fluoride intake above the suggested threshold for fluorosis of 0.1 mg F/kg body mass. However, if reconstituted with water containing 1.0 ppm F they should all provide a daily fluoride intake of above the suggested threshold for fluorosis with intakes up to 2-3 times the recommended upper 'optimal' limit of 0.07 mg/kg body mass. Under these conditions the water used to reconstitute the formulae would provide 65-97 per cent of the fluoride ingested. These figures are likely to be overestimates due to the intake of nutrients from other sources reducing formulae consumption and also due to the lower bioavailability of fluoride from milk-based formulae. Further, it is generally believed that the maturation stage of enamel formation is the critical period for fluorosis development by chronic, above-threshold fluoride exposure. The maturation stage for the anterior permanent teeth, however, is after the first twelve months of life where fluoride intake from infant formula consumption per kg body mass is highest. The level of fluoride in the commonly used Australian formulae would suggest that infant formula consumption alone is unlikely to be a risk factor for dental fluorosis in a non-fluoridated community, but could make a major contribution to an infant's daily fluoride intake. However, prolonged consumption (beyond 12 months of age) of infant formula reconstituted with optimally-fluoridated water could result in excessive amounts of fluoride being ingested during enamel development of the anterior permanent teeth and therefore may be a risk factor for fluorosis of these teeth.

Key words: Dental fluorosis; Infant formulae.

Reprints: M Silva, University of Melbourne, School of Dental Science, 711 Elizabeth St, Melbourne, Vic 3000, Australia.

INFLUENCE OF FLUORIDE IN SALIVA DURING THE EARLY CARIOGENIC CHANGES IN THE ENAMEL OF BOYS AND GIRLS

J H Woltgens, E J Etty, R J Gruythuysen and W G Geraets
Amsterdam, The Netherlands

Abstract from *Journal of Dentistry for Children 62* (3) 192-196 1995

In boys and girls cariogenic changes in the dental enamel in relation to fluoride (F^-) concentrations in stimulated and unstimulated saliva were studied in a six-month period. Also the use of various types of applications of F^- was assessed. No difference in the use of F^- between boys and girls before and after the interval was observed. Also no clear differences were found between boys and girls in the levels of F^- in both types of saliva, determined at the end of the six-month period. The most important finding was that for all children, a significantly positive relationship was found between the disappearance of white spots turning into sound enamel

(regression) and the F^- concentration in unstimulated saliva. In addition, girls who developed new white spots had higher levels of F^-, but those who developed new cavities had lower F^- levels in both types of saliva. Apparently F^- can prevent dental caries by acting very early on remineralization and demineralization processes in enamel surfaces.

Key words: Demineralization; Dental caries; Fluoride; Remineralization; Saliva.
Reprints: Department of Oral Cell Biology, Academic Centre for Dentistry Amsterdam, Vrije Universiteit, van der Boechorstrtr 7, 1081 BT Amsterdam, The Netherlands.

pH-CYCLING OF ENAMEL AND DENTIN LESIONS IN THE PRESENCE OF LOW CONCENTRATIONS OF FLUORIDE

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Abstract from *European Journal of Oral Sciences 103* (6) 362-367 1995

F-dentifrice usage causes slightly elevated fluoride levels in saliva. Therefore, the effects of permanent low fluoride concentrations versus daily dentifrice treatments were studied on enamel and dentin lesions in a pH-cycling model of alternating demineralization and remineralization. Groups received: 1) no fluoride treatment; 2) 3 μ M (0.06 ppm) F continuously present during re- and demineralization; or 3)daily 5-min F-dentifrice treatments. Solutions were analyzed for changes in calcium and fluoride. Cumulative results (10 d) showed that for the non-fluoride group the dentin lesions increased, while for enamel lesions mineral uptake and loss were balanced. Addition of 3 μ M F caused small, non-significant, enhancement of remineralization (1-7%), while demineralization was significantly inhibited for both tissues (9-23%). The daily dentifrice treatments resulted in a balance between mineral uptake and loss of dentin, due to inhibited demineralization (-33%) and enhanced remineralization (+79%). For enamel, the F-dentifrice treatments resulted in 43% reduction of demineralization, with no significant effect on remineralization. Fluoride loss from the 3 μ M F cycling solutions was significant (up to 50%) and constant during the experimental period. Microradiographic analysis showed remineralization at the lesion front in enamel. In dentin, the lesion depth was increased in all groups, with concomitant mineral deposition in the surface region of the dentifrice group. Results indicate that slightly elevated fluoride levels may be considerably less effective in inhibiting lesion progression in dentin than in enamel, and suggest mineral uptake and loss to occur at similar depths for enamel lesions, while demineralization and remineralization occur at different depths in dentin.

