HOW SCIENCE CAN ILLUMINATE ETHICAL DEBATES A CASE STUDY ON WATER FLUORIDATION

Mark Diesendorf
Canberra, Australia

SUMMARY: Some of the fundamental questions about the fluoridation of public water supplies are ethical in nature: *e.g.* Is medication with an uncontrolled dose wrong? Is mass medication, which is either compulsory or expensive to avoid, wrong? Is fluoridation right if its risks are less than its benefits?

Some leading proponents of fluoridation attempt to evade such ethical issues by quasi-scientific argument. For instance, they claim that fluoridation is not medication, but merely an 'adjustment' of the natural fluoride concentrations in drinking water to the 'optimal' level for reducing tooth decay. Or they allege that fluoride is an essential nutrient, rather than a medication.

But, ethical questions cannot be so easily transformed into scientific and technical ones to be answered glibly by dentists and medical practitioners. This paper assists the elucidation of several ethical questions about fluoridation by first clarifying several related questions of science, technology and logic. This clarification leads to the conclusions that fluoride, *at the levels recommended by pro-fluoridationists for reducing tooth decay*, is not an essential nutrient; is not a natural substance for babies or for most adults; is not a compulsory medication, but is an expensive-to-avoid medication with an uncontrolled dose; and is harmful to some people. There is scientific evidence that the benefits of fluoridation have been greatly overestimated, but the actual magnitude of benefits is still unclear. It is now clear that any benefit comes from the action of fluoride on the surface of teeth, but there is negligible benefit from swallowing fluoride. It is not possible to weigh risks against benefits in a value-free manner.

These scientific, technical and logical conclusions prepare the way for ethicists and others to examine the fluoridation issue, unencumbered by the usual 'scientific' myths. The original ethical concerns about fluoridation are found to be well-posed questions, an ethical question used by proponents to justify fluoridation is found to be improperly posed, and a new ethical question arises from the analysis.

Key words: Fluoridation; Ethics; Value judgements.

Introduction: the role of ethics

It is well known in the philosophy, sociology and politics of science that value judgements are inherent when science is applied to the real world.[1] For instance, value judgements are made in the choice of hypotheses to be tested, in the kinds of data to be collected, in the definition and rejection of 'outlying' data, in the choice of method of analysis, and in assumptions about unknown variables. Furthermore, in presenting the results of these selection processes to peers, decision-makers and the public, scientists and others make further value judgements by choosing definitions and terminology, the context in which results are exhibited, and where the onus of proof lies. Some examples of value-laden concepts in fluoride science, which assist the promotion of the fluoridation of water public supplies (hereafter 'fluoridation'), are listed in Table 1.[2]

The existence of value judgements in scientific research suggests that social and political decisions about applications should not be left to technical 'experts' alone.

Human Ecology Program, Department of Geography, School of Resource and Environmental Management, Australian National University, Canberra ACT 0200, Australia.

The latter have no special qualifications for dealing with issues which transcend the scientific and technical. Indeed, through their training they may be biased towards technical 'solutions' of social and political problems, itself clearly a problem in issues relating to the desirability of a particular technology. Debates about public issues in the fields of environment, energy and health are generally dominated by technical experts, although many of the principal issues involve a particular type of value judgement, namely ethical ones.

TABLE 1. SOME TYPICAL VALUE JUDGEMENTS WHICH FAVOUR THE PROMOTION OF FLUORIDATION

Type	Examples
Selection of data	The notion that evidence of ill-effects from fluoride in naturally fluoridated areas is irrelevant to artificial fluoridation. Alternatively, in naturally fluoridated regions where skeletal fluorosis is endemic, reporting only the maximum value of fluoride concentration of drinking water, while omitting to report the actual fluoride concentrations of water supplies used by particular patients.
Selection of scientific method	Failure to control or randomise trials purporting to show large benefits from fluoridated water.
Selection of assumptions	Assuming that fluoride concentration rather than daily dose is the important variable.
Selection of terminology	Use of terms 'controlled fluoridation', 'deficiency of fluoride' (to describe drinking water with natural fluoride concentrations less than those recommended by pro-fluoridation dentists), 'essential nutrient' (to describe fluoride), and 'noticeable mottling' of teeth. The definition of the 'optimal' concentration of fluoride in drinking water.
Selection of context	Use of the statement "Fluoride is a natural substance" to suggest that fluoridation must be harmless.
Selection of onus of proof	Making the above selections and then placing the onus on opponents to demonstrate risks.

Source: reference 2

Ethical questions are about what is right and what is wrong. For instance, in debates about the fluoridation of water supplies, some opponents base their case on the ethical position that it is wrong to impose a mass medication with an uncontrolled dose. On the other hand, some proponents argue for fluoridation on the ethical grounds it is allegedly of particular benefit to low-income earners, who may have poor diets and who are less likely to encourage their children to clean their teeth regularly. Examples of fundamental questions concerning fluoridation which are primarily ethical in nature are exhibited in Table 2, where 'EQ' denotes 'ethical question'.

