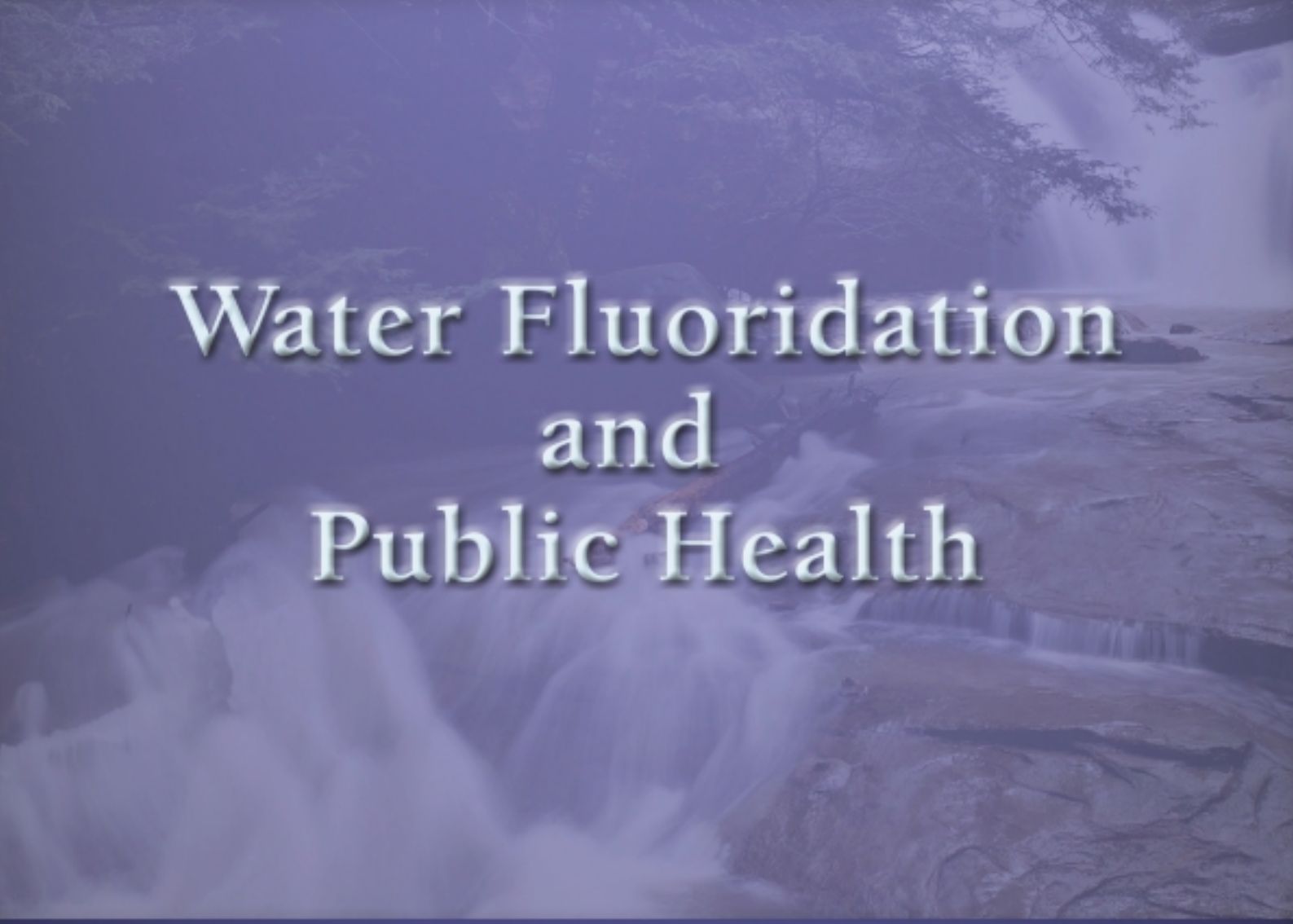
Water Fluoridation and Public Health



Faculty of Public Health Medicine
Royal College of Physicians of Ireland

Dental Health Foundation
Ireland

Water Fluoridation and Public Health

FACULTY OF PUBLIC HEALTH MEDICINE

ROYAL COLLEGE OF PHYSICIANS OF IRELAND

Dr. M. O'Connor
Dr. P. Fitzpatrick
Dr. H. Johnson
Dr. L. Thornton

October 1999

CONTENTS

PREFACE

This a most welcome report produced by the Research Committee on behalf of the Faculty of Public Health Medicine for its members.

There has been considerable debate in Ireland since the introduction of water fluoridation in the 1960s, so it was an opportune time to update members on the key issues in relation to water fluoridation and to place these in the Irish context.

Since the completion of this report, scientific papers on water fluoridation continue to emerge such as that of the Centres for Disease Control and Prevention*. The report from the Centre for Reviews and Dissemination** will synthesise and present the best evidence on the subject of water fluoridation in an accessible and up to date manner.

I believe the members of the Faculty of Public Health Medicine will find this a most informative document as it is a topic which will remain high on the Public Health agenda.

Joseph Barry,
Dean,
Faculty of Public Health Medicine.

*US Department of Health & Human Services, Centers for Disease Control and Prevention Morbidity and Mortality Weekly Report, 1999, Vol 48 No 41

**www.york.ac.uk/inst/crd/fluores.htm

Section 1 • INTRODUCTION

The influence of fluoride on dentition has been known for many decades. In the United States in 1942, Dean demonstrated that where drinking water supplies had a natural fluoride content of 1 part per million (ppm), the prevalence of dental caries among children was below average, yet the children did not have the mottled enamel which occurred when the level of fluoride was in excess of 2 ppm.[1]

Subsequently, to determine whether the addition of fluoride to drinking water was associated with the same beneficial action against dental decay as fluoride naturally present in water, fluoride was added on a trial basis to the drinking water supplies of Grand Rapids, Michigan. After six years, the prevalence of dental caries among children living in that area was found to be 50% lower than that for children in a control town where water had not been fluoridated.[2] Similar effects were also noted in studies in the United Kingdom (UK).[3-5]

In 1958, a World Health Organisation (WHO) Expert Committee on Fluoridation summarised its findings by stating 'the effectiveness, safety and practicability of fluoridation as a means of preventing dental caries, one of the most prevalent and widespread diseases in the world, is now well established'.[6]

Today, there are 40 countries world wide with national water fluoridation programmes, serving over 170 million people, with an additional 40 million people served by water which is naturally fluoridated at equivalent levels.[7] Fluoridation of the major public water supplies commenced in Ireland in the1960s.

Section 2 • THE INTRODUCTION OF FLUORIDATION IN IRELAND

The potential benefits of fluoridation, based on research carried out in North America and the UK emerged during the 1940s and 1950s.[8-10]

In 1956, the Fluorine Consultative Council was established by the then Minister for Health (Mr O'Higgins) with the following terms of reference: 'whether with a view to reducing the incidence of dental caries, it is desirable to provide for an increased intake of fluorine and if the Council considers it so desirable to advise as to the best methods of securing such an increased intake and as to any safe-guards and precautions necessary'.

