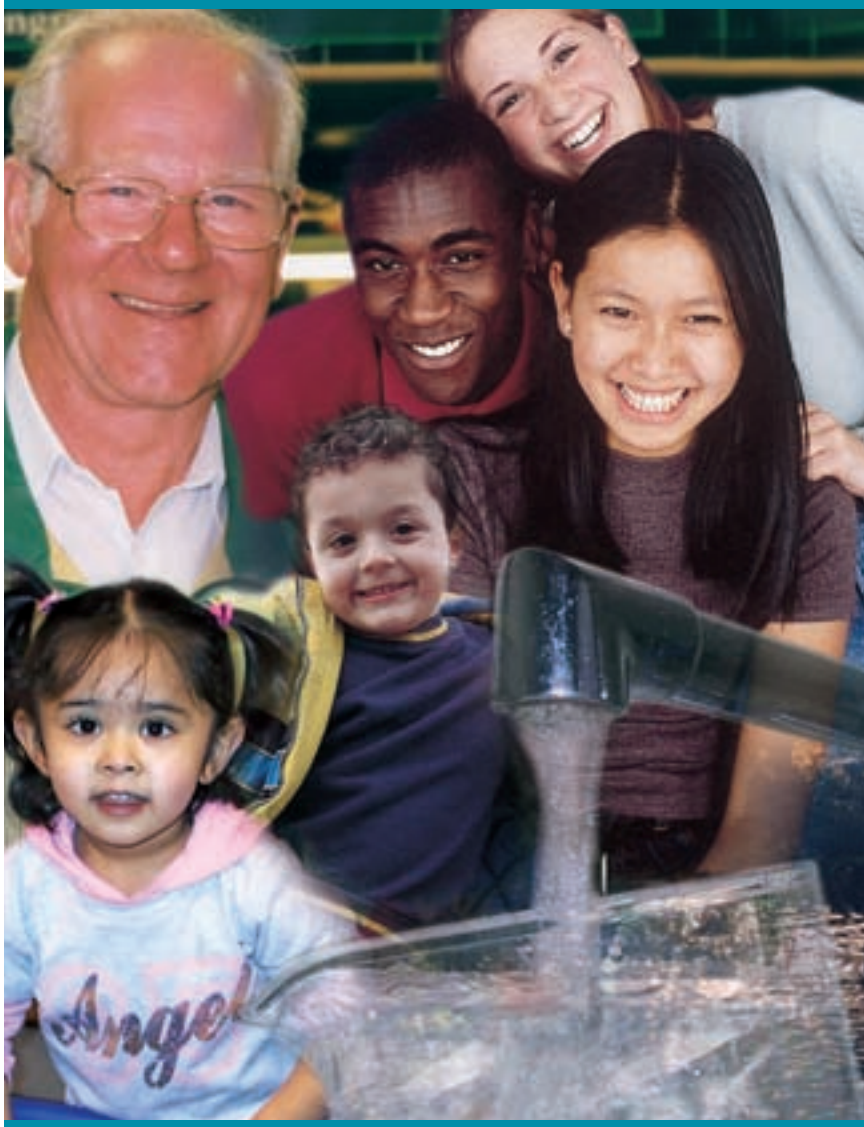
One in a Million

The facts about water fluoridation

2nd edition



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The British Fluoridation Society

The British Fluoridation Society was founded in 1969 by a group of concerned professionals anxious to see an improvement in the dental health of the UK population by the implementation of Government policy for water fluoridation. Founder members include Eric Lubbock MP (now Lord Avebury, former Chairman of the Parliamentary Human Rights Group). From its inception the Society has been a multi-disciplinary organisation, and has enjoyed the support of politicians from all political parties. The aims of the Society are:

- To promote improvement of dental health by securing the optimum fluoride content of water supplies (one part per million);
- To promote and co-ordinate medical, dental, educational, and administrative efforts to achieve this;
- To distribute information about dental health.

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The UK Public Health Association

The United Kingdom Public Health Association - known by the initials UKPHA - is an independent voluntary organisation, formed by the coming together of three organisations in 1999 to unite the public health movement in the UK. As a multidisciplinary membership organisation, the UKPHA:

- Brings together individuals and organisations from all sectors who share a common commitment to promoting the public's health.
- Seeks to promote the development of healthy public policy at all levels of government and across all sectors.
- Acts as an information platform and aim to support those working in public health both professionally or in a voluntary capacity.