Those with expertise in ethics rarely examine the fluoridation issue. This could be because many of the proponents of fluoridation deny the existence of ethical grounds for objection to fluoridation. For instance, they argue that fluoridation is not medication, because it is preventive,[3] or because fluoride is natural[3] and 'an essential nutrient'.[4,5] In this way they try to argue that all the issues are technical.

They, of course, claim to be the experts on technical issues. Thus, one is given the impression that the only valid ethical issue is EQ4, which proponents answer with a resounding 'no' and then use to justify fluoridation.

TABLE 2. ETHICAL QUESTIONS RELATING TO FLUORIDATION

EQ1	Is mass medication, which is compulsory or expensive to avoid, wrong?
EQ2	Is medication with an uncontrolled dose wrong?
EQ3	Is it right to promote fluoridation on the basis that its risks are less than its benefits?
EQ4	Is it right to deprive people, especially low-income earners, of a valuable nutrient or preventive medication?

But, the analysis offered below shows that the ethical issues EQ1 to EQ3 cannot be manipulated out of existence. The quasi-scientific and technical arguments against the validity of these ethical issues[3-5] are wrong. Moreover, it is shown here that EQ4 is not as clearcut as proponents of fluoridation would like - indeed it turns out to be improperly posed.

Thus, even though scientists and health professionals have no special qualifications for answering the ethical questions, they do have a role to play in the ethics of fluoridation. They can demystify and elucidate the ethical issues by attempting to answer related scientific, logical and technical questions. Examples of scientific questions, which are useful for clarifying the ethical questions EQ1 to EQ4, are questions SQ1 to SQ11 given in Table 3, where 'SQ' denotes 'scientific question' in a broad sense.

TABLE 3. SCIENTIFIC QUESTIONS WHICH ELUCIDATE THE ETHICAL QUESTIONS OF TABLE 2

	Scientific questions	Related ethical questions
SQ1	Is the daily dose of fluoride, obtained from fluoridated drinking water, controlled?	EQ1, EQ2
SQ2	Is fluoride ingestion, in doses of several mg per day, natural?	EQ1, EQ2
SQ3	Is fluoride, in doses of several mg per day, an essential nutrient?	EQ1, EQ4
SQ4	Is fluoridation mass medication? Is it compulsory medication?	EQ1, EQ2
SQ5	What are the benefits of fluoridation?	EQ3, EQ4
SQ6	What are the risks of fluoridation?	EQ3, EQ4
SQ7	How can risks and benefits be compared?	EQ3, EQ4
SQ8	Can the same amount of benefit be also obtained by other means?	EQ3, EQ4
SQ9	In fluoridated areas, do low-income earners have the same average levels of tooth decay as middle- and high-income earners?	EQ4
SQ10	Are low-income earners at greater risk from the health hazards of fluoridation than middle- and high-income earners?	EQ4
SQ11	Are any of the alternative means of reducing tooth decay especially useful to low-income earners?	EQ4

Each of these eleven scientific questions is now examined in turn, and its relationship to the ethical questions is indicated. Then, in this light, the ethical questions EQ1 to EQ4 are re-examined at the end of the paper.

SQ1. Is the daily dose of fluoride controlled?

Proponents of fluoridation often refer to it as 'controlled fluoridation'. This involves artificially raising the natural fluoride concentration in drinking water to 1 part per million (ppm) of fluoride in places with a temperate climate. This is the same as 1 mg fluoride per litre of water. In the vast majority of water supplies around the world the natural concentration of fluoride is less than 0.2 ppm, so fluoridation generally entails an average increase in fluoride intake by the exposed population of 5 times or more.

In cold climates a slightly higher concentration than 1 ppm is recommended by proponents and in hot climates a slightly lower level. In practice, it is impossible to keep the concentration of fluoride constant throughout the water supply of a town. In practice, some people actually receive up to about 20 percent higher concentration than the recommended one, while others receive down to about 20 percent lower.

But, this variation in *concentration* (measured in ppm or mg per litre) is minor compared with the variation in *dose* (measured in mg per day). The daily dose is the amount of fluoride a person actually ingests in a day. This depends on the amount of tapwater a person drinks, and tapwater is usually the major constituent of any beverage made with water, including tea, coffee, soft drinks, beer and reconstituted fruit juice. In addition, it is necessary to take into account the fluoride intake from food processed with fluoridated drinking water. Fluoride also occurs naturally in some foods, notably tea leaves and the bones of fish (which are ingested by those who eat canned fish).

Originally, proponents of fluoridation made the assumption that adults in fluoridated areas would all ingest about 1 mg fluoride per day, and that children would ingest proportionately less.[6] But, in practice, there is a wide variation in water intake and hence in fluoride intake. For example, in the USA, 5% of adults aged 20-64 years ingest less than 1.133 litres per day of 'total water' (= tapwater + intrinsic water), while 5% ingest 3.8 litres or more per day.[7]

In a fluoridated area, groups with high fluoride consumption include:

- infants fed on milk formula reconstituted with fluoridated water;
- young children who drink mostly tapwater based beverages;
- outdoor labourers;
- long-distance runners;
- people with diabetes and other diseases which involve high water consumption.