The Council responded two years later as follows:

- 'An increased intake of fluorine will reduce the incidence of dental caries and that it is desirable to provide for such an increased intake'.
- 'The increased intake of fluorine can best be provided by the fluoridation of public water supplies to the level of 1 ppm of fluorine'.

The Council had received representations to the effect that fluoridation of public water supplies was unethical on the grounds that it was a form of 'mass medication', a 'usurpation of parental rights by public authorities', and an 'interference by the public authority with the integrity of the human body'.

The Council concluded, however, that there were no ethical objections to the fluoridation of public water supplies within the margin of safety recommended in the Report.[11] The Report was accepted by the Minister for Health who then made provisions for mandatory fluoridation.

The reasons the Minister opted for mandatory rather than discretionary fluoridation were as follows:[12]

- 'The need to fluoridate all the public water supplies within the state with four exceptions was uniform throughout, as the prevalence and extent of caries was uniformly high'.
- 'If the issue was to be left to the discretion of each local health authority, all the members of such local bodies would need to familiarise themselves with the mass of scientific literature on the subject before coming to a conclusion. Such members who either would not or could not do the necessary reading and study would be open to the propaganda of the anti-fluoridationists which would undermine their confidence'.
- 'More than 80 separate water authorities would be involved, many of them supplying piped water to two or more areas. A chaotic situation could arise if some areas elected to have fluoridated water and some others rejected it.'

The Health (Fluoridation of Water Supplies) Act was signed into law in 1960.[13] Part of the provision of the Act was that prior to the commencement of fluoridation of a particular water supply system, in addition to a study of the natural fluoride composition of the water, a survey of the incidence of dental caries in school children in the area would be carried out. These reports are made available to each House of the Oireachtas before the Minister can include a particular water supply under the regulations, which require the local authority, as an agent of the health authority, to fluoridate the supply.

A national study of 96,000 children was carried out in the early 1960s. A high level of dental caries in all areas of the country was revealed, with little or no difference between urban and

rural areas.[14] The methodology used in the study, as in an earlier study in 1952, did not include an estimation of early caries, and so the overall burden of dental caries in the population was underestimated. Fluoride levels in 660 different water supplies were analysed, of which only six were found to have a fluoride concentration of 0.5 ppm or more.

Following the passing of the Act a constitutional challenge was raised under Articles 41 and 42 of the constitution i.e. the rights of the family as an institution, and the rights of parents to provide for the education of their children. The case was heard by Justice Kenny who judged in favour of the constitutionality of the Act. Following an appeal, the decision was upheld by the Supreme Court.

In addition to the challenge under Articles 41 & 42, the plaintiff also challenged the State, on the grounds that the Oireachtas had not respected the general guarantee of the Constitution to the individual's right to bodily integrity, claiming that fluoridation of the drinking water involved a health hazard. As a result of this challenge the scientific basis for fluoridation was argued by both scientists and lawyers, with the outcome that the Judges came to the same conclusion as the Fluorine Consultative Council.[15]

Following this judgement, the process of fluoridation of public water supplies commenced. By the end of 1964, more than 25% of the population received fluoridated public piped water supplies. This proportion has increased until now, when in the Republic of Ireland 73% of people receive fluoridated water through their piped public water supplies.

Section 3 • FLUORIDATION MONITORING

Under the Fluoridation of Water Act, 1960, health boards shall arrange for the fluoridation of water supplied to the public by local authorities through pipes.[13] The health board has the general responsibility for the satisfactory operation of fluoridation in the board's area.[16] A wide variety of fluoride dosing and monitoring technologies are in current use, and are largely dependent on the age, site and size of the water treatment plant. Compliance with legal standards for fluoride levels in drinking water is an essential element in determining the quality of the water fluoridation programme.

The regulations made under the Fluoridation of Water Act, 1960, require that a daily colorimetric test is carried out to determine the fluoride level in the water. The aim is to maintain a level of free fluoride ion between 0.8 to 1.0 ppm. The sample for fluoride measurement is generally taken below the injection point at the waterworks by the engineering staff of the local authority, and at intervals at other points in the distribution system, such that the whole system is tested over a period of time. A report summarising the results of the colorimetric tests carried out by the local authority are forwarded to the health board each month, with a copy also forwarded to the Department of Health.[17]

The regulations made under the Act also require that fluoride levels are determined in the distribution system using the distillation test, at intervals not exceeding four weeks, from different points in the distribution system. This is arranged by the health board, through the Public Analyst Laboratories, and is intended to be an independent check on the fluoride content of the water. The results of these distillation tests are forwarded to the Department of Health on a quarterly basis. Although use of an ion probe has generally replaced the distillation test as the method of choice, this evolution in technology has yet to be reflected in legislation.

The European Communities Regulations, 1988, give formal effect in Irish Law to the European Union (EU) Drinking Water Directive.[18] The minimum frequencies of sampling and analysis, based on the population supplied for over 50 parameters, including fluoride, are defined. For each parameter, an upper concentration limit or maximum admissible concentration (MAC) is specified. The MAC for fluoride in public drinking water is 1ppm. The data is analysed according to the number and percentage of exceedances per water supply in each local authority area. Under this Directive a lower limit for any parameter is not specified.

In keeping with the Fluoridation of Water Supplies Act, 1960, since the introduction of fluoridation national and regional oral health surveys have been carried out at intervals.

The circular 'Protection of Drinking Water Supplies, Guidelines for Local Authorities', issued by the Department of the Environment in 1992, states that 'monitoring results should be made available to the public and to the Health Board as soon as possible'.[19] The Freedom of Information Act, 1997, emphasises the importance of providing full and timely access to information collected by public bodies.[20]

Water quality monitoring data, carried out under the EU Directive, is collated nationally by the Environmental Protection Agency (EPA) and published annually in 'The Quality of Drinking Water in Ireland' reports.[21]

Section 4 • SOURCES OF FLUORIDE

Fluorine is one of the most reactive elements. It is never found naturally in its element form. The fluoride ion is abundant in nature and occurs almost universally in soils and waters, generally in low concentrations. The availability of free fluoride ions in soils and water is not uniform. All ground waters contain fluoride in varying concentrations, but there can be major differences within a relatively small area and at different depths. Significant environmental pollution with fluoride can occur from unprotected mines, industrial emissions, coal burning, fertilisers, and pesticides. The fluoride content of foods and beverages can be significantly affected by its concentration in the water used during processing. This can be important in the preparation of baby foods and should be listed with all ingredients on the packages.[7]

