FLUOROSIS AND FLUORIDATION*

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Briefly put, the fluoridation of water supplies is a public health measure, the aim of which is to reduce the incidence of the disease known as dental caries by increasing the resistance of tooth enamel to decay, and by so altering the oral environment that certain nefarious microbiological processes are interfered with to the extent of making them virtually harmless.

In order to get as clear a picture as possible of the present status of the fluoridation question, it is essential to look at its background as well as to consider its biochemical and pharmacological aspects. On looking back to what has happened since the beginning of this century, one cannot but come to the conclusion that one of the most brilliant exercises ever carried out in the epidemiology of chronic disease was the series of studies which led to the demonstration of the caries-inhibitory properties of fluoridated water.

THE BACKGROUND

It began, as is so frequently the case in scientific progress, with the study of something else. That something was a peculiar condition of dental enamel which became known along the continental divide of the USA formed by the great Rocky Mountain chain, as 'Colorado Brown Stain'. This condition was usually harmless enough, although it could be disfiguring in some instances. The first important mention of this brown stain occurred in 1902 when Frederick S. McKay, a dentist then recently qualified in Philadelphia and who had started a practice in Colorado Springs, noted a condition he had not encountered before and which, as far as he was aware, was nowhere described in the scientific literature. McKay soon began to study systematically the staining he found on the teeth of most of those of his patients who were long-term residents and either had been born there, or had come to the city as infants. His investigations even led him to form the hypothesis that the defect was due to something in the water supply; something which was active during the formation of the teeth.

Six years later he had studied enough cases and interested enough of his colleagues in the problem to invite Dr G. V. Black, then Dean of Northwestern University Dental School in Chicago, to join him in a local study. Black, at the time the most famous dental educator in America, by his visit to Colorado Springs drew national attention to the brown staining of enamel, and cases were reported soon thereafter from many parts of the country. The name 'Colorado Brown Stain' eventually gave way to that of mottled enamel, and later, when the aetiology had been established, it became known as dental fluorosis. The process soon became associated with communal water supplies, usually (though not always) from deep artesian wells; but repeated chemical analyses, covering all known elements found in drinking water, failed to disclose anything common to all of the waters associated with mottled enamel, and, *a priori*, McKay's hypothesis seemed absurd. Nevertheless, he continued with his investigations and identified various degrees of mottling, from the mild mottling involving only a few chalky white spots on the surface of the enamel, to moderate mottling where large areas of white are mixed with brown, and finally to the severe mottling where brown predominates and hypoplasia of the teeth becomes evident.

As time went on, mottled enamel became documented in ever-widening geographical areas, with apparent confirmation of the deep-well hypothesis in several localities, and in 1925 the citizens of Oakly, Idaho, where mottling was prevalent, undertook to test McKay's hypothesis by changing from an artesian to a shallower supply. In succeeding years, the children brought up on the new water supply developed no mottling, but the children brought up on the old supply were not cured. This was the first known instance of community action to improve dental health by an alteration in the domestic water.

It is interesting to note that in 1925 also, other workers who were studying the chemical elements known to occur in teeth by feeding them in excess to rats, developed staining in the incisors of these animals following ingestion of quantities of fluoride. This finding remained for several years unrelated to the occurrence of mottled enamel in humans.

Studies initiated in 1928 in Bauxite, Arkansas, led to the eventual discovery that mottled enamel was associated with fluoride in water. An exceptionally high incidence of mottling occurred in this town, and action on the problem was more far-reaching than usual because of the presence there of a subsidiary plant of the Aluminum Company of America. Samples of Bauxite water were sent to H. V. Churchill, then chief chemist for the company, who applied new methods of spectrographic analysis, with the result that nearly 14 parts per million of fluoride were found in Bauxite water; a finding which eventually reached McKay in 1931. McKay then arranged for a re-analysis of water supplies in other areas where mottled enamel had been reported, and reports of high fluoride levels were soon assembled. Subsequent rechecking in many parts of the USA developed a striking correlation between mottled enamel and a fluoride content of public water ranging from 2 to 18 parts per million. Almost simultaneously with Churchill's discovery, similar findings were announced by workers in the University of Arizona and by two Frenchmen who had been studying *le darmous*, a dental defect in Moroccan sheep.