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The British Dental Association

The BDA is the largest professional association for dentists in the UK, and develops policies to represent dentists working in every sphere, from general practice, through community and hospital settings, to universities and the armed forces. It aims to be a national player in the development of healthcare policy.

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The Faculty of Public Health

The Faculty of Public Health of the Royal College of Physicians is a medical professional organisation which gives independent advice on the public's health. It aims to:

- Promote, for the public benefit, the advancement of knowledge in the field of public health.
- Develop public health with a view to maintaining the highest possible standards of professional competence and practice, and to act as an authoritative body for consultation in matters of education or public interest concerning public health.

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Tom Reeves and Peter Jackson deserve our special thanks. Tom's hard work secured, or validated, much of the information on the extent of fluoridation worldwide; while his knowledge, expertise, and patience significantly improved the chapter on the technical aspects of water fluoridation. Peter helped to 'translate' the WRc-NSF's expert review of the chemistry and uptake of fluoride in drinking water into everyday language, whilst maintaining its scientific accuracy.

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The report was edited by Catherine Stillman-Lowe.

Foreword

One in a Million

There have been major improvements in oral health over the past twenty years, but despite this there remains persistent oral health inequalities across the United Kingdom. Dental disease broadly correlates with social deprivation, the results of which are only too evident in terms of pain from dental decay, time off school and work, and young children having teeth extracted under general anaesthetic.

The West Midlands and parts of the North East of England are notable exceptions, and have some of the best oral health in the UK, despite having significant areas of multiple deprivation. The almost unanimous agreed reason for this remarkable success story is that a large proportion of the population in these areas receives fluoridated drinking water and has done so for a considerable period of time. Indeed seven out the ten Strategic Health Authorities with the best oral health in the UK have naturally occurring or artificially fluoridated water supplied to a varying proportion of their populations.

It has been the policy of successive governments that health communities in areas of high dental disease should have the option of fluoridating their water. The present government signalled its support for the targeted use of fluoridation to reduce oral health inequalities in *The Health of the Nation* and *Modernising NHS Dentistry* (issued as part of the *NHS Plan*). The *Independent Inquiry into Inequalities in Health* (the Acheson Report) also commended fluoridation.

Previous legislation did not place the water industry under a statutory obligation to fluoridate when asked to do so by health authorities. This has resulted in no new fluoridation schemes since at least 1985. Therefore, I was very pleased when in 2003 both Houses of Parliament voted by a considerable margin to correct this anomaly under the new Water Industry Act 2003.

We are anticipating that with secondary legislation in place by the end of the year those Strategic Health Authorities who wish to proceed to consult on new water fluoridation schemes will now do so in the knowledge that, providing their local populations agree, water fluoridation will happen.

One in a Million is an excellent resource for Primary Care Trusts, Strategic Health Authorities and the public as they decide whether or not to take water fluoridation forward in their localities. It chronicles the history and effectiveness of this important public health measure and importantly also discusses its safety. I commend it to all local decision-makers as they enter into the process of local consultation required by the new Act and I am very pleased to be able to give it my full endorsement.

Professor Raman Bedi
Chief Dental Officer (England)

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Chief Dental Officer (England)
April 2004

Preface

Tackling poor oral health

There are many reasons why people, from young children to older adults, suffer from poor oral health – from the social and economic conditions in which they live, to their personal habits, including their diet and standard of oral hygiene. There are a number of steps that individuals can take on a personal basis to prevent oral problems occurring. These include: reducing their consumption and especially the frequency of intake of drinks, confectionery and foods containing sugars; brushing their teeth thoroughly twice every day with a fluoride toothpaste; and going to the dentist for an oral examination every year. Educational campaigns are designed to give people the information they need to choose a healthier lifestyle, but delivered in isolation, they are far from a complete solution.

Monument commemorating 50 years of water fluoridation in Grand Rapids, Michigan. The five pillars of the white marble monument designed by Stephen H Pierpoint represent the five decades of fluoridation, and are inscribed with a brief history of water fluoridation. The monument is located on the riverside Louis Campau Promenade in Grand Rapids, and incorporates a drinking fountain which delivers fluoridated water.

Fortunately, there is a broad range of actions that can be taken on a community basis to help tackle the issue. These can help to make the healthier choices the easy choices. An example would be helping children to cut down on sugary foods and drinks by having healthier options available in the school canteen at lunchtime, and making drinking water freely available to pupils throughout the school day. Public policies can also promote health, for example, legislation enabling communities to opt for water fluoridation if this is suitable for their area, or if fluoridation is impractical, using other methods of delivering the benefits of fluoride, such as the distribution of free toothpaste for children at high risk of dental decay. Finally, health promotion can include: strengthening community action, so that people themselves have more power to develop ways of improving their lives, rather than having experts 'doing things' to them; and reorienting health services, away from purely curing illness to preventing it as well.