Fluoride's dental effect is largely therapeutic and mainly topical in action although some pre-eruptive effect especially in pits and fissures has also been demonstrated. Fluoride has its most effective use in caries prevention when a low level of fluoride is constantly maintained in the oral cavity. In terms of caries, the carious process is a delicate balance between demineralisation and remineralisation. In the mouth there is a constant see-saw between these two phenomena depending on the cariogenic challenge present. The presence of fluoride has been shown to promote the process of remineralisation. In addition the 'healed' lesion has been found to be more resistant to caries attack. There is also evidence to show that low levels of fluoride in plaque affects plaque metabolism in such a way that acid production is reduced.[22]

Since the link between fluoride levels in drinking water and the prevalence of dental caries and dental fluorosis was established, different strategies aimed at maximising the benefits of fluoride for communities and individuals have been developed. The effectiveness of systemic methods such as water fluoridation, fluoridated salt, fluoridated milk and fruit juices, dietary fluoride supplements including tablets and drops and topical agents, including those applied by the individual at home and those applied by the dentist, have been extensively investigated.[23]

Fluoridated salt was first used in Switzerland in 1955. As a dietary vehicle for ensuring adequate ingestion of fluoride, domestic salt comes second to drinking water. The caries preventive effectiveness of fluoridated salt is substantial, approaching that of fluoridated water.[23]

Human and bovine milk naturally contain low levels of fluoride, about 0.03 parts per million. Reported trials have shown substantial caries preventive effects when fluoride is added to milk.[23] As milk fluoridation requires greater logistic effort compared with water, it has not been used on a widespread community basis.

At least 18 different regimes for fluoride tablets and drops have been published.[23] The objective of such programmes is to obtain the maximum caries preventive effect with a low risk of enamel mottling. An expert working group of WHO reviewed the use of fluoride supplements and concluded that such fluoride supplements have limited application.[7]

The evidence for topical fluoride agents professionally applied is not strong enough to advocate their use as a public health measure. They are useful to dental practitioners for use in caries susceptible patients.[23,24] Self applied fluoride agents include individualised gel tray applications, supervised brushing programmes and mouth rinses. Gel trays are expensive and not feasible as a public health measure as well as carrying the risk of children swallowing significant amounts of fluoride. Supervised brushing programmes in developed countries have given way to

logistically simpler programmes such as water fluoridation. Mouth rinses are of use in areas where water fluoridation is not possible. Self-applied fluoride agents also include tooth-pastes with added fluorides. Studies have shown that those people who use pastes with higher fluoride content have the lowest caries.[23] However concerns about the fluorosis risk from children swallowing tooth-paste have led to lower fluoride levels for tooth-paste being tested and used.[24]

According to the World Health Organisation (WHO) Expert Committee Report on Oral Health Status,[7] strategies aimed at regular low level exposure to fluoride in the community are superior in terms of caries prevention to professional applications. Hence, the goals of community based oral health programmes should be to implement the most appropriate means of maintaining a constant low level of fluoride in 'as many mouths as possible' to maximise the beneficial effects on oral health, while minimising the incidence of non-beneficial effects, such as dental fluorosis. Among communities, the relative priority accorded to these outcomes can vary.

Section 5 • BENEFITS OF FLUORIDE

The main oral health benefit from fluoride is its cariostatic effect in preventing dental caries in both children and adults. This beneficial effect and its cost effectiveness have been well documented. However, concerns have been raised about potential negative effects of fluoridation. Despite the use of water fluoridation for almost 50 years, such concerns have remained unsubstantiated. However, as part of any intervention programme, irrespective of its effectiveness and safety record, ongoing evaluation and surveillance is an essential factor.

Dental caries is a multi-factorial disease which is strongly influenced by health behaviour, and can be associated with significant financial costs, morbidity and some mortality.[25] Caries prevention is associated with significant health and social gain.

5.1 Socio-Economic Factors

Sociological factors can have an important bearing on oral health. Results of a study in 1992 carried out by O'Mullane et al on almost 2,000 adults in Ireland indicated that persons on lower incomes in Ireland, especially women, had poorer oral health when compared with those on higher incomes.[26] Subjects who had resided in fluoridated communities had lower levels of decay in both the crowns and roots of their teeth.

Studies in Australia and in the UK have also shown the particular benefit that water fluoridation confers on children with more disadvantaged backgrounds.[27,28, 29] The UK study by Evans et al showed that the greatest improvement in oral health occurred in social groups 4 and 5 compared with social groups 1-3.[28] The prevalence of dental caries in social groupings, 1-3, 4 and 5 respectively were 23%, 39% and 31% in the fluoridated area and 38%, 47% and 62% in the non-fluoridated area.

5.2 Age groups

Newbrun reviewed the efficacy of communal water fluoridation in reducing dental caries based on surveys of caries prevalence in fluoridated and non-fluoridated communities in the US, Australia, Britain, Canada, Ireland & New Zealand.[30] The efficacy was greatest for deciduous dentition (primary/'milk' teeth), with 30-60% less caries in fluoridated communities. In the mixed dentition age, 8-12 years, the efficacy was more variable (20-40% less caries) while in adolescent 14-17 year olds, there was 15-35% less caries. Whilst data for adults and the elderly was limited, fluoridation was also associated with a 15-35% lower prevalence of dental caries.

Fluoridated communities were shown to experience a consistently and substantially lower caries prevalence than non-fluoridated communities. The review showed the wide variation in results from the numerous studies on the subject, and also demonstrated the ever increasing difficulty of conducting this form of research because of the increased mobility of society compounded by the halo effect from fluoridated communities.

There is increasing evidence that fluoride is effective in controlling root surface caries, with data from the United States showing that prevalence was inversely related to the concentration of fluoride in the drinking water.[7] A recent Irish study has supported this finding.[26] In Ireland the percentage of exposed root surface with caries in persons aged 65 years or older was 11.7 in fluoridated areas, compared with 18.9 in non-fluoridated areas.

Thomas and Kassal in their study in Anglesea examined dental caries among mothers at term.[31] The study populations from two areas (fluoridated water supply and non-fluoridated water

supply) were similar with respect to social class and age structure. The mean DMFT (decayed, missing or filled teeth) value for mothers with continual residences in non-fluoridated areas was 13.6, while the mean DMFT value for mothers living in fluoridated mains water areas from birth was 30% lower at 9.5, confirming that the benefits from water fluoridation during childhood continue into adulthood.

5.3 Duration of and type of fluoride exposure

Clark et al examined the effects of the duration of consumption of fluoridated water or use of fluoride supplements on dental caries prevalence in children in British Columbia, Canada.[32] Children from two communities were surveyed, questionnaires on the use of various fluoride preventive practices and residence histories during childhood were collated, and examinations performed on 1131 children. The 110 children with a lifelong exposure to fluoridated water only were found to have 35% fewer decayed or filled tooth surfaces per child in comparison to children with no exposure to fluoridated water or fluoride supplements, while among the 122 children taking fluoride supplements for four years or more, there was a 26% reduction.