Key words: Enamel; Dental caries; Dentin; Fluoride; Demineralization; Remineralization.
Reprints: J M Tencate, Academic Centre for Dentistry Amsterdam, Department of Cariology and Endodontology, Louwesweg 1, 1066 East Amsterdam,The Netherlands.

MECHANISTIC UNDERSTANDING OF ENAMEL MINERALIZATION UNDER FLUORIDE REGIME

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Tokyo, Japan

Abstract from *Connective Tissue Research 33* (1-3) 145-49 1995

In order to learn more about how the microenvironment for enamel mineralization is modified by fluoride at low concentrations (0 through 1 ppm) and how excess fluoride retards the degradation and removal of amelogenins, we studied precipitation reactions in an *in vitro* model utilizing a dialysis chamber. The results showed that, with the limited supply of Ca ions through the ultrafiltration membrane, the solution composition surrounding the seed crystals showed a proximity to the steady-state condition after 12-24 h equilibration. Major findings were that (a) fluoride overcame partially the inhibition of precipitation and growth reactions by enamel proteins and (b), with this accelerating effect of fluoride, the steady-state Ca concentrations in the media surrounding the seed crystals decreased substantially as a function of fluoride concentration. The overall results support the concept that the presence of fluoride in the mineralizing milieu can modify markedly the steady-state concentrations of mineral lattice ions, particularly decreasing free Ca^{2+} concentrations, which in turn may modulate protease activities *in situ*.

Key words: Amelogenins; Dental enamel; Fluoride; Mineralization.
Reprints: Department of Pathology, Nippon Dental University, Tokyo, Japan.

THE EFFECT OF FLUORHYDROXYAPATITE-DERIVED FLUORIDE ON ACID PRODUCTION BY *STREPTOCOCCI*

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Wellington, New Zealand

Abstract from *Journal of Dental Research 74* (9) 1618-1624 1995

The effect of fluoride derived from fluorhydroxyapatite (FHAp) minerals on bacterial glycolysis under aerobic and strictly anaerobic conditions was studied to validate the claims that this mineral could be used as a reservoir of fluoride in plaque. To isolate the direct effect of fluoride on bacterial glycolysis from that of an indirect pH-buffering effect of hydroxyl or phosphate ions which are also dissolved from the mineral, we equalized the pH-fall time course of reactions by manually adding KOH or HCl. This ensured that pH effects on glycolysis were minimized. Under controlled pH-fall and strictly anaerobic conditions, fluoride derived from the dissolution of FHAp containing more than 30,100 ppm fluoride (*i.e.*, when the substitution of OH by F in the mineral was greater than 80%) had a direct inhibitory effect on lactic acid production in *Streptococcus mutans*. Under free pH-fall and strictly anaerobic conditions, increasing amounts of fluoride in FHAp (starting as low as 2000 ppm fluoride), appeared to have a pronounced indirect inhibitory effect on lactic acid production. This was probably mediated through a reducing pH buffer effect of the mineral. Even in the presence of high-

fluoride FHAp, only 0.01 to 0.025 mmol/L fluoride was found in the reaction mixtures, a probable result of non-stoichiometric dissolution of FHAp. In spite of such low levels of fluoride, marked inhibitory effects on bacterial glycolysis were demonstrated. The results of this study suggest that high-fluoride FHAp may serve as a reservoir of fluoride for the inhibition of anaerobic acid production by *S. mutans*.

Key words: Apatites; Bacterial glycolysis; Fluorhydroxyapatite; *Streptococcus mutans*.