Based on the comprehensive US survey of water intake,[7] it has been estimated that about 1% of the adult population ingests daily 5.5-7.0 mg fluoride, excluding tea and fish, and that heavy tea drinkers may consume an additional 1.0-7.5 mg.[8] These estimates may be compared with earlier ones by the British Royal College of Physicians, which stated that a daily intake of fluoride from fluoridated water (excluding the natural fluoride in tea) of 6 mg is possible, with a 'maximum' total fluoride intake of 12 mg per day in heavy tea drinkers.[9]

When considering the fluoride intakes of infants and comparing them with adult intakes, it is necessary to take into account the large differences in body mass. From

the viewpoint of toxicology, the important parameter is the fluoride intake per kg of body mass. Infants drink much larger volumes of liquid, per kg of body mass, than adults, because most of the food ingested by infants is in liquid form and because infants have a higher metabolic rate. Specifically, during the first 6 months after birth, infants ingest on average about 150 ml of fluid per kg of body mass per day.[10] For those infants fed on powdered formula (assumed to be fluoride-free, which is rare in practice) which is reconstituted with 1 ppm fluoridated tapwater, the daily fluoride dose is 0.15 mg per kg body mass, or 1.2 mg per day for a typical 6-month old infant of mass 8 kg. These doses could be compared with 0.04 mg per kg per day for a typical 70 kg adult with a fluoride dose of 3.0 mg per day. Thus infants fed on powdered formula in a fluoridated area are a high-risk group for fluoride overdose.[11]

There is also the problem that some people excrete less fluoride than average, because their kidneys are malfunctioning. Kidney disease is a prevalent problem in developed countries, partly as a result of analgesic abuse.[12] In people with this condition fluoride builds up more rapidly in the bones over the years and, if they live in fluoridated areas, they become at particular risk for a bone disease known as skeletal fluorosis.[8,13]

So, even when the fluoride *concentration* in drinking water can be controlled, so that it varies between (say) 0.8 and 1.2 ppm over a water supply area which is fluoridated nominally at 1.0 ppm, the total daily *dose* of fluoride, ingested from both natural and artificial sources, could vary over the population exposed by much greater factors. In a fluoridated area the top 1% of adults ingest (excluding tea and fish) several times the average adult intake of fluoride. A typical infant on fluoridated formula ingests about 4 times the dose per kg body weight of a typical adult on fluoridated water and (see SQ2) 100 times the dose of a breastfed infant of the same mass.

Clearly, the fluoride dose is not controlled. This information is relevant to answering ethical questions EQ1 and EQ2 (see below).

SQ2. Is fluoride ingestion, in doses of several mg per day, natural?

The statement that fluoride is a natural substance is used by proponents of fluoridation to argue that fluoride is not a medication[3] - see also discussion of SQ4 - and to imply that fluoride must be harmless (despite the observations of harmful effects from many natural chemicals). In this section it is shown that fluoride at the doses recommended by proponents of fluoridation is neither natural for infants nor for most adults.

There is a natural physiological mechanism which stops fluoride from getting into breastmilk, whatever the fluoride consumption of the mother. As a result, the concentration of fluoride in breastmilk is about 0.01 ppm.[14,15] With a typical milk consumption of 150 ml per kg of body mass, the natural daily dose of fluoride to infants is about 0.0015 mg per kg of body mass (*i.e.* 1.5 microgrammes per kg), or about 12 microgrammes for a typical 6-month-old infant. So, milligramme doses of fluoride are not natural for infants.

For the vast majority of adults, natural fluoride concentrations in drinking water are less than 0.2 ppm, and daily fluoride doses from natural sources to those who drink little tea are generally much less than 1 mg.

This information is relevant to the ethical questions EQ1 and EQ2.

SQ3. Is fluoride, in doses of several mg per day, an essential nutrient?

A daily dose of several mg of fluoride per day is certainly not necessary for life, since most of the world's population lives with much lower intakes. But, is it essential for sound teeth?

Before taking up Western type diets, which are high in sugars, people in the Third World (and Australian Aborigines) generally had very low levels of tooth decay. Most of these peoples also had levels of fluoride in their drinking water typically below one-fifth or one-tenth the level of about 1 ppm recommended by the proponents of fluoridation. Tooth decay was also low in Britain and continental Europe during World War II, when sugar was a scarce commodity,[16] and in the 1950s at the Hopewood orphanage, near Bowral NSW Australia, where the children were fed on wholemeal bread and other "whole" foods.[17] In Britain, continental Europe and Bowral, there was no fluoridation during those times. So, people can have excellent teeth without 1 ppm fluoride in drinking water.