After the discovery of fluoride as the causative agent for mottled enamel in 1931, a number of other investigators also noted the direct relationship between mottling and the presence of fluoride in water. It remained for H. Trendley Dean, a dentist in the United States Public Health Service, to make a thorough documentation of the degree of mottled enamel and the degree of dental caries in different concentrations of fluoride in order to permit reliable statistical analysis. Dean's studies took him all

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over the USA, and he developed a classification for fluorosis which became a standard in this particular epidemiological field.

The next step forward involved more accurate studies in areas where fluoride in water supplies was low enough not to cause mottling, but to increase resistance to dental caries. Without going into details, these studies showed surprisingly regular decreases in dental caries as fluoride concentrations increased from 0 up to about 2 parts per million. These data, coupled with Dean's earlier data on endemic fluorosis, showed that at a concentration of 1 part per million most of the benefits in caries reduction at all ages had already been attained through the presence of fluoride, while mottling had not yet appeared. The epidemiology of fluorine was now becoming complete, and the next step lay in an attempt to prevent or, if this were not possible, to reduce the incidence of dental caries. In order to do this, it was necessary to demonstrate (*i*) that fluoride at a concentration of approximately 1 p.p.m. is safe, and (*ii*) that added fluoride would, in fact, produce the dental benefits associated with natural fluoride in the endemic fluoride areas. Only then could it be said with assurance that fluoride caused, and was not merely associated with, a low caries incidence.

FLUORIDE METABOLISM

In considering the first point to be demonstrated—that is, the safety of 1 p.p.m. of fluoride—one has to look at the pharmacology and metabolism of fluorine itself. As a chemical element, fluorine is a member of the halogen family which also includes bromine, chlorine and iodine. It is one of the most ubiquitous of all elements. It is doubtful whether elemental fluorine, which is a noxious gas, occurs in a free form in nature, because of its intense affinity for other elements. Combined fluorine is relatively abundant and commonly occurs as fluorspar and fluorite (CaF_2), cryolite (Na_3AlF_6) and fluorapatite —a complex compound of calcium, phosphorus and fluorine. According to Young and Striffler,[1] it has been estimated that the earth's crust contains, on an average, about 800 G/ton (or about 880 p.p.m.) of the fluoride ion, and the fluoride content of soil increases with depth. It is present in nearly all fresh water, although the concentration in some surface waters is very low—less than 0·1 p.p.m. Deep-well artesian water may carry as much as 30 p.p.m. Sea water generally contains 1·0 - 1·4 p.p.m. Hence, it is not easy to understand how any form of life, in the sea or on land, could have evolved or have survived unless it was fully able to cope with a continuous intake of fluorides from its environment. Species for species, the fluoride content of plants remains remarkably constant, whether they are grown in soil rich or poor in fluoride. There is no consistent difference in the fluoride content of the soft tissues of salt-water or freshwater fish. Very little fluoride appears in cows' milk, irrespective of large or small concentrations of fluoride in their drinking water. Negligible amounts are stored in human soft tissues, and these amounts do not change with rising concentrations of fluoride in the individual's domestic water. It seems clear, therefore, that no serious imbalance does or can exist between biological processes and ordinary amounts of fluoride acquired from the environment.

In human beings fluoride produces a wide spectrum of physiological activity, both normal and abnormal, and it can be considered a nutrient, a drug, or a poison, entirely on the basis of the dosage used. This is equally true of many familiar elements; small quantities of iodine prevent goitre, and to this extent are an essential nutrient. Tincture of iodine applied to a wound serves the purpose of a drug. Iodine if swallowed in large quantities constitutes a poison. Even table salt and water can be fatal in gross overdosage. In short, the best definition for a poison is: 'too much'.

The average daily normal diet, exclusive of drinking water, contains from 0·2 to 0·3 mg. of fluoride in one form or another, and the effects of increased intakes can be listed as follows:

1 - 2 mg. daily for many years reduces dental caries.

3 - 15 mg. daily for many years leads to dental fluorosis of varying severity and frequency.

20 - 80 mg. daily for 8 or more years leads to severe dental fluorosis, crippling skeletal fluorosis and gastric disturbances.

250 - 1,000 mg. produces toxic effects.

5,000 - 10,000 mg. results in probable death.