5.4 Geographical variations

The oral health of twelve year olds in Glasgow and Dublin was reported by Blinkhorn et al in 1992.[33] Glasgow's water supplies were not artificially fluoridated. Dublin had artificially fluoridated public water supplies. Dublin had similar caries levels to Glasgow in 1961 prior to water fluoridation. By the time of this study this was no longer the case. Dublin twelve year olds had on average 45% less DMFS* (Glasgow 4.85, Dublin, 2.69, CI 1.57 - 2.75) and DMFT** (Glasgow 2.70, Dublin 1.48, CI 0.96 - 1.47) scores than their Glasgow counterparts. The differences between the cities were statistically significant. (*DMFS = decayed, missing or filled surfaces.** DMFT = decayed, missing or filled teeth).

In 1994, Downer et al extended the study to 12-year-old children in North London and Edinburgh.[34] None of the cities had artificial water fluoridation except Dublin. Compared with children from North London and Edinburgh, Dublin children fared less well in terms of mean DMFT and caries prevalence, as shown in table 1, but better than their Glasgow counter-parts.

Table 1. Indicators of dental caries in four cities in Ireland and the United Kingdom

	Mean **DMFT	Caries free children
London	1.27	50%
Edinburgh	1.39	47%
Dublin	1.48	43%
Glasgow	2.70	24%

**DMFT = decayed, missing or filled teeth

A north/south gradient in caries prevalence has been observed in the UK, explanatory factors for which may include diet, dental treatment preferences, and socio-economic gradient between south and north. The findings that children in Dublin which had fluoridated drinking water supplies had a higher DMFT than their counterparts in non-fluoridated London and Edinburgh appeared paradoxical, and effects other than water fluoridation were considered. The comparatively low caries level found in London and Edinburgh was considered to reflect in part the effect arising from the use of dentrifices containing fluoride. In addition three of the London districts included in the study had a level of naturally occurring fluoride in the domestic water supply of 0.22 mg/l which may have marginal therapeutic benefit. In Edinburgh, at the time of

the study, children in a number of primary schools had taken part in a fortnightly school rinsing programme with 0.2% sodium fluoride solution.

The highest caries levels in the United Kingdom have been recorded in Northern Ireland, and this together with Glasgow, as areas where there were no fluoridation programmes and low natural fluoride may be a more valid comparison with Dublin. There was little difference in caries prevalence between north and south of Ireland prior to the implementation of water fluoridation in the Republic. The mean DMFT of 12 year old children in the Eastern Health and Social Services Board of Northern Ireland (a non-fluoridated area) was 3.2 in 1989, compared to 2.7 recorded for Glasgow and more than twice that observed for Dublin.

Blinkhorn's study[33] of 12-year-olds in Dublin recorded a mean DMFT of 1.48. O'Mullane et al in 1984 studied the effectiveness of water fluoridation in Irish school children.[35] This Irish nation-wide twenty year review post fluoridation study showed that 52% of 5 year olds who had a lifetime residence in fluoridated communities were free of dental caries compared with 38% in the non-fluoridation group. The percentage of 8, 12, and 15 year olds found to have caries free permanent teeth was highest in those children who resided in fluoridated communities.

A wide variation in the level of caries between the eight Irish health boards was observed. A similar geographical variation in the level of caries was also evident in the 1961 to 1963 baseline survey. There was also wide variation in the apparent effectiveness of water fluoridation between the eight health boards, e.g. in the case of 5 year olds, the percentage difference in the mean DMFT between fully fluoridated and non-fluoridated groups varied from 55% in the Eastern Health Board to 32% in the Western Health Board. This finding may reflect differences in ongoing levels of fluoride in drinking water supplies.

The differences between caries level among lifetime residents of fluoridated and non-fluoridated communities in Ireland were statistically significant for each group examined but were not as great as predicted on the basis of other studies, particularly among the older children. A number of explanations were postulated, including the fact that the population who reside in non-fluoridated communities in Ireland may occasionally be exposed to water supplies containing fluorides. Hence, it is difficult to isolate a group of children who can act as a true comparison group.

Residents in the North of Ireland where water supplies were not fluoridated and where fluoride tooth-pastes were also introduced in the early 1970s were used as an alternative comparison group. In 1963 a representative sample of school children in Belfast was examined for dental caries using criteria adopted by the pre-fluoridation baseline surveys in the Republic of Ireland. The caries experience of 8, 12, and 15-year-old residents in the Republic of Ireland in 1984 in fluoridated areas was considerably less than that of the corresponding age group in 1983 in Northern Ireland despite similarities in their levels in 1960 to 1963.

Since 1961 in Cork and 1963 in Kerry there has been a considerable drop in tooth decay levels, as elsewhere in Ireland.[36] In 1961-1963, 5 year olds had a mean DMFT score of 6.4. In fluoridated areas the figures were 2.5 in 1984 and 1.1 in 1995. In the non-fluoridated areas the figures for 1984 and 1995 for 5-year-olds were 4.0 and 2.3 respectively. The results for 12 and 15 year olds in 1984 and 1995 are shown in Table 2.

Table 2. Indicators of dental caries in fluoridated and non-fluoridated areas in the Southern Health Board region		
12 year old children	*DMFT score in 1984	*DMFT score in 1995
Non-fluoridated area	4.1	1.8
Fluoridated area	3.3	1.3
15 year old children		
Non-fluoridated area	6.8	4.3
Fluoridated area	5.4	2.8

*DMFT=decayed, missing or filled teeth

Epidemiological evidence from 5-year-old children living in non-fluoridated English communities between 1947 and 1980 indicated that a decline of caries experience began in the late 1950s or early 1960s. This steady decline accelerated in the mid 1970s. Fluoride tooth-pastes were first introduced in the 1970s and were therefore not associated with the initiation of the caries decline, but may have contributed to the subsequent accelerated decline, when there was also a parallel fall in caries experience in fluoridated communities.

The general decline in prevalence of dental caries in the past 20 years among children from all areas of Ireland could be a contributing factor to the apparent reduced effectiveness of water fluoridation when expressed in percentage terms. Any preventive agent will be apparently less effective when the condition becomes less prevalent. The general decline in the prevalence of dental caries in both fluoridated and non-fluoridated areas may reflect the widespread use of fluoride supplementation, especially fluoride tooth-pastes together with factors such as the changing patterns of sugar consumption, changes in oral hygiene practices, dental screening and increasing awareness of the importance of oral health.

Section 6 • COST EFFECTIVENESS

As the natural history of dental caries extends into adulthood, the cost effectiveness of water fluoridation cannot be assessed on evidence derived solely from children. The hypothesis that fluoride tooth-pastes are now carrying out the entire function expected of water fluoridation is not supported by the evidence. In discussing the action of fluoride in caries prevention, Levine commented that the daily use of fluoride tooth-pastes has given relatively disappointing results.[37] Despite the decline of dental caries in children, Jackson concluded that water fluoridation is and will continue to be a cost effective method of preventing dental caries in children and adults for many decades to come, with or without fluoride tooth-pastes.[38]

In 1990 Horowitz reviewed the future of water fluoridation and other approaches to delivering systemic fluorides.[39] As caries has declined in many developed countries the absolute caries reduction will be considerably smaller when systemic fluoride methods are implemented now than was the case 20-40 years ago. He concluded that for countries where most of the population live in cities with communal water supplies, community water fluoridation is the most logical approach from the standpoints of cost effectiveness and total caries prevention impact. In countries with a mostly rural population without central water supplies salt fluoridation may be more practical. Dietary fluoride supplements may be appropriate only for regions where neither water fluoridation nor salt fluoridation is possible or as a temporary measure.