In this context, therefore, water fluoridation is one of many strategies that are available for improving oral health. A different combination of approaches will be right for different areas, and in geographical localities of high dental need, fluoridation is a safe, effective and cost-effective option. Where water fluoridation is technically feasible, this report will help decision-makers in health and local authorities authorities to decide if it is a public health measure that they want to pursue, and to consult their communities about it so that they can make a genuinely informed choice.

Water fluoridation – a brief history

During the 1930s researchers discovered that people living in areas where drinking water contained naturally elevated fluoride levels experienced less tooth decay. Further work demonstrated that, in a temperate climate, a level of 1 part of fluoride per million parts of water (1ppm) was 'optimal' for the prevention of tooth decay. Researchers then hypothesized that the benefits of naturally occurring fluoride might be replicated in communities where the drinking water was low in fluoride by artificially adjusting the level to around 1ppm.

In 1944, Dr Trendley Dean and his colleagues established a community intervention trial in Grand Rapids, USA, to test this hypothesis. The results of their pioneering trial, along with others undertaken elsewhere in the US, Canada, the Netherlands, New Zealand, East Germany, and the UK showed clear benefits to dental health from drinking water 'artificially' fluoridated at 1ppm.

In 1953, the UK Medical Research Council recommended that the Government should send an expert committee to visit the North American trial sites. On the basis of this committee's report the government established demonstration schemes in Anglesey, Watford and Kilmarnock, publishing detailed reports after 5 and 11 years. Impressed by the results, local authorities in Birmingham and Newcastle established new fluoridation schemes and by the early 1980s around 10% of the UK population were benefiting from these.

Despite the success story of water fluoridation in Birmingham and Newcastle, subsequent efforts to extend water fluoridation in the UK beyond the current 10% have been thwarted by inadequate legislation and a small but vocal anti-fluoridation lobby. As a result, tooth decay remains an intransigent public health problem in socially deprived, non-fluoridated communities throughout the UK. The extension of water fluoridation from the current 10% to around 25-35% of the UK population - targeted to communities with high levels of disease - would make substantial inroads towards reducing the still wide inequalities in dental health.

Fluoridation in the future

After decades of frustration over water fluoridation, there is light at the end of the tunnel. We now have in place a new Act that will enable health authorities to implement water fluoridation in areas of high need where there is community support. This publication, originally produced in 1994, has been thoroughly revised and updated to provide a balanced, comprehensive and reliable reference document, as we enter what should now be a period of successful implementation.

Professor Michael A Lennon
Chair, British Fluoridation Society

Executive Summary

The facts about water fluoridation

All water supplies contain fluoride naturally. Water fluoridation is the process of `topping up' the natural fluoride content of public water supplies to a level that is known to improve dental health safely and effectively. In temperate climates that level is 1 part of fluoride per million parts of water (1 ppm); this is a level that occurs naturally in many places throughout the world.

What are the dental benefits?

Despite an overall improvement in dental health over the past 30 years, tooth decay remains a significant public health problem in some parts of the UK. Inequalities in dental health are widespread throughout the UK, with children living in the poorest, non-fluoridated communities continuing to suffer unacceptably high levels of tooth decay. Many studies have confirmed that water fluoridation reduces tooth decay, and has no harmful side effects. Children are the group that benefit most from water fluoridation, but adults benefit too.

Is dental fluorosis (marks on the teeth) a serious problem?

Dental fluorosis appears as mottling or marks on the tooth surface. It has been recognised for over 70 years and is known to be associated with fluoride ingestion. In the UK, fluorosis is mainly a cosmetic problem, with the more severe unsightly and cosmetically unacceptable forms being uncommon in both fluoridated and non-fluoridated areas. So, whilst dental fluorosis is not a serious problem, to reduce the possibility of excessive fluoride intake by young children, parents are advised to use only a smear or small pea sized piece of toothpaste and to supervise their children's tooth brushing. Children who are at low risk of tooth decay, living in a fluoridated area, or receiving fluoride supplements, should use a lower strength fluoride toothpaste.

Are there any effects on general health?

Oral health and general health are strongly linked. Fluoridation improves a population's dental health, and as a consequence its general health. Studies and independent reviews of the relevant medical and scientific literature over many years have consistently failed to find evidence that water fluoridation has *any* effect on the health of the body other than reducing tooth decay.