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ANTIMICROBIAL ACTIONS OF FLUORIDE FOR ORAL BACTERIA [Review]

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Abstract from *Canadian Journal of Microbiology 41* (11) 955-964 1995

Fluoride is widely used as a highly effective anticaries agent. Although it is felt that its anticaries action is related mainly to effects on mineral phases of teeth and on the process of remineralization, fluoride also has important effects on the bacteria of dental plaque, which are responsible for the acidification of plaque that results in demineralization. The results of recent studies have shown that fluoride can affect bacterial metabolism through a set of actions with fundamentally different mechanisms. It can act directly as an enzyme inhibitor, for example for the glycolytic enzyme enolase, which is inhibited in a quasi-irreversible manner. Direct action seems also to occur in inhibition of heme-based peroxidases with binding of fluoride to heme. The flavin-based peroxidases of many oral bacteria are insensitive to fluoride. Another mode of action involves formation of metal-fluoride complexes, most commonly AlF_4^-. These complexes are responsible for fluoride inhibition of proton-translocating F-ATPases and are thought to act by mimicking phosphate to form complexes with ADP at reaction centers of the enzymes. However, the actions of fluoride that are most pertinent to reducing the cariogenicity of dental plaque are those related to its weak-acid character. Fluoride acts to enhance membrane permeabilities to protons and compromises the functioning of F-ATPases in exporting protons, thereby inducing cytoplasmic acidification and acid inhibition of glycolytic enzymes. Basically, fluoride acts to reduce the acid tolerance of the bacteria. It is most effective at acid pH values. In the acidic conditions of cariogenic plaque, fluoride at levels as low as 0.1 mM can cause complete arrest of glycolysis by intact cells of *Streptococcus mutans*. Overall, the anticaries actions of fluoride appear to be complex, involving effects both on bacteria and on mineral phases. The antibacterial actions of fluoride appear themselves to be complex but to be dominated by weak-acid effects.

Key words: Dental caries; Fluoride; Oral bacteria; Glycolysis.

Reprints: R E Marquis, University of Rochester Medical Center, Departtment of Microbiology and Immunology, Rochester, NY 14642, USA.

ACIDULATED PHOSPHATE FLUORIDE TREATMENT AND FORMATION OF CARIES-LIKE LESIONS IN ENAMEL: EFFECT OF APPLICATION TIME

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San Antonio, Texas, USA

Abstract from *Journal of Clinical Pediatric Dentistry 19* (2) 105-110 1995

The aim of this study was to evaluate the effect of acidulated phosphate fluoride (APF) application time (1 and 4 minutes) on caries-like lesion formation in enamel. Following a fluoride-free prophylaxis, the specimens (10 extracted human molars) were divided into tooth quarters and assigned to treatment groups: 1) Distobuccal and Distolingual Quarters - 1 minute APF; 2) Mesiobuccal and Mesiolingual Quarters - 4 minute APF. Acid-resistant varnish was applied to the tooth quarters, leaving sound enamel windows exposed on buccal and lingual surfaces. Following treatment, the APF gel (Oral-B Minute Gel) was removed by air-water spray rinsing, followed by a 24-hour water rinse. Sound enamel windows protected from APF treatment by acid-resistant varnish were created adjacent to APF-treated sound enamel windows and served as paired controls. Lesions were created in APF-treated and paired control sound enamel windows with an acidified gel. After lesion formation, sections were obtained and imbibed with water for polarized light study. Body of the lesion depths were measured and compared statistically. Mean body of the lesion depths were: 186 ± 28 microns for control lesions, 117 ± 12 microns for APF-1min; and 111 ± 14 microns for APF-4min. Significant differences ($p < 0.05$) were found between paired control and APF groups. No difference ($p > 0.05$) was found between APF-1min and APF-4min groups. APF treatment prior to lesion formation resulted in a significant reduction in lesion depth, regardless of whether a 1 or 4 minute APF treatment period was used. The 1 minute APF treatment provided the same degree of caries protection as the longer treatment period.

Key wordss: Acidulated phosphate fluoride; Dental caries; Topical application.