Horowitz also stated that 'although diverse views exist concerning the relative caries preventive effects of pre-eruptive and post-eruptive fluoride administration, the effectiveness of systemic fluoride methods for preventing dental caries remains unchallenged. The future of these methods will be influenced by the findings of new clinical and epidemiological research. Social, political, economic and educational factors will be of equal if not greater importance. Perceptions of the current severity of dental caries as a health problem and of risks associated with preventing the problem may affect the future use of systemic fluorides more than will recommendations of scientists'.

7.1 Fluorosis

Dental fluorosis is a defect of enamel caused by excess fluoride disrupting the developing enamel prior to tooth eruption[7] or, as defined by Murray et al, fluorosis is a 'permanent hypo-mineralisation of enamel characterised by greater surface and sub-surface porosity than in normal enamel resulting from excess fluoride reaching the developing tooth during developmental stages'.[23] In its mildest form, the individual concerned is frequently unaware that he or she has fluorosis. It appears as barely discernible fine lacey markings on the teeth detectable only by an experienced dental examiner. Fluorosis is a dose response condition. Research evidence suggests that periodic spikes of high fluoride in the oral cavity are more likely to produce fluorosis than a constant intake from day to day.[23] The association between the concentration of fluoride in drinking water and the development of dental fluorosis has been known for over half a century. The early trials of fluoridation of water established that a fluoride concentration of 1ppm in drinking water imparted a 50% reduction in caries prevalence, while the prevalence of enamel fluorosis remained low and was generally present to such a minor degree that it would be unnoticeable except to the trained eye.[1,40]

The optimal level of fluoride intake has yet to be fully determined.[41] The original work of Dean established 1.0 mg/L as the most appropriate concentration of fluoride in drinking water, i.e. the concentration at which maximum caries reduction could be achieved while limiting dental fluorosis to acceptable levels of prevalence and severity. This figure was modified to a range of 0.7-1.2 mg/L to take into consideration that in hot climates the population drink more water than in temperate climates. However, this standard was soon found to be inappropriate for tropical and subtropical areas of the world, since the prevalence of fluorosis was found to be excessive. The level of 1.0 mg/L became the recommended upper limit.

In recent years concerns have been raised about the increased prevalence and severity of dental fluorosis in the United States.[42-44] Mild levels of fluorosis in some children are associated with the ingestion of 'optimally fluoridated' water.[45] Other sources of ingested fluorides have increased the levels of exposure to fluorides including fluoridated tooth-paste, bottled water and processed foods.[7,45] In non-fluoridated and optimally fluoridated areas, reports of higher prevalence of dental fluorosis was confined mainly to the milder categories of the condition.[44,46]

Recent studies have explored the role of tooth-paste as a risk factor for enamel fluorosis. Children younger than six years may swallow, and subsequently absorb fluorides, rather than expectorate the tooth-paste. Three factors have been shown to account for much of enamel fluorosis: the early and frequent brushing with fluoride tooth-paste,[40,47-49] the inappropriate use of fluoride supplementation[48] and use of infant formula prior to 1979[47,50] when it contained variable and often high concentrations of fluoride.

A window of maximum sensitivity to fluorosis has been sought with inconclusive results so far. Some evidence suggests that the window of maximum sensitivity occurs during the first year of life while others suggest a later window of maximum sensitivity at 15-24 months in males and 21-30 months in females.[51,52]

The World Health Organisation (WHO) concluded that in communities served with optimally fluoridated water supplies a small proportion of the population will continue to be affected by very mild fluorosis, evident as diffuse white lines and patches, which is not aesthetically

damaging and which usually cannot be seen by the untrained eye.[7] In communities where additional sources of fluoride are available the prevalence of fluorosis may increase.

WHO recommended that dental fluorosis prevalence should be regularly monitored, using indices sensitive enough to detect early changes in enamel following minor changes in fluoride intake, and that when mild or more severe fluorosis is found to a significant extent in a community, steps should be taken to reduce fluoride ingestion during the ages of tooth development.[7] Prudent use of small (pea-sized) quantities of fluoridated tooth-paste is recommended for children, along with parental supervision to minimise swallowing of tooth-paste.

The prevalence of fluorosis or enamel opacities in Irish school children was examined by O'Mullane et al in 1984.[35] The prevalence of fluorosis was found to be negligible. The prevalence of enamel opacities or fluorosis was similar in children living in fluoridated and non-fluoridated areas.

Bio-markers to measure the body burden of fluoride, periodic assessment of total fluoride intake in a population, as well as regular monitoring of oral health and fluorosis prevalence and degree may be helpful both to assess the effect of total exposure to fluoride and to contribute to decisions regarding management of fluoride programmes for caries prevention.

Some degree of dental fluorosis will accompany the maintenance of a low level of fluoride in the mouth. The presence of mild fluorosis should, therefore, be seen in the context of the significant dental caries effect of fluoridated water and the associated health and social gain.[53]

7.2 Bone Health

Concerns have been expressed regarding the alleged association between fluoridation of water and the incidence of hip fractures. Most of the available evidence stems from ecological studies and is inconsistent, documenting either no relationship,[54,55] a raised incidence of fracture[56-58] or a reduced incidence of fracture.[59,60] Those studies which did show a raised incidence reported a weak association as evident by low relative risks (1.08-1.27 for women, 1.17-1.41 for men). Given the inherent limitations of ecological studies, generalisation of the findings are restricted.

Ecological studies have as their units of analysis populations or groups of people rather than individuals. Exposure to a factor is estimated by using a proxy variable. An example of such a proxy might be the use of a postal code to represent fluoride exposure because a large number of residents in that postal code have fluoridated water. An ecological study design is useful in generating hypotheses, rather than proving hypotheses.[61] Lack of control for confounding variables is a problem in ecological studies.[62]

The temporal relationship between fracture incidence and fluoridation has also been examined. A national ecological study in the US showed a small positive association between water fluoridation and hip fracture, with hip fractures occurring immediately after fluoridation.[58] A further study by the same author, however, showed a higher incidence of hip fracture in the period prior to fluoridation of water than in the period following fluoridation.[60]

A number of studies used individual measurements of bone mass. Although exposure to fluoride in drinking water was associated with reduced radial bone mass, this did not occur until the

fluoride levels were 3.5-4.0 mg/l, far in excess of that recommended for optimal fluoridation.[63,64] These high levels of fluoride were due to naturally occurring fluoride.