Who takes decisions on fluoridating water supplies?

Local health authorities are responsible for deciding in principle whether fluoride should be added to local water supplies. They have to consult the local population, and then ask the water supplier to make the necessary technical arrangements. Health authorities, with the aid of Government grants, will meet the total cost of water fluoridation schemes.

How is water fluoridated?

Fluoridation takes place at the water treatment works where a calculated solution of fluoride is added to water under close control. The chemicals used for water fluoridation are specifically manufactured to very high quality standards, and must meet Department of Environment purity specifications. There is no difference between fluoride added to water supplies and that which occurs naturally. Water fluoridation has an excellent safety record.

Where is water fluoridated at present?

In the UK around 6 million people (approximately 10% of the population) currently receive a fluoridated water supply. The West Midlands being the most extensively fluoridated region.

Worldwide around 400 million people benefit from a fluoridated water supply, with the US being one of the most extensively fluoridated countries.

What is the impact on the environment?

Fluorides are very common in the environment. Reviews of the literature and environmental impact assessments have found no evidence of any adverse environmental effects resulting from water fluoridation. Water fluoridation could be described as *environmentally friendly* since it ensures maximum utilisation of natural resources and reduces waste.

How much support is there for water fluoridation?

There is strong professional and public support for water fluoridation. Worldwide, every major health body that has ever considered

the evidence, including the World Health Organisation, has confirmed the effectiveness of water fluoridation and found no evidence of harm. Independently conducted opinion surveys consistently show that around 70% of the public believe that fluoride should be added to water supplies to prevent tooth decay.

Is it ethical to fluoridate water?

From an ethical perspective, water fluoridation can be seen as replicating the benefits already conferred on those communities whose water supplies naturally contain optimal levels of fluoride. Fluoride-free drinking water is not a basic human right but a question of individual preference. However, in a society where people come together for mutual benefit, such personal preferences must be balanced against the common good – particularly when the main beneficiaries are children as they are least able to help themselves.

Is it cost-effective to fluoridate water supplies?

Water fluoridation is highly cost-effective in areas where tooth decay rates remain high, and the local water treatment works serve large populations.

What progress has been made recently in fluoridating water in the UK?

Legislation enacted in 1985 is widely acknowledged to have been a failure. No new schemes have been introduced under that legislation. However, following calls from health professionals and the water industry, in 2003 the Government changed the law, so that where there is strong community support for water fluoridation it can be implemented. There is a strong case for targeted water fluoridation in parts of the UK, particularly the North of England, Scotland, Wales, Northern Ireland and Inner London.

What should happen next?

Local strategic health authorities have the power to decide whether fluoride should be added to the water supplies consumed by their populations. If formal consultation demonstrates local support, the Strategic Health Authority may then request the relevant water supplier to make the necessary technical arrangements, and the water company will be obliged to do so.

The legislative framework should be in place by the end of 2004; meanwhile Primary Care Trusts, in liaison with Strategic Health Authorities, should consider water fluoridation without delay – especially in areas where dental health is poor.

The Dental Benefits of Water Fluoridation

Key points

- Fluoridation of water supplies reduces the number of decayed, missing and filled teeth in children and adults.
- As a result of fluoridation, children experience less toothache, have fewer dental abscesses, and require fewer dental extractions and general anaesthetics.
- The cost to the NHS of treating avoidable disease is therefore reduced substantially.
- While decay levels have fallen in both fluoridated and non-fluoridated communities in recent years, inequalities in dental health remain wide. There is still a strong case for targeted fluoridation in parts of the UK, particularly the North of England, Scotland, Wales, Northern Ireland and Inner London.

How fluoride works to prevent tooth decay

Tooth decay begins when the enamel, the outer surface of the tooth, is destroyed by acid. The acid is produced by bacteria, which form on the surfaces of the teeth as a layer called plaque. When foods or drinks containing sugars enter the mouth, the bacteria within the plaque rapidly convert the sugars into acid. The plaque can hold the acid in contact with the tooth surface for up to 2 hours before it is neutralised by saliva.

During the time that the plaque is acidic, some of the calcium and phosphate minerals, of which enamel is largely composed, are dissolved out of the enamel into the plaque. This process is called demineralisation. However, once the plaque acid has been neutralised the minerals can return into the enamel – a process called remineralisation. This whole process is often described as an 'ionic see-saw' in which mineral ions constantly move back and forth between the tooth enamel and the plaque [1].