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ARE CURRENT MODELS FOR PREVENTIVE PROGRAMS SUFFICIENT FOR THE NEEDS OF TOMORROW? [Review]

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Abstract from *Advances in Dental Research 9* (2) 77-81 1995

We can be proud of our accomplishment in the prevention of dental caries. Many children in developed countries are now caries-free; however, by age 50, fewer than 5% of the population is caries-free. The drop in the prevalence of caries among specific age groups is undoubtedly due to widespread exposure to fluorides. However, caries protection by fluorides is not absolute; if caries attack continues throughout life, the prevalence of caries will increase. All available evidence

strongly suggests that ambient levels of fluoride in the mouth play a critical role in protection against caries. It is clear that novel methods of delivery, such as sustained-release technology, will be developed to enhance the protective effect of fluoride, utilizing amounts of fluoride significantly less than those currently in use. The problems of preventing dental caries in developing countries are much more severe than those facing Western countries. The prevalence of caries appears to be increasing in no small measure due to the introduction of Western diets. Administration of fluoride through conventional routes is either impractical or inordinately expensive. It appears sensible, therefore, to direct preventive measures through dietary constituents associated with caries. Fluoridation of sugars appears to be highly practical and safe way to reduce the prevalence of caries in such communities. Fluoride and iodide are currently added to salt in many parts of the world. If we are to reduce the prevalence of caries effectively in all countries and in all age groups, current methods of prevention will have to be greatly enhanced, and/or effective additional approaches will need to be developed.

Key words: Preventive programs; Sugar fluoridation.

Reprints: W H Bowen, Department of Dental Research, University of Rochester, NY 14642, USA.

THE EFFECTS OF A SODIUM HYPOCHLORITE TREATMENT ON DEMINERALIZED ROOT DENTIN

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Abstract from *European Journal of Oral Sciences 103* (6) 368-374 1995

The effects of a 10% NaOCl treatment for 2 min on demineralized human root dentin were investigated by means of: microradiography (MR), scanning electron microscopy (SEM), confocal laser scanning microscopy (CLSM) and secondary ion mass spectroscopy (SIMS). MR measurements revealed that NaOCl caused a tissue contraction not related to water loss but to removal of organic substance(s), resulting in reductions of the lesion depth and mineral loss values by 15% and 42%, respectively. CLSM observations on wet dentin showed that the dentinal tubules underneath the surface are clearly observable and not deformed substantially by the NaOCl, except near the outermost surface. This indicates the importance of wet as well as of dried (high vacuum) observations. SEM micrographs (high vacuum) showed definite changes in the outer dentin surface structure; 85% of the originally open dentinal tubules were closed after NaOCl treatment. No marked changes were observed in the dentin ultrastructure inside lesions, as shown by SEM on fractured surfaces. SIMS data, pertaining to samples in high vacuum, showed a remarkable increase of chlorine (Cl) content in the entire lesion due to the NaOCl, indicating deep penetration of the original OCl ions. The results suggest that the 2-min treatment of demineralized dentin by NaOCl solutions removes and/or changes part of the dentin matrix in nearly the whole lesion. As a consequence the mineral is somewhat redistributed, the outermost surface of a few μm is changed, but the main dentin structure and element composition are still intact.

These findings indicate that NaOCl treatments are of interest in remineralization and hyper-remineralization studies of dentin.

Key words: Demineralization; Dentin; Organic material; Root caries; Sodium hypochlorite.
Reprints: D Inaba, Nagasaki University, School of Dentistry, Department of Preventive Dentistry, 1-7-1 Sakamoto, Nagasaki, 852 Japan.

THE DISTRIBUTION OF FLUORIDE IN CARIOUS HUMAN ENAMEL

E I F Pearce, G E Coote and M J Larsen
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Abstract from *Journal of Dental Research 74* (11) 1775-1782 1995

The proton probe has been used to map F concentration changes in the enamel of 15 teeth showing clinical evidence of caries. Thin sections through the lesions were microradiographed and measurements made of the surface zone (radiodense) and body (radiolucent) areas. Each section was then scanned with a focused beam of 2.5 MeV protons, 2000 spot analyses being performed over areas up to 2 x 3 mm. F was determined by detecting gamma rays from a nuclear reaction and the data used to construct 3-D surface plots. The maximum F concentration in the lesion surface zone was extremely variable, ranging from 1750 to 21,700 ppm, and rarely occurred over the deepest part of the lesion. F levels were elevated in the lesion body but usually to a small extent only. A large increase in F throughout the lesion body was found in 3 lesions only, and was associated with a surface zone that was thin or of low X-ray density. Relatively small F increases in the lesion body were associated with either a thick, X-ray dense surface layer having a greatly increased F level (> 10,000 ppm) or, conversely, with a surface layer having a relatively small F increase. Since F uptake can be regarded as a "marker" of past remineralization events, this study shows that remineralization can and does occur in the body of natural enamel caries lesions, especially when the surface layer is thin or lost. Fluoride availability that encourages the formation of an extremely dense surface layer may result in under-achievement of this natural repair process in the lesion body.