It has been established that acute toxicity in man probably begins at about the level of 250 mg. of sodium fluoride in one retained dose. Nausea and vomiting are the first signs of poisoning to be expected. A lethal dose would be anything from 5 to 10 G, and with such a concentration acute gastro-intestinal irritation would develop almost immediately. Nausea, vomiting, diarrhoea and a state of shock would soon follow. Death could be expected within 2 - 4 hours, but if the victim survived for more than 4 hours, recovery would be probable. Since 5 G of sodium fluoride would produce only half that weight of fluoride ion, it is evident that drinking water containing 1 p.p.m. fluoride, consumed at the rate of approximately one litre per day, carries with it a safety factor of about 2,500 in respect to death. If he could, an average adult would have to drink about 600 gallons of such water within 2 - 4 hours to ingest a lethal dose, and an average child about 260 gallons. The danger of chronic poisoning might ensue only after the consumption of anything from 5 to 20 gallons of fluoridated water every day for more than 3,000 consecutive days.

Studies on fluoride physiology indicate that human blood does not accumulate fluoride. Certain quantities are stored in bones and teeth, increasing with age, and any excess is eliminated by urinary excretion. Chronic fluoride intoxication from large doses appears to involve such pathological conditions as osteosclerosis, gastric disturbance, cardialgia, nausea, vomiting, dyspnoea, pain and stiffness in joints and, eventually, joint deformities. Roholm, in his book *Fluorine Intoxication*,[2] describes a series of such cases found among cryolite miners in Denmark. This group is estimated to have received a dosage of about 70 mg. a day of fluoride in cryolite dust. The amounts of fluoride inhaled by these workers far exceeded those available from potable waters.

Sporadic reports have appeared in the literature of isolated cases in which symptoms of systemic disability were attributed to the ingestion of fluoridated water of a concentration in the region of 1 p.p.m. Typical complaints included 'gnawing sensations in the stomach after eating', 'stiffness and pain in the spine', 'severe muscular pains in arms and legs', 'brittle fingernails' and the like. It was claimed that some of the symptoms were promptly relieved by a change to water containing no fluoride. Evidence of direct causation is lacking in these cases, and they are not matched by controls. If cases of this sort are to be taken seriously, causation by, and not mere association with, fluoridated water must be shown, as well as systemic damage comparable to that arising from dental disease.

A large mass of evidence concerning the effects of high and low fluoride intake has been accumulated over the years—studies on individuals, on communities, and direct experimentation with large animals such as sheep, dairy cattle and pigs, as well as with numerous laboratory animals. Three examples might be cited:

1. It was found that massive ingestion of fluorides might be followed by a reduced breaking strength in the long bones of dairy cattle and swine. If increased bone fragility were a hazard in human beings using a fluoride water, it could be assumed that long-term residents of areas with high levels of fluoride in the water should have more fractures than persons using a low-fluoride water, but in fact specific investigations into this possibility have shown no relation between fracture experience and even lifetime use of waters containing from zero to as much as 6·0 p.p.m. of fluoride.

2. Diseased or disabled persons have been imagined to react unfavourably to low concentrations of fluoride, especially with regard to those suffering from renal insufficiency, as the elimination of excess fluoride from the system depends on good kidney function. A special study of 50 patients who showed evidence of damaged kidney function and have also used drinking water containing 1 p.p.m. of fluoride, showed that they had an excretion pattern of fluoride similar to that of healthy young persons.

3. A third study demonstrated that fluorine in urine was 'strikingly proportional' to the amount of fluoride in domestic water supplies, ranging from 0·5 to 5·1 p.p.m., and within this range the metabolism of fluoride appears to be a normal function of the human body characterized by a condition approaching metabolic equilibrium—in other words, the elimination of absorbed fluoride via the urine and perspiration is practically complete when the quantities absorbed do not exceed 5 mg. daily.