The capacity for remineralisation is, however, limited. If sugars enter the mouth too frequently the net loss of mineral from the enamel surface will result in a cavity, through which bacteria can penetrate and infect the inner structure of the tooth. This is tooth decay. If left untreated, it will gradually destroy the tooth causing pain and leading to the formation of a dental abscess.

The relationship between fluoride and tooth decay is complex and probably not yet fully understood. However, it is known that fluoride modifies the process of tooth decay in at least three ways:

Severe tooth decay

- If children take in sufficient fluoride during the period of enamel development, the fluoride improves the chemical structure of the enamel, making it more resistant to acid attack. This effect can theoretically occur from the first stage of mineralisation in the foetal stage until the last teeth erupt, which for the wisdom teeth can be about 20 years of age. This was originally thought to be the most important mechanism of fluoride; however, with advances in knowledge this is now understood to be of lesser importance.
- When teeth are subjected to alternating demineralisation and remineralisation, as described above, the presence of low levels of fluoride in the plaque and saliva both encourages remineralisation, and ensures that

the enamel crystals that are laid down are of improved quality. This means that low levels of fluoride in the mouth gradually improve the strength of the tooth enamel and its ability to resist acid attack. This important mechanism was first described in 1966 and means that early patches of decay can be arrested and damaged enamel will 'heal'. This topical effect explains the dramatic improvement in dental health since the introduction of fluoride into toothpaste formulations in the mid-1970s.

- The third way in which fluoride works is by reducing the ability of the plaque bacteria to produce acid. This is another factor in the prevention of tooth decay. It results from the ability of the plaque bacteria to concentrate the low levels of fluoride at the tooth surface up to a level that inhibits the function of some enzymes, which are essential to the bacteria's ability to produce acid.

Work to further develop our knowledge of the mechanism of fluoride continues. However, our knowledge is sufficiently well developed to be able to say that the, topical, remineralisation effect is the most significant. The goal of maintaining low levels of fluoride in everybody's mouths for as long as possible is therefore critical. Hence, the importance of water fluoridation, and the regular use of fluoride toothpaste.

The dental benefits of fluoridation

All water supplies contain fluoride naturally, and early studies of tooth decay in the United States established that a natural concentration of 1 part of fluoride per million parts of water was associated with significantly lower levels of tooth decay [2]. In most places in the UK the natural fluoride level is too low to be of benefit to dental health. However, it is possible by a process known as water fluoridation to `top up' the natural fluoride in order to reproduce the dental benefits. Water fluoridation was first introduced in the United States in 1945, and in the UK and many other countries throughout the world since the mid-1950s. Its impact on tooth decay has been closely observed since.

The evidence of the dental benefits of water fluoridation has been reviewed by the University of York NHS Centre for Reviews and Dissemination [3]. The York review included 26 studies representing the best available evidence on the effectiveness of water fluoridation, and found that:

- Water fluoridation reduces the number of decayed, missing and filled teeth by on average just over 2 teeth per child.
- Water fluoridation increases the percentage of children totally free from tooth decay by approximately 15%.
- The reduction in the number of decayed, missing or filled teeth following fluoridation is greatest in those areas with the highest levels of tooth decay at the outset.

Why fluoridate water when people can use fluoride toothpaste?

Since fluoride toothpaste became the norm in the UK (from the 1970s), tooth decay rates have fallen in both fluoridated and non-fluoridated communities. The key question, therefore, is whether children living in fluoridated communities still have better dental health. To answer this question, the York review focussed on studies conducted since 1975 when widespread use of fluoride toothpaste can be assumed.

- York concluded that the benefits of water fluoridation are in addition to the benefits derived from the use of fluoride toothpaste.
- Furthermore, a Cochrane systematic review of 74 studies of the effectiveness of fluoride toothpaste also concluded that water fluoridation had a benefit over and above the benefits of fluoride toothpaste [4].

Does water fluoridation reduce inequalities in dental health?

Improvements in dental health (mainly due to the introduction of fluoride in toothpaste) have not been evenly distributed across all social groups. Because the more well-informed and affluent parents are the most likely to restrict their children's sugar intake, and ensure that they brush twice daily with fluoride toothpaste, children from these environments have benefited more than those from poorer backgrounds. [5]. Severe tooth decay remains a problem among young children in disadvantaged communities; for example more than half of Manchester's 5-year-olds have some tooth decay. As a result of these higher levels of disease, young children living in poverty suffer more of the problems associated with tooth decay: toothache, dental abscesses, and tooth extractions. As many as 1 in 5 Manchester 5-year-olds have had at least one tooth extracted, and tooth extraction in such young children is generally performed under general anaesthetic. Clearly, a reduction in the number of tooth extractions required would bring

significant benefits to the health and well being of young children living in poverty - and allow better use to be made of scarce NHS resources.