Key words: Dental caries; Dental enamel; Fluoride; Microradiography; Proton probe.
Reprints: E I F Pearce, Dental Research Unit, Health Research Council of New Zealand, PO Box 27007, Wellington, New Zealand.

ORAL HYGIENE AS A VARIABLE IN DENTAL CARIES EXPERIENCE IN 14-YEAR-OLDS EXPOSED TO FLUORIDE

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Oslo, Norway

Abstract from *Caries Research 30* (1) 29-33 1996

The aim of the study was to examine the relationship between oral hygiene level and caries experience in 14-year-olds using fluoride dentifrices on a regular basis. Oral hygiene expressed as Gingival Bleeding Points (GBP) was recorded in 267 individuals in the county of Lillehammer in Norway. Total caries experience

as DMFS and approximal carious lesions in the outer half of the enamel (D-2), in the inner half of the enamel (D-2), in dentin (D-3), and filled approximal surfaces were registered clinically and on standardized bite-wing radiographs. Using multiple regression analysis, oral hygiene level expressed as GBI was the only factor that could account for variation in caries experience (DMFS). Any significant effect of consumption of sweets on caries experience could not be demonstrated with the multivariate analysis. The average percentage of GBP (± SD) was 35.7 ± 10.0%. The individuals were divided into one group with good oral hygiene (GBP < 35.7%) and one group with poor oral hygiene (GBP greater than or equal to 35.7%). Significantly fewer carious lesions and filled approximal surfaces were demonstrated in the group with good oral hygiene compared with the group with poor oral hygiene. About 16% of the study population used fluoride tablets or fluoride mouthrinses in addition to a fluoride toothpaste. Only in the good oral hygiene group, additional fluoride resulted in a lower caries experience compared with those using only a fluoride toothpaste. In the group with poor oral hygiene, additional fluoride did not result in lower caries experience. The study thus supported the view that during regular fluoride exposure oral hygiene level is an important variable to explain caries risk.

Key words: Adolescence; Caries experience; Consumption of sweets; Fluoride prophylaxis; Oral hygiene.

Reprints: B Ogaard, University of Oslo, Faculty of Dentistry, Department of Orthodontia, POB 1109 Blindern, N-0317 Oslo, Norway.

THE DENTAL HEALTH OF 3-YEAR-OLD CHILDREN IN EAST CUMBRIA 1993

S G Jones and J H Nunn
Carlisle, England

Abstract from *Community Dental Health 12* (3) 161-166 1995

A study of the dental health of 135 3-year-old children, with reference to social class group, was undertaken in East Cumbria District between September and December 1993. Caries free subjects numbered 110 (81.5 per cent), the mean number of decayed, missing, and filled teeth was 0.59; the value of the decayed component of the dmft index was 0.49. Caries experience was confined to 25 (18.5 per cent) individuals whose mean dmft was 3.20, seven of these subjects experienced rampant decay to the maxillary incisor teeth and three had received a dental general anaesthetic. An inverse relationship was demonstrated between dental caries and social class. Trauma to the maxillary incisors had occurred in 17 (12.6 per cent) children, with discolouration and fracture of the enamel and relatively high proportion of the subjects, 39 (28.9 per cent), had experienced erosion to palatal surfaces of the maxillary incisors. The most prevalent type of erosion was that involving both enamel and dentine. Only 14 (10.4 per cent) children examined used fluoride supplements in this low-fluoride area; 98 (72.6 per cent) subjects reported registration with a dentist.

Key words: Dental caries; Fluoride supplements.

Reprints: S G Jones, North Lakeland Healthcare, Carlisle, England.