Examination of sufficiently large population samples for accurate study of the systemic effects of low concentrations of fluoride in drinking water presents a difficult problem. Even those signs which are associated most closely with gross excess of fluoride may also arise from other causes, and samples must be large enough in both test and control areas to allow for normal variability. Medical examination of children was included from the start in those areas in the USA and Canada in which fluoride trials had been instituted since 1945, and over periods of 10 - 20 years no significant differences were found between children in the study cities and in the control cities. To indicate the detail with which such studies were conducted, they included measurements of height and weight, onset of menstruation, bone density as determined by radiograms of hands and knees, skeletal maturation, haemoglobin levels and erythrocyte counts, leucocyte counts, urine-analysis, ophthalmological and otological examinations, tonsillectomy rates, studies of stillbirths and maternal and infant mortality rates, and death rates from cancer and cardiovascular-renal disease. To cite another example, various studies of mortality from specific causes have been made in communities with fluoride levels in water of approximately 1 p.p.m., and in similar communities with negligible fluoride. Death rates from the five leading causes of death were reported: heart disease, cancer, intracranial lesions, nephritis and cirrhosis of the liver. No statistically significant differences were found between the mortality rate of the fluoride and the non-fluoride cities, either for these 5 specific causes or for all causes combined.

Under normal conditions, when a small amount—5 mg. or less—of a soluble fluoride is ingested by the human adult, it is rapidly removed from circulating body fluids. A portion appears promptly in urine; some 25% is eliminated by this route within 3 - 5 hours. Balance studies have indicated that nearly all is eliminated via urine, faeces and perspiration when the quantities ingested do not exceed 5 mg./day. Where the domestic water is free of fluoride, the fluoride present in urine averages about 0·4 p.p.m., and this has been obtained from foodstuffs. With a fluoride-containing domestic water, the level of fluoride in urine rises in proportion, as outlined earlier. The excretory mechanism in the kidney is strikingly selective for fluoride, which does not enter the 'halogen pool' —that is, its elimination is not modified by the numbers, or proportions, of chlorine and bromine ions present. In fact, though fluorine is a halogen, its metabolism and physical effects in no way parallel those of other members of this group.

This prompt and efficient excretory mechanism, however, is insufficient in itself to explain the rapid disappearance of the fluoride ion from circulating body fluids after ingestion. The rhythm of excretion suggests that the larger portion of ingested fluoride is very quickly placed in inert storage in some body site where it can be immobilized and retained until disposed of by the routine processes of elimination. While this may be a somewhat oversimplified explanation of what actually happens, there is no doubt that the storage site is the inorganic portion of skeletal bone.

The hydroxy-apatite crystals of bone and teeth have a strong physical and chemical affinity for fluoride. The fluoride content of fossil bone increases with time, and more rapidly in soils or ground waters with the higher concentrations of fluoride. Fluoride in living human bone builds up slowly as the individual ages, even though his water is fluoride-free, because of absorption from food. A stabilized dynamic equilibrium is developed between the amounts of fluoride ingested from all sources and the amount stored in bone; little is retained by an adult living in a temperate zone who uses a water containing about 1 p.p.m. of the fluoride ion. There is more storage in the skeleton as water levels are increased, and an increased bone density to X-ray can sometimes be demonstrated with waters carrying 4 or 5 p.p.m. or more. At these levels the increase in bone fluoride content can be demonstrated only by radiological studies or chemical analysis, for there is no interference with normal function, or alteration in the physiology of the tissue. From this point of view bone may be considered as a convenient bin in which an excess of ingested fluoride can be stored to await orderly elimination.

The relation of fluoride to the chemistry and physiological properties of bone is more complex, however, than simple storage. If formed during a period when the individual receives adequate fluoride, the size of the hydroxy-apatite crystal is increased; a change which is said to add to the stability of bone. There are indications that osteoporosis may be less frequent in elderly persons who have used a fluoride water, than in those whose water has been fluoride-deficient.

Nevertheless, the principal protective mechanism is provided by the parallel processes of rapid elimination by urine plus inert storage in the non-living portion of bone, and this mechanism appears to be remarkably effective against either the sudden, accidental high-level dose or the prolonged intake of lesser, but still excessive, amounts.

Fluorides are not stored in soft tissues and do not accumulate there. The trace amounts found on analysis are due in large part to levels in circulating body fluids. The amount of fluoride in blood plasma remains about the same in persons using waters with fluorides in the range of 0·15 - 2·5 p.p.m., with individual values ranging from 0·14 to 0·19 p.p.m. Relatively new and delicate techniques, based upon measurements of the radioactive isotope of fluorine, ^{18}F, have indicated that the apparent accumulation of fluoride in the placenta is due to absorption by the small islands of calcification which often develop late in term. Evidence is equivocal as to whether the very slight elevation of fluoride in umbilical circulation following fluoride ingestion by the mother is great enough to have any effect on the foetus.