Conversely, it is also true that some people can have highly decayed teeth when their drinking water is fluoridated. For example, some fringe-dwelling Aborigines, whose diet is high in sugars, have highly decayed teeth, even where their drinking water is naturally fluoridated from bores.[18] Moreover, in non-Aborigines living in fluoridated cities, there are high levels of tooth decay in certain groups (see SQ8).

Thus, in the language of logic and of science, fluoridation is neither 'necessary' nor 'sufficient' for sound teeth. It is no more an essential nutrient than a mouthrinse or a dental fissure sealant. Not a single person has ever been shown to have a genuine 'deficiency' of fluoride. Nevertheless, it is almost standard practice for dental textbooks and public health authorities of pro-fluoridation governments to refer incorrectly to fluoride as an 'essential nutrient'[5] and unfluoridated water supplies as 'fluoride-deficient'.[19,20]

Recent studies also provide evidence that fluoride in mg/day doses is not a nutrient at all. A major review of the dental literature of the 1970s suggests that there is no relationship between caries experience of the individual and fluoride content of dental enamel.[21] Furthermore, the difference in fluoride content of surface enamel in low and 'optimal' fluoride areas appears to be too small to produce a significant reduction in the prevalence of tooth decay.[21] In experiments on laboratory rats, a slow-release source of fluoride fixed in the mouth certainly was associated with reduced tooth decay. But, when the mouth was bypassed, with the fluoride source implanted subcutaneously and releasing fluoride directly into the bloodstream, there was no decline in tooth decay.[22]

So, it now appears that the principal, and possibly the only, mechanism of action of fluoride is a 'topical' one (*i.e.* on the surface of teeth and on the oral bacteria which assist in the decay process) rather than systemic. This means that people are ingesting fluoridated water when there is negligible benefit from actually swallowing it. Any reduction in tooth decay would come from fluoridated water passing over the teeth. It would be the same if the water was spat out. The evidence is now recognised by some leading dental researchers, including Brian A. Burt, who are proponents of fluoridation,[23] but is still ignored, evaded or misrepresented by other profluoridation dental researchers.[24]

The answer to this question is intended to clarify ethical questions EQ1 and EQ4. It also raises another ethical question, namely, is it right for medical, dental and

public health professionals to mislead people that fluoride is an essential nutrient, when fluoridated drinking water has negligible systemic benefit, but may at best have a small topical benefit?

SQ4. Is fluoridation mass medication? Is it compulsory medication?

The medical dictionaries define 'medication' to be 'impregnation with a medicine', and a medicine is 'any drug or remedy', including a preventive medicine. Since fluoridation puts a medicine, albeit a preventive one, into drinking water, fluoridation is medication. That preventive medicines are still medicines is not only the consequence of a theoretical definition in a medical dictionaries such as Dorlands.[25] It is also established by the practice of using antibiotics to prevent the infection of wounds or to prevent bacterial complications from a viral infection.

The fact that fluoride is a natural substance does not exclude it from being a medicine, since penicillin, quinine, digitalis, salicylates, radium and many other medicines are also natural substances. The natural concentration of fluoride in most water supplies is less than 0.2 ppm, so fluoridation usually involves a substantial change from natural conditions. It has also been pointed out in a previous section (SQ2) that fluoride, in the doses recommended by profluoridation doctors and dentists, is not a natural substance for babies.

The fact that fluoride, at the levels recommended by proponents of fluoridation, is not an essential nutrient (see answer to SQ3), counters the claim that fluoridation is not a medication because it is simply the removal of a dietary 'deficiency'.

So, fluoridation is a form of (preventive) medication, but is it compulsory as some anti-fluoridationists claim? It is expensive to remove fluoride from drinking water. The cheapest effective 'filters', those based on ion-exchange resins, have an initial cost in Australia in 1994 of about A$200 plus the A$60 cost of a recharge every 6-12 months depending on the size of the household. (Note: A$1=US$0.73 approximately). Reverse osmosis units, domestic distillation plants and rainwater tanks are even more expensive. For this reason, some opponents of fluoridation label fluoridation as 'compulsory medication'. But a more accurate description is that fluoridation is medication which is expensive or difficult to remove. Of course, if free unfluoridated drinking water were provided at convenient locations, this description would no longer be appropriate.

This answer is relevant to ethical questions EQ1 and EQ2.

SQ5. What are the benefits of fluoridation?

In reading this section, the conclusion of Section SQ3 should also be kept in mind: namely that any benefit of fluoridation in reducing tooth decay comes from its topical (*i.e.* surface) effect and that it is now well established that there is negligible value in systemic doses (*i.e.* actually swallowing it).

It used to be claimed that fluoridation reduces tooth decay by 50-70 percent and that the benefits of fluoridation add on to the benefits of other applications of fluoride, such as fluoride toothpaste.[5,26] But many of the classical studies on the benefits of fluoridation were so badly designed that they are worthless for this purpose.[27-32] To the best of my knowledge there is not a single time-dependent study on human populations with randomly selected test and control populations and 'blind' examination of children's permanent teeth.[28] Almost all the existing studies were performed by enthusiastic supporters of fluoridation, who knew which children

they examined came from the fluoridated and which from the unfluoridated areas. In those few studies where examination was 'blind' (*e.g.* Anglesey), the experimenters chose the controls from known high tooth decay areas.[30] This is not to suggest that deliberate fraud was common - rather, it is the well-known experimental problem of unconscious bias influencing experiments with inadequate controls. A common example comprises the comparison of large fluoridated cities with small unfluoridated rural towns, which is an inappropriate comparison because diet is generally worse and tooth decay higher in rural areas.