A FIVE YEAR FOLLOW UP INTO CHANGES IN CARIES EXPERIENCE AMONGST A SAMPLE OF 12 YEAR OLD CHILDREN FROM ATHENS

G J Salapata, C Bakoula, G M Hawley and A S Blinkhorn
Manchester, England

Abstract from *International Dental Journal 45* (2) 160-162 1995

A five year follow up study of the dental health of 12 year old children in Athens has recorded a significant ($P < 0.01$) 32.3 per cent reduction in DMFT. In 1988 the mean DMFT score was 2.41 compared with 1.63 in 1993. The caries reduction may be due in part to increased marketing of fluoride dentifrice by a number of competing national and international companies.

Key words: Dental caries reduction; Toothpaste.
Reprints: G J Salapata, University Dental Hospital, Manchester, England.

RELATIVE CONTRIBUTION OF DENTAL SERVICES TO THE CHANGES IN CARIES LEVELS OF 12-YEAR-OLD CHILDREN IN 18 INDUSTRIALIZED COUNTRIES IN THE 1970s AND EARLY 1980s

P Nadanovsky and A Sheiham
London, England

Abstract from *Community Dentistry and Oral Epidemiology 23* (6) 331-339 1995

The contribution of health services to improvements in health is contentious. The main aim of the present study was to assess the relative contribution that dental services may have made to the changes in dental caries (decayed, missing or filled permanent teeth) level of 12-year-old children in some industrialized countries in the 1970s and early 1980s. A secondary aim was an analysis of the association of the changes in caries levels with broad socioeconomic factors. In this study aggregate (ecological) data from 18 industrialized countries were analyzed at a national level. Data were obtained from published papers and official publications and included 3 kinds of variables: caries, presence of dental service and broad socioeconomic factors (including fluoridated toothpastes). Dental services explained 3% of the variation in changes in 12-year-old caries levels in the 1970s and early 1980s period whereas broad socioeconomic factors (including or excluding fluoridated toothpastes) explained 65%. The findings suggest that dental services were relatively unimportant in explaining the differences in changes in 12 year-old caries levels in the 1970s and early 1980s in the 18 countries. The view that fluoride in toothpaste was the only important cause of the declines in decayed, missing or filled permanent teeth in industrialized countries was questioned. A possible important contribution of the dental services to the declines was a change in the diagnostic and treatment criteria of caries.

Key words: Dental caries reduction; Dental services; Social factors; Trends.
Reprints: P Nadanovsky, University of London, University College, Departtment of Epidemiology and Public Health, 1-19 Torrington Place, London WC1E 6BT, England.

CAN PREVENTION ELIMINATE CARIES? [Review]

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Abstract from *Advances in Dental Research 9* (2) 106-109 1995

There are four main factors involved in the carious process: at-risk tooth structure, plaque flora, fermentable carbohydrates, and time. Based on our knowledge of the carious process, four main preventive strategies have been developed over the years, namely, fluorides, fissure sealing, dietary choice, and plaque control. Fluorides are having a major impact on smooth-surface caries; hence, strategies combining fluorides and fissure sealing are very effective. However, use of fissure sealing is still problematic. Changing dietary practices with a view to reducing dental caries seems to be having little impact on a global scale. Plaque control, as practiced routinely by the majority of people, is not sufficient to result in caries reductions. Deprivation and poverty are strongly associated with high caries levels. Although the preventive strategies currently available are likely to result in lower caries levels for many, for logistical reasons and because of factors associated with deprivation and poverty, caries is likely to remain a major public health problem in most communities for the foreseeable future.

Key words: Dental caries; Prevention; Social factors.

Reprints: D O'Mullane, WHO Collaborating Centre for Oral Health Services Research, University Dental School, Ireland.

ORAL HEALTH OF INDIVIDUALS AGED 3-80 YEARS IN JONKOPING, SWEDEN IN 1973, 1983, AND 1993
1. Review of findings on dental care habits and knowledge of oral health

A Hugoson, G Koch, T Bergendal, A L Hallonsten,
C Slotte, B Thorstensson and H Thorstensson
Jonkoping, Sweden

Abstract from *Swedish Dental Journal 19* (6) 225-241 1995

The aim of the present study was to compare data on dental care habits and knowledge of oral health in three cross-sectional studies carried out in 1973, 1983, and 1993. The 1973 study constituted a random sample of 1000 individuals evenly distributed in the age groups 3, 5, 10, 15, 20, 30, 40, 50, 60, and 70 years. The same age groups with addition of a group of 80-year-olds were included in the 1983 and 1993 studies which comprised 1104 and 1078 individuals, respectively.