Other possibilities, predicted upon the known enzyme-inhibiting properties *in vitro* of fluorides in high concentrations, have failed to materialize in human populations using water with a level of about 1 p.p.m. of the ion. Carpal growth is not inhibited, nor growth in height or weight. Renal function is not altered. The incidence of goitre is not affected, and there is no interference with the usefulness of iodine in controlling goitre. There is, in short, no indication of acute or chronic damage to any of the systems of the human body as the result of usage of water fluoridated to recommended levels.

THE USE OF FLUORIDES

All the available scientific and experimental evidence indicates that our first requirement, a demonstration that fluoride at a concentration of approximately 1 p.p.m. is safe, has been satisfactorily met. The second requirement, a demonstration that added fluoride would produce the dental benefits associated with natural fluoride in endemic fluoride areas, has also satisfactorily been met. The evidence for this stems from the results obtained from numerous city-wide field trials in the USA, Canada and elsewhere, and all this is in itself evidence of the successful application of epidemiological methods in controlling a mass disease—dental caries. In general, a reduction in the incidence of caries of up to 65% has been obtained in the various areas where the public water supplies have been artificially fluoridated.

Other Methods of Fluoridation

Because of the problems sometimes involved in the fluoridation of public water supplies, other vehicles for systemic ingestion have been proposed and sometimes used. These problems may be of a physical nature (such as the nature and accessibility of the supplies of small communities, and the costs of fluoridation plant and machinery), or they may be of—for want of a better term—what might be called a political, moral or ethical nature, of which more will be said below. The actual costs of fluoridation of public water supplies have been found to range from 7 to 14 cents/person/year in the USA, and in Britain to be about 6 pence/person/year. The estimated cost in South Africa is 10 cents/person/year. But, by whatever estimate, the lifetime cost of fluoridation per person ordinarily is less than the dentist's fee for the restoration of one carious tooth.

Much thought has certainly been given to methods for making the benefits of fluoride available to people who cannot use a community water supply, and some of the basic difficulties involved in the use of vehicles other than the common water supply have been well explored. Though fluoride intake from a normal diet is uniform enough to be considered as a constant factor, most community water supplies contain some fluoride, and the actual amount tends to fluctuate from season to season. Hence, fluoride intake from any other source must be kept in constant adjustment to the fluoride supplied in the domestic water. Intakes from such sources as milk or table salt are difficult to control, because individual consumption of these items varies much more widely than individual requirements for water. Nevertheless, these vehicles offer some promise in areas where there are a few or no public water supplies, where the water actually used is consistently virtually free of fluorides, and where distribution and utilization of the vehicle is under effective control. One possible vehicle is table salt. In 1960 fluoridated table salt was made available in about half of the cantons of Switzerland. A study of 550 families in Wäldenswil indicated that the average adult used from 3 to 9 G of salt per day, with some individuals taking as much as 16 G. Salt was fluoridated by the addition of 200 mg. of sodium fluoride to each kilogram. The data suggest that the intake of salt by small children was much less than that of adults. It was concluded that caries was inhibited, but to a lesser degree than would have resulted from use of a fluoridated water at the same ages, in a group of 662 children who began use of the salt at the age of 4 or 5 years. Their daily fluoride intake from the salt was estimated at 0·33 - 0·61 mg. Caries inhibition has been reported in very small groups of children who used fluoridated milk, and bottled fluoridated water has been sold in some areas of the USA.

American children who had used a tablet containing 2·21 mg. of sodium fluoride (yielding 1 mg. of the fluoride ion) for one year or more were found to have about the same dental caries experience as children using fluoridated water. When taken daily, these tablets supplied about twice as much fluoride as the fluoridated salt used in Switzerland. The conclusions arrived at in one study indicated that while fluoride taken daily in tablet form has a beneficial effect on the teeth, it is doubtful whether any large-scale or community-wide programme of caries control would be successful if tablets were used. Although the persons involved were, on the whole, a highly educated group, only about half of them actually continued to give their children tablets for the necessary number of years.