Tooth decay has been declining substantially over the past 20-30 years in both unfluoridated and fluoridated regions of the developed world.[33-36] In several developed countries, the decline commenced before the use of fluoride in any form became widespread.[31,35,36]

A result of these declines is that now there is little or no difference in average levels of tooth decay between comparable unfluoridated and fluoridated regions of at least four countries: Australia,[32] Canada,[37] New Zealand,[38] and the USA.[39,40]

There has been an interesting debate about the US national results. Using the sample of 40,000 schoolchildren from 84 communities selected by the US National Institute of Dental Research (NIDR), Yiamouyiannis has shown that there is no difference between average levels of tooth decay, measured by the traditional DMFT index (the number of decayed, missing and filled permanent teeth per child), between fluoridated and unfluoridated communities of the USA.[40] Using the same sample, but measuring tooth decay by the DMFS index (the number of decayed, missing and filled permanent tooth surfaces per child), authors from the NIDR itself have found that fluoridated communities have 18 percent less tooth decay than unfluoridated.[41] Since they are using different indices, it is possible that both sides are correct. But, since the original claims of enormous benefits were based on the DMFT index, it can now be said that the benefits of water fluoridation are too small to be detected by this index.[31,32,37-40]

Nowadays, even the pro-fluoridation New York State Department of Health admits that "firm conclusions cannot be drawn regarding the independent effect of fluoride in drinking water and caries prevention".[42] Some other proponents claim that the benefits of fluoridation are around a 20% reduction in tooth decay as measured by DMFS in developed countries. But, in an average 10-year-old Australian, this corresponds to about one-fifth of a cavity, which is negligible.[32]

In developing countries, tooth decay is increasing in prevalence, presumably as a result of a shift towards more western-type foods.[43] In India a recent review of data from a very large population over 30 years suggests that tooth decay *increases* with the (natural) fluoride content of drinking water.[44]

This answer gives scientific input to ethical question EQ3 and EQ4.

SQ6. What are the risks of fluoridation?

This is an area with great differences in expert opinion. In this debate, much hangs upon which published scientific papers are accepted or rejected as offering valid data and results.

This difference is highlighted by different national policies on fluoridation. In most English-speaking countries, a large percentage of the population drinks artificially fluoridated drinking water: Australia (66%), Canada (50%), Ireland (66%),

New Zealand (50%), USA (50%). But, in western continental Europe, fluoridation has been terminated in Sweden, Holland and West Germany, so that now only about two towns in the whole region are still fluoridated. The consumption of fluoridated water is also declining in the former eastern Europe.

Scientists and health professionals who are questioning fluoridation draw attention to a body of evidence, published in reputable medical and scientific journals, that some people suffer from dental fluorosis, skeletal fluorosis, bone fractures and intolerance/hypersensitivity reactions from naturally and/or artifically fluoridated water. All these diseases have been confirmed by several independent studies and so could be regarded as well-established. They have been reviewed in more detail elsewhere.[13,8,45]

Dental fluorosis is a particular type of mottling of teeth which is caused only by the ingestion of fluoride during early childhood, while the teeth are still mineralising, before they erupt into the mouth. It is generally believed that dental fluorosis is the expression of the toxicity of fluoride to the ameloblasts, the enamel-forming cells of the teeth.

In the early days of fluoridation, about 10% of children exposed to water fluoridated at 1 ppm used to exhibit some degree of dental fluorosis, although proponents tended to make the value judgement that it was not 'objectionable'. But, over the past decade, evidence has been published from the USA and New Zealand which suggests that the prevalence and severity of dental fluorosis have been increasing.[46,47] Although these increases have been occurring in both fluoridated and unfluoridated areas, they are generally much greater in the former. This evidence is now accepted by most members of both sides in the fluoridation debate. However, proponents tend to dismiss dental fluorosis by describing it as a 'cosmetic' effect, while others recognise it as physiological damage which shows that fluoride has the potential to be harmful to human health.