A questionnaire (23-101 questions) about dental care habits and knowledge of oral health was used in connection with a clinical and radiographic examination. The same questions were used in all the three studies. An addition to the 1993 investigation was questions concerning ethnographic background.

In 1993 approximately 95% of all individuals were visiting the dentist on a regular basis every or every second year. The 30-year-olds, however, did not visit a dentist as regularly in 1993 as in 1983. The 70- and 80-year-olds visited a dentist

more regularly in 1993 than in 1983. An increased number of adults in all age groups, except for the 70-year-olds, received their dental care in the Public Dental Service in 1993 compared to 1983 and 1973. Most 40-year-olds and older, however, received their dental care by private practitioners. About 80% of all adults in 1993 were enrolled in a recall system on the dentist's initiative while in 1973 most appointments were based on the patient's own initiative.

The number of individuals who felt discomfort at the prospect of an appointment with the dentist was more or less the same in 1973, 1983, and 1993.

The knowledge of the etiology of dental diseases has not changed much between 1973 and 1993. The frequency of toothbrushing has increased since 1973 and in 1993 more than 95% of all individuals brushed their teeth daily. The use of dental floss and toothpicks as well as disclosing tablets decreased in 1993 compared to 1983.

Almost all individuals in 1993 used fluoride toothpaste. The use of topical fluorides and fluoride tablets in children had decreased considerably in 1993 compared to 1983.

Key words: Dental care; Dental care habits; Epidemiology; Knowledge of oral health; Oral health.

Reprints: A Hugoson, Institute for Postgraduate Dental Education, Box 1030, S-55111 Jonkoping, Sweden

CARIES EXPERIENCE IN DECIDUOUS DENTITION OF RURAL CHINESE CHILDREN 3-5 YEARS OLD IN RELATION TO THE PRESENCE OR ABSENCE OF ENAMEL HYPOPLASIA

Y Li, J M Navia and J Y Bian
Birmingham, Alabama, USA

Abstract from *Caries Research 30* (1) 8-15 1996

The association of enamel hypoplasia (EHP) with dental caries of the deciduous dentition was determined in 1,344 rural Chinese children aged 3-5 years. The degree of EHP was determined using a modified DDE Index. Number of decayed, missing, and filled teeth and tooth surfaces were determined for all subjects. Anthropometric assessment of body weight and height was done as an indirect measure of the nutritional status of the children. Results from the study showed that the prevalence of EHP was 22.3% in the total study population. The prevalence of dental caries was 82.3%. There was no difference in the caries experience between males and females. Significantly greater caries experience was observed among the children living in a low socioeconomic county and children with low height for age. Children with low birth weight showed a slightly higher percentage of caries than those born with normal birth wight. Children with enamel hypoplasia demonstrated a significantly higher caries experience than those who did not have such defects. The results of this study consistently support previous studies that found nutritional deficiency to have an important impact on tooth development and susceptibility to dental diseases. This study also indicates that the presence of enamel hypoplasia may he a predisposing factor for initiation and progression of

dental caries, and a predictor of high caries susceptibility in a community, particularly if fluoride programs are not implemented.

Key words: Children; Dental caries; Enamel hypoplasia; Low birth weight; Nutritional deficiency.

Reprints: J M Navia, University of Alabama, School of Public Health, Birmingham, AL 35294, USA.

CHARACTERIZATION OF AN UNUSUAL FLUORIDE-RESISTANT *STREPTOCOCCUS MUTANS* ISOLATE

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Abstract from *Current Microbiology 32* (3) 156-161 1996

A fluoride-resistant *Streptococcus mutans* isolate NCH105 was characterized and compared with wild-type strain UA130. The growth and lactic acid production of strain NCH105 were found to be unaffected by the presence of fluoride at the initial medium pH values of 6.5 and 6. In addition, NCH105 was found to be capable of lowering the pH of the medium to approximately 5.5, which is the critical level where enamel demineralization begins *in vivo*. Lactic acid production, glucose uptake at pH 6.5 and 6, as well as ATPase activity at pH 5 were found to be unaffected by fluoride. Finally, strain NCH105 is capable of binding as well as the wild-type bacterium to artificial tooth pellicles. These results are unusual when compared with previously isolated fluoride-resistant mutants and suggest that NCH105 may have the ability to colonize the tooth surface and initiate dental caries.