All alternatives are more costly in terms of money and effort than the fluoridation of a community water supply, and some are decidedly less effective. But such measures are worth careful consideration when a fluoridated community supply cannot be had.

The topical application of fluoride solutions to the crowns of newly-erupted teeth has been found to reduce caries by up to 40%. This method was actually the first experimental approach made in the public health use of fluoride, and antedates the fluoridation of community waters by several years. There are 3 serious drawbacks to a widespread programme of topical application: it is not as effective as water fluoridation; it is much more costly; and it requires the services of trained personnel who may be in short supply. On the other hand, encouraging results have been found in some of the Scandinavian countries where children are required to rinse their mouths every second week, under supervision by their teacher, with 15 ml. of a fluoride solution of a concentration low enough (0·2%) to be non-toxic if part or all of it were accidentally swallowed.

A form of topical application is also possible through the use of toothpaste containing stannous fluoride. Clinical tests have shown the effects to vary considerably, although with one exception all were positive, the improvement varying from 10 to 35%.

Fluoridation and the Public

As well stated by Dunning,[3] it is hard indeed to call to mind an issue which has thrown a somewhat retiring professional group into the public arena more suddenly than has the fluoridation issue the members of the dental profession. For decades dental practitioners had little to offer in the way of mass preventive measures requiring community action. Then, within a relatively short space of time, a powerful preventive procedure was devised which is effective and inexpensive, and is endorsed by all the dental medical and public health groups to which it is of concern. It is the irony of fate that this method cannot be applied to volunteers with more than a fraction of its total effectiveness, but must be applied through a major public utility, the communal water supply. A clear-cut governmental decision has been necessary on every fluoridation programme, whether it has been made by elected or appointed officials, or by referendum to the whole voting population. It is not compulsory to drink from a communal water supply, but it is sufficiently difficult to avoid doing so that a cry of 'compulsion' is often raised.

The dental practitioner, suddenly thrown into a community fluoridation controversy, realizes that he is dealing not merely with a professional matter where scientific evidence can be weighed objectively, but with a public political problem of very high voltage. He has been expecting to have to educate people on the benefits of fluoridation and also upon its systemic safety. For this task he is fairly well prepared, thanks to clear-cut reports in dental and other journals, but for political manoeuvring he is not so ready. He is distinctly not prepared for the proportion of the population which is ignorant of the dosage concept and insistent upon saying: 'once a poison always a poison,' and 'who wants rat-poison in our water?' Nor is he prepared for those who would raise the flag of individual and minority rights, and insist that their personal freedom is being violated by water fluoridation. In addition, he is surprised to note that the antifluoridation cause draws to it not only the fanatics, the paranoid fringe and the health faddists, but also a large number of older, conservative people who simply do not want to adopt a personal health measure on the basis of an incomplete knowledge of the scientific facts.

The vehemence of the antifluoridation reaction has been such as to attract the attention not only of dentists, doctors and other health workers, but of the social scientists. Social-science studies have already been done and several more are under way in a number of areas, particularly again in the USA. The first efforts of the social scientists on the matter of fluoridation have usually involved studies of communities in which heated contests have occurred, with emphasis upon the opinions of the vocal antifluoridationists. Of greatest interest to them have been such communities as Northampton and Williamstown in Massachusetts, where controversy reached its height after the adoption of fluoridation and the measure was later abandoned. In the former community, social scientists became struck by the pervasive attitude of suspicion among those who opposed fluoridation. There was suspicion not only of scientific organizations, but of the scientists themselves. Some antifluoridationists found it perfectly reasonable to suppose that scientists would lend themselves to a conspiracy with enemies of the USA (the Communist 'brain-washing plot' theme), and at the same time would permit themselves to be used by a giant monopoly (the Aluminum Company of America, which was supposed to be profiting from the sale of fluorides). This attitude of suspicion was so clear-cut, so prevalent and so polarized, that it became known as 'the anti-scientific attitude'. Other workers in this field did not feel that real antagonism existed, but that the vocal antifluoridationists (who are probably not as large a proportion of the whole group as one might imagine) differed in their definition of science. They included in the ranks of scientists such fringe groups as astrologers and chiropractors, and were unable to distinguish between these and the major professional groups responsible for the main mass of evidence in the field of fluoridation.