Skeletal fluorosis is a disease involving the abnormal increase in density of bone and also sometimes the calcification of ligaments, resulting from the ingestion of fluoride over many years. Early clinical stages resemble arthritis, with patients experiencing pain and stiffness in the joints. In its more severe, later forms, the disease can be crippling. Evidence of skeletal fluorosis, with severe clinical manifestations, has been reported in at least 8 studies from 4 countries where water supplies contain fluoride naturally in the range 0.7-2.5 ppm.[8]

Proponents either ignore these data, or denigrate them by describing them as 'isolated' occurrences, by implying that data from naturally fluoridated areas or 'native' (*sic*) populations is irrelevant to artificial fluoridation, by claiming that other factors must have been operating (there is little evidence for this), and by stating that there is no skeletal fluorosis in the USA in regions where fluoride concentration in drinking water is below 4 ppm, and that 'clinically significant' skeletal fluorosis only occurs above 8 ppm.[5,42] But, the US surveys (*e.g.* [48]), upon which some of these dismissive attitudes are based, have serious flaws.[8]

In most artificially fluoridated areas, older people have consumed only fluoridated water for 15-35 years. So skeletal fluorosis is not expected to become a noticeable public health problem in those areas until people who have ingested fluoridated water since birth reach old age. But, some concerned scientists believe that the disease could be already observable in certain high-risk groups in artificially

fluoridated areas: notably, in people who drink large quantities of water and those who have malfunctioning kidneys and therefore excrete less fluoride than average (see answer to SQ1). Unfortunately, there do not seem to have been any surveys of the prevalence of skeletal fluorosis in such high-risk groups.[8]

Bone fractures: Since about 1990, several epidemiological studies have been published from the USA and Britain, showing that there is an increased rate of bone fractures (notably hip fractures) in older people in fluoridated areas.[49] Proponents of fluoridation have either ignored the evidence or pointed out that the increase is small, but have failed to consider that the prevalence will inevitably become greater with time, until people become exposed from birth to old age. Hip fracture is fatal in about 25% of cases.

Hypersensitivity, allergic reactions and/or chronic poisoning have been reported from fluoridated water, fluoride supplements and fluoride toothpaste.[13] These reactions include skin rashes, stomach pains and effects on the nervous system. They are generally denied by proponents who tend to rely on reassuring statements from the executive committees of such bodies as the American Academy of Allergy. Whether such executive statements are genuine scientific refutations or merely expressions of the politics of medicine is subject to debate.[13]

In addition to the above well-established health hazards, there is some evidence that fluoridated water may be a causal factor in genetic damage, cancer and damage to the immune system (reviewed in [45]), but more evidence is still required before such relationships can be said to be firmly established, in my assessment.

Together with the answer to SQ5, this answer offers a scientific perspective on ethical questions EQ3 and EQ4.

SQ7. How can risks and benefits be compared?

My own interpretation of the scientific evidence, which was given in SQ5 and SQ6, can be summarised as follows: There are risks to some members of the population and, if there are benefits to others, they have been overestimated. Indeed, in some communities there is now no difference in the average levels of tooth decay (as measured by DMFT) between fluoridated and unfluoridated areas.

There is no way of comparing risks and benefits without making value-judgements. For instance, how many cavities saved in a child's teeth are equivalent to a hypersensitivity reaction induced in a young adult or a hip fracture in an old person? How can we compare risks and benefits in the case of people who have lost their natural teeth as the result of factors not connected with tooth decay? These people receive no benefits from fluoridation, yet they suffer the risk of skeletal fluorosis arising from the accumulation of fluoride in their bones over their lifetimes. Therefore, EQ3 (see below) cannot be treated simply as a scientific or technical question.

SQ8. Can the same amount of benefit be also obtained by other means?

The comparisons of tooth decay in unfluoridated and fluoridated cities within Australia, New Zealand and the USA, together with the large declines in tooth decay observed in many unfluoridated cities (see answer to SQ5), show that children can have good teeth without fluoridation. The problem is that nobody knows for certain what are the most important factors causing the reductions in tooth decay in unfluoridated cities, such as Brisbane, Australia, and Christchurch, New Zealand.

For instance, how important is the program of daily toothbrushing with fluoride toothpaste in some of Brisbane's primary schools? This program is not expensive, because it is carried out by schoolteachers rather than dental therapists. How important are changes in diet, and how important is better education of parents and children about oral health?

Despite these uncertainties, there is no doubt that improved diet reduces tooth decay. In particular, reducing sugar consumption and increasing the consumption of cheese and possibly wholemeal bread reduces tooth decay considerably (see Goldsworthy,[17] also[50,51]). It should be noted that, at least in Australia, the consumption of cheese increased substantially from 1959 to 1985, and so this could possibly be an important factor in the decline in tooth decay observed in both unfluoridated and fluoridated areas over approximately the same period.

One suggestion is that cities discontinuing fluoridation could start a daily fluoride toothbrushing program in primary schools. (Some authorities, such as the Swedish Department of Health, recommend that children less than 4 years old should not use fluoridated toothpaste, because they tend to swallow it.) In addition, there is a need for more extensive and intensive programs to reform the food sold in school canteens, by subsidising healthy foods (wholemeal bread, low-salt/low-fat cheese, salads, *etc*) and increasing the cost of sugary foods. None of these programs is expensive.

This answer bears on ethical questions EQ3 and EQ4.

SQ9. In fluoridated areas, do low-income earners have the same average levels of tooth decay as middle- and high-income earners?

In fluoridated areas, it is still the poor who tend to have unhealthy diets and have the worst teeth.[52] This answer seeks to clarify ethical question EQ4.