Key words: Fluoride resistant; *Streptococcus mutans*.

Reprints: M C Hudson, University of North Carolina, Department of Biology, Charlotte, NC 28223, USA.

SALT FLUORIDATION

There appear to have been no studies clearly demonstrating effectiveness of salt fluoridation. However, advocacy of the measure continues, based on continued belief in a systemic dental benefit from fluoride ingestion. The first of the following list concludes: "By and large, in areas of low drinking water fluoride, fluoridated table salt has the potential to become a means of systemic supplementation comparable with drinking water fluoridation."

SALT FLUORIDATION AND GENERAL HEALTH [Review] by K E Bergmann and R L Bergmann in *Advances in Dental Research 9* (2) 138-143 1995. Reprints: K E Bergman, Department of Pediatrics, Virchow-Klinikum Humboldt University, Berlin, Germany.

FLUORIDATED SALT IN FRANCE by P Hescot, E Roland and J Desfontaine in *Advances in Dental Research 9* (2) 144-145 1995. Reprints: P Hescot, Union Francaise pour la Sante Bucco-Dentaire, Paris, France.

FLUORIDE CONTENT OF TABLE SALT IN MEXICO CITY [Spanish] by G Maupome Carvantes, R D Jaramillo Lanchero, L C Andrade Delgado *et al* in *Boletin de la Oficina Sanitaria Panamericana 119* (3) 195-201 1995. Reprints: G Maupome Carvantes, Universidad Nacional Autonoma de Mexico, Facultad de Odontologia, Division de Estudios de Posgrado e Investigacion, Mexico DF, Mexico.

A STUDY OF THE CAUSE OF THE MANGO BLACK TIP DISORDER

C L Zhang, H B Huang and Y H Kuang
Canton, China

Abstract from *Scientia Horticulturae 64* (1-2) 49-54 1995

Causative factors of the fruit black tip disorder (BT) in mango (*Mangifera indica L.*) have been studied in Guangdong Province, China. Dipping fruits in 150 and 600 mg kg(-1) fluoride solutions induced symptoms similar to that of the black tip disorder. The F content of the fruits with artificially induced symptoms was about 25% higher than that of control (healthy) fruits. The F content of BT fruits from an affected orchard was twice as much as that of the normal (healthy) fruits from an unaffected orchard. The leaf F content of affected trees was about six times as much as that of the control. This study has provided evidence that fluorine in fumes emitted from adjacent brick kilns was the direct causative factor of the mango black tip disorder.

Key words: Black tip disorder; Industrial fluoride pollution; Mango.

Reprints: C L Zhang, South China Agricultural University, Department of Land Resources and Environmental Science, Canton 510642, China.

FLUORIDE ACCUMULATION AND TOXICITY IN LABORATORY POPULATIONS OF WILD SMALL MAMMALS AND WHITE MICE

I C Boulton, J A Cooke and M S Johnson
Liverpool, England

Abstract from *Journal of Applied Toxicology 15* (6) 423-431 1995

A laboratory experiment was conducted to compare the toxicological response and metabolism of inorganic fluoride by three species of wild mammals and laboratory white mice (*Mus musculus L.*). The experimental populations of the wild species-the short-tailed field vole (*Microtus agrestis L.*), the bank vole (*Clethrionomys glareolus L.*) and the wood mouse (*Apodemus sylvaticus L.*) were laboratory reared from wild stock, and all test animals were exposed to 0, 40 or 80 μg F mL^{-1} in their drinking water for up to 84 days. The 40 and 80 μg F mL^{-1} treatments induced premature mortalities in *M. agrestis* and *C. glareolus* only. Differential intakes, absorption and retention of fluoride were evident between *M. musculus* and *M. agrestis*, the two species subject to cage studies of fluoride metabolism budgets, Interspecific variation in accumulation of fluoride with time was also evident between all four species as regards the femur, molars and incisors, Severe dental lesions were apparent in species surviving the 80 μg mL^{-1} treatment for 84 days. Overall, however, there were few clear differences in inherent species sensitivity to fluoride, the interspecific variation in metabolism and accumulation rates being attributable mainly to variation in intake.

Key words: Fluorosis; Wild mammals.

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