7.3 Cancer

Claims have been made that fluoride results in an increased occurrence of malignancies. The Knox report in England in 1985 failed to find such a link.[66] A large number of studies in many countries have evaluated cancer mortality in large population groups in relation to concentration of fluoride in the water supply. In an extensive review by Kaminsky et al in 1990 of the benefits and risks of fluoride exposure, the conclusion of the authors was that there is no evidence that chronic exposure to concentrations of fluoride reported to be greater than 2 mg/l in drinking water increases human cancer mortality or incidence.[67]

A similar conclusion was reached by Cook-Mozaffari who in 1996 reviewed the evidence on whether fluoride in drinking water is associated with any risk of developing cancer. The author commented on the errors in the analyses that purport to show such an increase.[68] The author reported that early geographical studies of cancer in areas that have naturally occurring fluoride at different levels gave no indication of an effect on cancer rates associated with higher intakes of fluoride. Following widespread fluoridation to improve oral health in the United States and Britain, some analyses of cancer data have purported to demonstrate such an effect. However, subsequent large-scale comparisons of cancer rates in fluoridated and non-fluoridated areas for successive periods following fluoridation have not indicated any increase, either for all cancer or for malignancies across the range of individual sites. Despite the many claims that such an association exists, the purported effects cease to be apparent when accurate data and correct statistical methods are used.

The relationship between fluoride concentration in drinking water and uterine (corpus and cervix) cancer mortality for the years 1973-1992 was reported by Tohyama in 1996 in Okinawa, Japan.[69] An association was found between fluoride concentration in drinking water and uterine cancer mortality. However, while some confounders were controlled for, smoking exposure, oestrogen exposure, dietary factors and sexual activity were not included among these. As the study had many limitations both in its methodology and analysis, no conclusion regarding causation could be drawn from this study. This association has not been found elsewhere.

In a study in 1995 of the relationship between osteosarcoma and seasonality and environmental factors in Wisconsin, no association was found between potential exposure to fluoridated drinking water and osteosarcoma.[70] A time trend analysis of the cumulative risk of bone cancer for the period 1958-87 for 40 cancer registry areas showed an increased risk for young males in Canada, Europe and the United States, and a decreased lifetime risk for either sex in Europe. This was unrelated to water fluoridation and may have resulted from changes in coding practices.[71]

To test the hypothesis that fluoride is a risk factor for osteosarcoma, a case control study by McGuire et al in 1991 compared the complete residential fluoride histories of osteosarcoma patients with matched hospital-based controls. Fluoridation was not found to be a risk factor for osteosarcoma in the study population. The trend in the data from this small sample study suggests the hypothesis that a protective effect may exist against osteosarcoma for individuals consuming fluoridated water.[72]

A study was carried out in New York by Mahoney et al in 1991 to investigate the potential relationship between water fluoridation and bone cancer. This involved an examination of the

trends in the incidence of primary bone cancers and a comparison of average annual osteosarcoma incidence rates in fluoridated and non-fluoridated areas. The resulting data did not support an association between fluoride in drinking water and the occurrence of cancer of the bone.[73]

7.4 Renal disease

In a review of the benefits and risks of fluoride exposure, Kaminsky et al in 1990[67] concluded that there is no evidence of increased incidence of renal disease or renal dysfunction in humans exposed to up to 8 mg fluoride per litre in drinking water. The authors recommended that studies on the effects of fluoride in individuals with renal insufficiency were needed.

7.5 Immune function

In a review in 1996 of studies on fluoride and immune function, Challacombe[74] stated that the studies do not support the suggestion that fluoridation might affect immunity. Whilst fluoride at high concentrations can have inhibitory effects on lymphocytes and polymorphonuclear leucocyte function, these concentrations are many times higher than levels which would be expected from fluoridation, and the author concluded that there is no evidence of any deleterious effect on specific immunity following fluoridation.

Section 8 • ETHICAL ISSUES

The ethical debate on the fluoridation of drinking water involves, at one end of the spectrum, the concern of depriving those most at risk of caries of the proven benefits of water fluoridation, and at the other end, concern in relation to what is perceived to be mass medication.

It has been pointed out by Harris that in society generally we are used to accepting some diminution in our autonomy for the general good.[75] Examples of this include taxation, the control of drugs, the licensing of the sale of alcohol, and the regulation of road transport. However, in the medical context great importance is attached to the principle of autonomy. If it is established that fluoridation is both harmless and beneficial then the issue is clear according to Harris - 'those who object to it are in the position of depriving the community of a benefit at no cost to themselves, save that of having their personal preference frustrated.' The right to a fluoride-free water supply is not a basic civil right, as many water supplies have naturally occurring fluoride. The purpose of artificial fluoridation is to replicate the beneficial effects observed in communities receiving water with fluoride naturally present at 1ppm.

There are competing demands on limited resources for health care. Hence, there is an ethical responsibility to make available those measures which can achieve significant health gain. A reduction in the incidence of preventable conditions such as dental caries allows for the re-allocation of the finite resources available to the dental services in the Republic of Ireland into the earlier treatment of conditions that are not preventable.

Harris also suggested that the question is not whether we are entitled to impose fluoridation on unwilling people but are those against fluoridation entitled to impose the risks, damage and costs of failure to fluoridate on the community at large. The costs of failure to fluoridate could be measured in terms of wasted resources used to treat dental caries, pain and even death (related to anaesthetics and bacterial endocarditis). A Royal College of Physicians enquiry in England also expressed concern at the propriety of withholding a procedure if safe and of benefit and stated that 'caries is not a trivial disease'.[76]

It has been argued by some that fluoridation is unnecessary because there are other equally effective methods of preventing dental decay. However, experience has shown that for example, strict adherence to a regimen of daily fluoride supplements cannot be maintained. Inducing behavioural change through health education can be a difficult, slow and expensive process. Furthermore, it is likely that the children from relatively disadvantaged backgrounds, and who are at the greatest risk of dental caries, will be the least likely to take fluoride supplementation.

Section 9 • CONCLUSIONS

The oral health status of our population has improved over time, and this improvement is considered to be due primarily to the effects of achieving optimum levels of oral fluoride.

The greatest burden of dental caries is to be found amongst the poorer sections of society. The fluoridation of drinking water, at the appropriate level, has been convincingly shown to be associated with a significant improvement in the oral health of the population, through a reduction in dental caries, and especially with regard to the more disadvantaged in society. Other forms of fluoride supplementation, including tooth-pastes, have been associated with additional benefit, but to a lesser degree.

The challenge today includes the need to maintain progress in further improving the oral health, both at the individual and population levels, whilst ensuring that total fluoride exposure does not contribute to any unwarranted or unacceptable degree of dental fluorosis.