SQ10. Are low-income earners at greater risk from the health hazards of fluoridation than middle- and high-income earners?

It is well known that the prevalence of almost all diseases tends to be higher in low-income groups. But this author knows of no specific scientific studies on the effect of socio-economic level on the prevalence of dental fluorosis, skeletal fluorosis, fluoride-induced bone fractures or intolerance/hypersensitivity reactions.

This answer seeks to clarify ethical question EQ4.

SQ11. Are any of the alternative means of reducing tooth decay especially useful to the low-income earners?

One alternative proposal for reducing tooth decay - school-based toothbrushing and reform of canteens (see comments on SQ7) – is likely to be effective in reaching the poor in developed countries, because everyone has to go to school and the benefits will transcend dental health. If governments wish to go beyond this in helping low-income earners, they could provide more public housing, higher unemployment allowances and higher pensions to single parents. These measures will assist dental health as well as health in general. It is possible that these measures could do more for the total health of a nation's children than a palliative such as fluoridation. The cost of these measures is likely to be higher than that of fluoridation, but the range of benefits would be much wider as well.

This answer bears on ethical question EQ4.

Discussion

What can citizens and decision-makers believe when scientists disagree?

Not all health professionals will agree with the author's assessment of questions SQ5 and SQ6. Moreover, those who support fluoridation tend to avoid the other questions, SQ1 to SQ4 and SQ7 to SQ11. What can citizens believe when 'the experts' disagree?

Scientists and health professionals, such as doctors and dentists, like to imagine that there is only one scientific answer to a problem. This usually turns out to be the answer given by the most powerful groups of scientists and professionals. But, in reality, conventional wisdom is often proven to be incorrect, eventually. For example:

- The early medical misuses of the radioactive substance radium offer a particularly close parallel with fluoridation.[53]
- The former practice of treating pregnant women with the drug diethylstilbestrol (DES) led to the development of vaginal cancers in their daughters.[54]
- The widespread use of toxic and long-lasting pesticides such as dieldrin (now banned in the USA) have poisoned farmworkers and created pesticide-resistant insect pests.[55]
- Nuclear physicists and nuclear engineers once claimed that nuclear energy would be too cheap to meter. But, nowadays in Britain, nuclear energy is cross-subsidised by the Fossil Fuel Levy of about 1.2 billion pounds sterling per annum and is one of the most expensive of the conventional sources of electricity.[56]

Even when they concede that they can make mistakes, many scientists and health professionals claim that they are somehow completely 'objective' in assessing the evidence available at a particular time. But there is a growing body of evidence from the sociology of scientific knowledge which suggests strongly that scientists and professionals are generally biased in their attitudes and in the work they do. Their sources of funding, socio-economic class, professional status and career paths often affect the choice of a research problem, the formulation of the problem, the selection of data and assumptions, and the presentation of the results. So, it is not surprising that very often the fruits of scientific research turn out more useful for elite groups – such as the military, big business, governments and elite scientists and professionals themselves – rather than for the community at large.[1]

This is why the politics (that is, power relationships) of fluoridation have to be considered too. Who benefits in terms of power and money from the promotion of fluoridation? What are the roles of dental and medical associations, the sugary food and aluminium industries, and governments? An examination of the roles of these political structures has been offered by Varney.[57] The main point is that scientists and professionals have their own biases and their own agendas. Martin has pointed out the inadequacies of traditional sociological and psychological theories of opposition to fluoridation and has drawn on theories of social interests and scientific knowledge to show how protagonists in the fluoridation debate use various 'resources' in a struggle to promote their respective positions.[58] These 'resources' include control over publication, research grants and appointments; claims about authority and the validity of evidence; assumptions and methodologies.[58] The perspectives of 'resources' and political structures allow the roles of both proponents and opponents to be analysed symmetrically.

Therefore, citizens are taking a risk if they limit themselves to the ethical questions. They also have to find out who is funding the technical 'experts', how the promotion of/opposition to fluoridation has affected the professional status of these experts, what assumptions they made in their work, what evidence they discarded or included, and why.

Citizens can be assisted in their investigations of such questions by scientists and professionals who question the dominant view on the issue and who attempt to inform the public and demystify the issue. But, when experts are divided, which group can citizens believe?

There is good reason to be very sceptical about the group which says: "The issues are too complicated for people who lack dental or medical degrees. The safety and effectiveness of fluoridation has been endorsed by the Australian Dental Association, the Australian Medical Association and the National Health and Medical Research Council (or US equivalents). We are the advisors to these bodies. Trust us. We are the experts."[59]

Community groups opposed to nuclear energy and war, and working towards environmental protection, renewable energy and peace, often find that the 'trust us' group generally has something to hide, whether it be ignorance, incompetence, cutting corners, financial gain, or gains in status and power.[60]

This is the context in which this paper encourages people without medical and dental degrees, as well as scientists and health professionals, to take an interest in the ethical (such as EQ1-EQ4), sociopolitical[57-60] and scientific questions (such as SQ1 to SQ9) of the fluoridation debate.