The antifluoridationists' arguments are generally understandable and easy to follow. The weaknesses of the arguments are often difficult for a layman to grasp, while the arguments themselves are grounded in some of the most widely held ideas and emotions of our culture: respect for individual rights, fear of poison, and so on. Some feel that the proponents of fluoridation have too often ignored psychology in presenting their case. They relied too heavily on the *fiat* of organized science, and tended to dismiss opponents as 'crackpots'. As lessons for the future, they point to the necessity of avoiding the errors of relying on prestige, of namecalling, and of failing to reach people before issues become polarized.

One of the problems in the mind of a voter (where voting is possible), trying to make up his mind on the question of fluoridation is, 'Whom shall I believe?' and 'Whom shall I trust?' In spite of the almost universal endorsement of fluoridation by recognized scientific groups, the antifluoridationists can almost always muster a small number of scientists to their cause, and these individuals invariably use all their degrees and institutional connections in an endeavour to impress the layman. The layman himself, without scientific background, is at a loss to know which set of scientists to believe. Since he is not in a position to distinguish between a genius and a fanatic in a field beyond his own competence, he has little choice but to rely upon the decisions of the major professional organizations, studying the way those decisions are worded, and doing his best to appreciate the evidence offered in support.

Another type of social science study on the fluoridation question involves statistical appraisal of the communities which adopt and the communities which reject fluoridation. This was done in 53 Massachusetts communities, 27 of which decided in favour of fluoridation and 26 against. The analyses showed that the communities accepting fluoridation tended to be smaller, wealthier, more educated, growing more, and to have a higher proportion of children under 15 years and a lower proportion of people aged 65 years or more, than did communities rejecting fluoridation. These factors were found to be interrelated to a considerable degree. The strongest connections were between the percentage of population change from 1945 to 1955 and two other measures, educational level and percentage of population under age 15 years.

These investigations included interviews with civic leaders and dentists in order to appraise their roles in fluoridation controversies. In general it was found that civic leaders, political and otherwise, tended to avoid an open stand even when personally convinced of the merits of fluoridation. They hesitated to split their following over a controversial issue relating to a problem (dental caries) which neither they nor their adherents considered to be of grave importance. Not without reason, they preferred to save their influence for issues apparently more vital to the community or to their own continuation in elective or appointive office. The dentists, too, were found to be hesitant to go on record on an issue which might antagonize actual or prospective patients, and, moreover, they were generally unprepared by training or experience to manoeuvre adeptly in the political storm in which they often found themselves. Nevertheless, failure on the part of the dentists of the community to take a firm stand on the fluoridation issue seemed often to be one of the major causes of its defeat.

The Massachusetts study also brought to light some of the ways of reasoning of the vocal antifluoridationists. Their arguments were found to centre upon three main issues: the uncertainty of benefits, the possibility of injurious consequences, and the violation of individual rights. The first was found to be the least effective (and to weaken gradually as additional results of fluoridation field trials became public knowledge). The second argument (poisoning) was found to be more forceful and to be universally used. Yet among many of the people intensively interviewed, only a few were found who said that they would bother to order fluoride-free bottled water if fluoridation were adopted.

The third issue, that of personal freedom, was found to be held most vehemently by leading antifluoridationists. This argument is important—not because it is demonstrable, but because it rests upon an important ethic or value assumption, and is impervious to proof or disproof. In an era (to quote Dunning again) where individuals are unable to protect themselves from or to alter such acts of government as nuclear testing, with its long-range fall-out problem, the impulse arises to resist any encroachment upon the prerogative of the individual citizen where resistance is possible. It is almost as though the allegation of physical poisoning derives some of its strength from the fact that is symbolizes a kind of moral poisoning, generated by the increasing complexity of technology, specialization and bureaucracy in the modern age.

SUMMARY

This paper sets out the historical background which led to the discovery of the relationship between the occurrence of mottled enamel in teeth (dental fluorosis) and the presence of relatively high concentrations of fluorine compounds in drinking water, and eventually to the use of artificially fluoridated water in the epidemiological control of dental caries. The pharmacology and metabolism of fluorides is reviewed, and also the relative effectiveness of methods other than the fluoridation of public water supplies in controlling caries. In the final section an analysis is made of the sociological basis of the so-called fluoridation controversy.

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