According to WHO, further reductions in dental caries are achievable throughout the European Region, and the introduction of new fluoridation schemes to bring the benefits of fluoridation to other populations should be facilitated.[7]

In conclusion, the data available to date strongly support the continuation of the current water fluoridation policies. The epidemiological evidence that fluoride protects against dental caries is overwhelming. Concerns about adverse effects other than dental fluorosis have not been substantiated. As in all other areas of health care provision, due regard should continue to be taken of the findings of the ongoing research in this area, so that the optimal format and degree of fluoridation can be harmonised with the changing health needs of the population.

REFERENCES

1. Dean HT. The Investigation of Physiological Effects by the Epidemiological Method. In: Moulton RF, ed. Fluorine and Dental Health. Washington DC, American Association for the Advancement of Science, 1942: 23-31.

2. Arnold FA., Dean HT., Knutson JW. Effects of Fluoridated Public Water Supplies on Dental Caries Prevalence. Public Health Report 1953; 68:141-148.

3. Weaver R. Fluorine and Dental Caries: Further Investigations in Tyneside and in Sunderland. British Dental Journal 1944; 77:185-193.

4. Ministry of Health, Scottish Office, Ministry of Housing and Local Government. The conduct of the fluoridation studies in the United Kingdom and the results achieved after five years. Rep Publ Hlth Med Subj London 1962:105.

5. Murray JJ. Adult dental health in fluoride and non fluoride areas. British Dental Journal 1971, 131:391-395.

6. World Health Organisation 1958. Expert Committee on Fluoridation.

7. World Health Organisation. Fluorides and Oral Health: Report of a WHO Expert Committee on Oral Health Status and Fluoride Use. WHO Technical Report, Series 1994; 846.

8. Drum JA. Sc. Proceedings of the Royal Dublin Society 1949; 25.

9. Report of the Medical Research Council. Dental Caries in Ireland. 1952. Stationery Office, Dublin.

10. MacNeill S. Journal of Irish Dental Association 1972; 18: 59.

11. Report of the Fluorine Consultative Council 1958. Stationery Office, Dublin.

12. O'Hickey S. Water Fluoridation and Dental Caries In Ireland: Background, Introduction and Development. Journal of Irish Dental Association 1972; 22:61-64.

13. Health (Fluoridation of Water Supplies) Act, 1960. Stationery Office, Dublin.

14. Reports on the Incidence of Dental Caries in School Children and on the Analysis of Public Piped Water Supplies (1961-1965). Presented by the Minister for Health. Stationery Office, Dublin.

15. Fluoridation: Judgement Delivered by Mr. Justice Kenny in the High Court, Dublin 1963.

16. Fluoridation of Public Water Supplies. Department of Health 1969, Circular 14/1977.

17. Fluoridation of Public Water Supplies. Department of Health 1969, Circular 18/69.

18. Quality of Water Intended for Human Consumption Regulations 1988: EU.

19. Protection of Drinking Water Supplies 1992. Guidelines for Local Authorities. Department of Environment, Circular L14/92.

20. Freedom of Information Act 1997. Government Publications, Dublin, Ireland.

21. Environmental Protection Agency 1996. 'The Quality of Drinking Water in Ireland'.

22. Shellis RP., Duckworth RM. Studies on the Cariostatic Mechanism of Fluoride. International Dental Journal 1994; 44: 263-273.

23. Murray JJ., Rugg-Gunn AJ., Jenkins GN. Eds. Fluorides in caries prevention. 3rd Edition. Butterworth-Heinemann Ltd 1991.

24. Burt BA., Eklund SA. Dentistry, Dental Practice, and the Community 4th Ed. WB Saunders 1992.

25. Scottish Needs Assessment Programme. Dental Caries in Children. Scottish Forum for Public Health Medicine 1994.

26. O'Mullane D., Whelton H. Oral Health of Irish Adults 1989-1990. A Survey Conducted by the Oral Health Services Research Centre, University College Cork. 1992. Stationery Office, Dublin.

27. Slade GD., Spencer AJ., Davies MJ., Stewart JF. Influence of Exposure to Fluoridated Water on Socio-Economic Inequalities in Children's Caries Experience. Community Dentistry & Oral Epidemiology 1996; 24(2): 89-100.

28. Evans DJ., Rugg-Gunn AJ., Tabari ED., Butler T. The Effect of Fluoridation and Social Class on Caries Experience in 5 year old Newcastle Children in 1994 Compared with Results over the Previous 18 years. Community Dental Health 1996; 13(1): 5-10.

29. Jones CM., Taylor GO., Whittle JG., Evans D., Trotter DP. Water Fluoridation, tooth decay in five year olds, and social deprivation measured by the Jarman score: analysis of data from British dental surveys. British Medical Journal 1997; 315: 514-517.

30. Newbrun E. Effectiveness of Water Fluoridation. Journal of Public Health Dentistry 1989; 42: 279-289.

31. Thomas FD., Kassal JY. Fluoridation in Anglesey: A Clinical Study of Dental caries in Mothers at Term. British Dental Journal 1992; 173: 136-140.

32. Clark DC., Hann HJ., Williamson MF., Berkowitz J. Effects of Lifelong Consumption of Fluoridated Water or Use of Fluoride Supplements on Dental Caries Prevalence. Community Dentistry and Oral Epidemiology 1995; 23: 20-24.

33. Blinkhorn AS., Attwood D., Gavin G., O'Hickey S. Joint epidemiological survey on dental health of 12-year-old school children in Dublin and Glasgow. Community Dentistry and Oral Epidemiology 1992; 20: 307-308.

34. Downer M., Blinkhorn A., Holt R., Wight C., Attwood W. Dental Caries Experience and Defects of Dental Enamel Among 12 year old Children in North London, Edinburgh, Glasgow & Dublin. Community Dentistry & Oral Epidemiology 1994; 22: 283-285.

35. O'Mullane D., Clarkson J., Holland T., O'Hickey S., Whelton H. Children's Dental Health in Ireland 1984. A Survey Conducted on Behalf of the Minister for Health by University College Cork. 1986. Stationery Office, Dublin.

36. Southern Health Board: Oral Health of Children and Adolescents. Directed by Oral Health Service Research Centre. 1995. University College, Cork.

37. Levine RS. The Action of Fluoride in Caries Prevention. A Review of Current Concepts. British Dental Journal 1976; 140: 9-13.

38. Jackson D. Has the Decline of Dental Caries in English Children made Water Fluoridation both Unnecessary and Uneconomic? British Dental Journal 1987; March 7: 170-173.

39. Horowitz HS. The Future of Water Fluoridation and Other Systemic Fluorides. Journal of Dental Research 1990; 69: 760-764.

40. Pendrys DG. Risk of fluorosis in a fluoridated population. Implications for the dentist and hygienist. Journal of the American Dental Association 1995; 126: 1618-24.

41. Levy SM., Kohout FJ., Kiritsy MC., Heilman JR., Wefel JS. Infants' fluoride ingestion from water, supplements and dentifrices. Journal of the American Dental Association 1995; 126: 1625-29.