Concluding remarks on the ethical questions

The scientific-logical analysis offered in this paper tries to clarify the ethical issues. In the light of this analysis of the related scientific questions (SQ), the status of the ethical questions (EQ) now becomes:

EQ1. Is mass medication, which is compulsory or difficult to avoid, wrong?

Fluoridation is a form of preventive medication (see SQ4 and SQ2) and is not an essential nutrient for anyone (see SQ3). Although fluoride ingestion is not compulsory (see SQ4), it is certainly difficult or expensive for most people to avoid it in fluoridated areas, unless free potable unfluoridated drinking water is also supplied at convenient locations. Therefore, EQ1 is a well-posed ethical question in its modified form: "Is mass medication, which is difficult or expensive to avoid, wrong?"

EQ2. Is mass medication with an uncontrolled dose wrong?

It is impossible to control the daily dose of fluoride from drinking water (see SQ1). Moreover, since dental fluorosis, skeletal fluorosis, bone fractures and hypersensitivity reactions have all been reported in people when the fluoride concentration in drinking water is around 1 ppm, for some people there is no safety margin (see SQ6). Although a small fraction of the world's population (mostly in India) ingests naturally fluoridated water with fluoride concentrations equal to or greater than 1 ppm, there are programs to defluoridate some of these water supplies. Many doctors would regard the prescription of an uncontrolled dose of a medication as unethical, but when fluoridation is mentioned, they tend to grant it special dispensation. Therefore, EQ2 is a well-posed ethical question which is relevant to the fluoridation issue.

On the ethical side, it could be argued that mass medication with an uncontrolled dose (see SQ1) is worse that the medication of an individual with an uncontrolled dose, because the former is more difficult to discontinue.

EQ3. Is it right to promote fluoridation on the basis that its risks are less than its benefits?

In the section on SQ7 it was argued that EQ3 is not simply a scientific or technical question. Rather, the scientific evidence reviewed in SQ5 and SQ6, together with the discussion in SQ7, suggest that another, related ethical question is more pertinent, namely:

EQ 3a: Is it right for society to impose risks on some people for the possibility of conferring minor benefits or convenience on the same or other people?

But, those who reject or are unaware of the evidence in SQ5 and SQ6, believing that there are negligible risks and enormous benefits, might pose this additional ethical question differently, as:

EQ3b: Is it right to impose questionable risks on a tiny minority in order to confer substantial benefits on the majority?

From consideration of the scientific question SQ3 in this paper, yet another new ethical question EQ5, which is stronger than EQ3 and separate from EQa and b, has arisen, namely:

EQ5. Is it right for medical, dental and public health professionals to mislead people that fluoride is an essential nutrient, when fluoridated drinking water has negligible systemic benefit, but at best a small topical benefit?

These new ethical questions are listed in Table 4.

TABLE 4. ADDITIONAL ETHICAL QUESTIONS ARISING IN THIS PAPER

EQ3a	Is it right for society to impose risks on some people for the possibility of conferring minor benefits or convenience on the same or other people?
EQ3b	Is it right to impose questionable risks on a tiny minority in order to confer substantial benefits on the majority?
EQ5	Is it right for medical, dental and public health professionals to mislead people that fluoride is an essential nutrient, when fluoridated drinking water has negligible systemic benefit, but may at best have a small topical benefit?

Note:

EQ3a and EQ3b are mutually exclusive ethical questions related to EQ3, chosen according to one's scientific perspectives on SQ3, SQ4 and SQ7. In this author's view, EQ3b is inconsistent with the scientific evidence reviewed in this paper and so is poorly posed.

EQ5 is a new ethical question which arises from the discussion of SQ3.

EQ4. Is it right to deprive people, especially low-income earners, of a valuable nutrient or preventive medication?

Fluoride, at the level recommended by proponents of fluoridation, is neither necessary for life nor for sound teeth (see SQ3). No-one has ever been shown to suffer from a 'deficiency' of fluoride. There is also recent evidence suggesting that fluoride in mg per day doses may have zero nutritional value (see SQ3). So, it seems

that the only 'justification' for putting fluoride in drinking water is that the small fraction of children, who do not brush their teeth with fluoride toothpaste or would not use fluoride mouthrinses, might miss out on a possibly small topical benefit from this non-essential substance. But they may also miss out on the chronic toxic effects of swallowing fluoride: dental fluorosis, skeletal fluorosis, bone fractures and hypersensitivity reactions.

So, EQ4 is a poorly posed question which does not conform with the realities of the physiological role of fluoride.

It is important to note that fluoridated drinking water does not solve the tooth decay problems of the poor: even in fluoridated areas, the poor still have the highest levels of tooth decay (see SQ9). On the other hand, it may help a little in reducing their tooth decay, while increasing their risks of other diseases.

Now that the status of the ethical questions has been examined in the light of their associated scientific questions, the ethical judgements are for the reader to make.

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