42. Pendrys DG., Stamm JW. Relationship of total fluoride intake to beneficial effects and enamel fluorosis. Journal of Dental Research 1990; 69: 529-38.

43. Clark DC. Trends in prevalence of dental fluorosis in North America. Community Dentistry & Oral Epidemiology 1994; 22: 148-52.

44. US Public Health Service. Review of fluoride benefits and risks. Report of the ad hoc subcommittee on fluoride. Washington, DC: US Government Printing Office, 1991.

45. Bawden JW. 'Where is Waldo?': the timing of fluorosis. Journal of Public Health Dentistry 1996; 56: 5-6.

46. Szpunar SM., Burt BA. Trends in the prevalence of dental fluorosis in the United States: a review. Journal of Public Health Dentistry 1987; 47: 71-79.

47. Pendrys DG., Katz RV. Risk of enamel fluorosis associated with fluoride supplementation, infant formula and fluoride dentifrice use. American Journal of Epidemiology 1989; 130: 1199-208.

48. Pendrys DG., Katz RV., Morse DE. Risk factors for enamel fluorosis in a fluoridated population. American Journal of Epidemiology 1994; 140: 461-71.

49. Lalumandier JA., Rozier RG. The prevalence and risk factors of fluorosis among patients in a pediatric dental practice. Pediatric Dentistry 1995; 17: 19-25.

50. Osuji OO., Leake JL., Chipman ML., Mkiforuk G., Locker D., Levine N. Risk factors for dental fluorosis in a fluoridated community. Journal of Dental Research 1988; 67: 1488-92.

51. Ismail AI., Messer JG. The risk of fluorosis in students exposed to a higher than optimal concentration of fluoride in well water. Journal of Public Health Dentistry 1996; 56: 22-27.

52. Evans RW., Darvell BW. Refining the estimate of the critical period for susceptibility to enamel fluorosis in human maxillary central incisors. Journal of Public Health Dentistry 1995; 55: 238-49.

53. Skotowski MC., Hunt RJ., Levy SM. Risk factors for dental fluorosis in pediatric dental patients. Journal of Public Health Dentistry 1995; 55: 154-59.

54. Arnala I., Alhava EM., Kivivuori R., Kauranen P. Hip fracture incidence not affected by fluoridation: osteofluorosis studied in Finland. Acta Orthopaedica Scandinavia 1986; 40: 137-42.

55. Suarez-Almazor ME., Flowerdew G., Souanders LD., Soskolne CL., Russell AS. The fluoridation of drinking water and hip fracture hospitalization rates in two Canadian communities. American Journal of Public Health 1993; 83: 689-93.

56. Cooper C., Wickham CAC., Barker DJR., Jacobsen SJ. Water fluoridation and hip fracture. Letter. Journal of the American Medical Association 1991; 266: 513-14.

57. Jacobsen SJ., Goldberg J., Miles TP., Brody JA., Stiers W., Rimm AA. Regional variation in the incidence of hip fractures. US white women aged 65 years and older. Journal of the American Medical Association1990;264:500-2.

58. Jacobsen SJ., Goldberg J., Cooper C., Lockwood SA. The association between water fluoridation and hip fracture among white women and men aged 65 years and older: a national ecologic study. Annals of Epidemiology 1992; 2: 617-26.

59. Simonen O., Laitinen O. Does fluoridation of drinking water prevent bone fragility and osteoporosis? Lancet 1985; 2: 432-4.

60. Jacobsen SJ., O'Fallon WM., Melton LJ. Hip fracture incidence before and after the fluoridation of the public water supply, Rochester, Minnesota. American Journal of Public Health 1993; 83: 743-5.

61. Coggon D., Cooper C. Fluoridation of Water Supplies. British Medical Journal 1999;319:269-270.

62. Raheb J. Water fluoridation, bone density and hip fractures: a review of recent literature. Community Dentistry and Oral Epidemiology 1995; 23: 309-16.

63. Sowers MR., Clark MK., Jannausch ML., Wallace RB. A prospective study of bone mineral content and fracture in communities with differential fluoride exposure. American Journal of Epidemiology 1991; 133: 649-60.

64. Phipps K., Burt BA. Water-borne fluoride and cortical bone mass: a comparison of two communities. Journal of Dental Research 1990; 69: 1256-60.

65. Phipps K. Fluoride and bone health. Journal of Public Health Dentistry 1995; 55: 53-56.

66. Knox EG, Chairman. Fluoridation of water and cancer: a review of the epidemiological evidence. Report of the DHSS Working Party. London, Her Majesty's Stationery Office,1985.

67. Kaminsky LS., Mahoney MC., Leach J., Melius J., Miller MJ. Fluoride: benefits and risks of exposure. Critical Reviews in Oral Biology Medicine 1990; 1: 261-81.

68. Cook-Mozaffari P. Cancer and fluoridation. Community Dental Health 1996; 13 Suppl 2: 56-62.

69. Tohyama E. Relationship between fluoride concentration in drinking water and mortality rate from uterine cancer in Okinawa prefecture, Japan. Journal of Epidemiology 1996; 6: 184-91.

70. Moss ME., Kanarek MS., Anderson HA., Hanrahan LP., Remington PL. Osteosarcoma, seasonality, and environmental factors in Wisconsin, 1979-1989. Archives of Environmental Health 1995; 50: 235-41.

71. Freni SC., Gaylor DW. International trends in the incidence of bone cancer are not related to drinking water fluoridation. Cancer 1992; 70: 611-18.

72. McGuire SM., Vanable ED., McGuire MH., Buckwalter JA., Douglass CW. Is there a link between fluoridated water and osteosarcoma? Journal of American Dental Association 1991; 122: 38-45.

73. Mahoney MC., Nasca PC., Burnett WS., Melius JM. Bone cancer incidence rates in New York State: time trends and fluoridated drinking water. American Journal of Public Health 1991; 81: 475-9.

74. Challacombe SJ. Does fluoridation harm immune function? Community Dental Health 1996; 13 Suppl 2: 69-71.

75. Harris J. The Ethics of Fluoridation. Centre for Social Ethics and Policy, University of Manchester.

76. Royal College of Physicians. Fluoride, Teeth and Health. A Report of the Royal College of Physicians, London, 1976. Pitman Medical.

77. Alec Samuels. Editorial: Fluoridation: A Lawyer looks at the issues. Med Sci Law, 1993; 33:185-187.

78. World Health Organisation, Health and Welfare. Canada and the Canadian Public Health Association. Fluorep11.

79. O'Mullane D. Introduction and rationale for the use of fluoride for caries prevention. International Dental Journal 1994; 44, 257-261.

80. Limeback H. Towards a Caries-Free Society - Fluoride Therapies for Today and the Next Century. Journal of Canadian Dental Association 1995; 61(7): 601-605.

81. Horowitz H. Proper Use of Fluoride Products in Fluoridated Communities. Lancet 1999; 353: 1462.

NOTES