The reduction of dental health inequalities is therefore an important goal and, although the small number of studies and their low quality rating suggest caution in interpreting these results, it is worth noting here that:

- The York review found that, in terms of the average number of decayed missing and filled teeth, *`there appears to be some evidence that water fluoridation reduces the inequalities in dental health across social classes in 5 and 12 year olds'.*

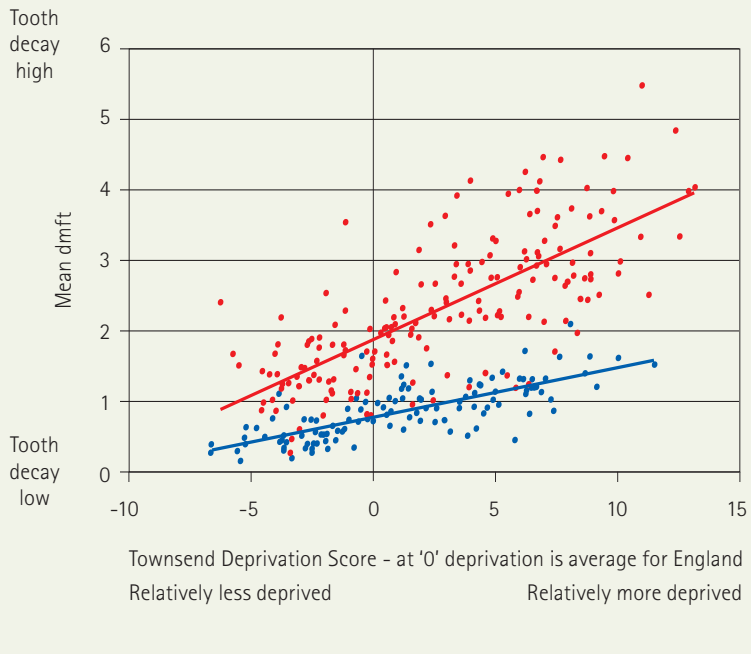
One important study included in the York review looked at the dental health of 5-year-olds living in fluoridated and non-fluoridated areas of varying degrees of social deprivation [6]. It concluded that water fluoridation reduces tooth decay more in disadvantaged communities than in affluent communities, and that the introduction of water fluoridation in areas where levels of poverty and tooth decay are high - such as Manchester - 'would substantially reduce inequalities in dental health'. Figure 1 shows the relationship between tooth decay and social deprivation in both fluoridated communities and non-fluoridated communities. It demonstrates that:

- Young children living in poverty have higher levels of tooth decay than more affluent children.
- However, fluoridation reduces the effects of deprivation on tooth decay.

Where the level of deprivation is the same, children in non-fluoridated communities have more tooth decay than those in fluoridated communities. The difference is just over one tooth per child at `average' levels of deprivation, but importantly the difference increases as levels of deprivation increase. So, for example, at deprivation score 10 children in non-fluoridated communities have around two more decayed teeth per child than children in fluoridated communities. The link between poverty and tooth decay is well established in non-fluoridated areas, but weaker in fluoridated areas.

Figure 1

Relationship between tooth decay and social deprivation in fluoridated and non-fluoridated communities



Graph reproduced from Riley et al [6], by permission of Oxford University Press

The position of each community shown on the chart below is determined by two factors:
1. The average number of decayed, missing or filled teeth (mean dmft) per 5-year-old child, and
2. The level of social deprivation in the community as measured by the Townsend score.
Blue dots mark the positions of fluoridated communities, and the position of non-fluoridated communities are marked by red dots. The average number of decayed, missing or filled teeth per 5-year-old child is shown on the vertical (upright) axis.

Measuring relative social deprivation

Along the bottom or horizontal axis is a ranking for social deprivation - the Townsend score [7]. The average Townsend score for England is a score of 0. A very socially deprived community would have a score of +10 or more (over on the right hand side of the chart). Whereas, a relatively affluent community would be less than 0 (so a score of say -5, over to the left-hand side of the chart, indicates low levels of social deprivation).

What does the graph tell us about the relationship between water fluoridation, tooth decay and social deprivation?

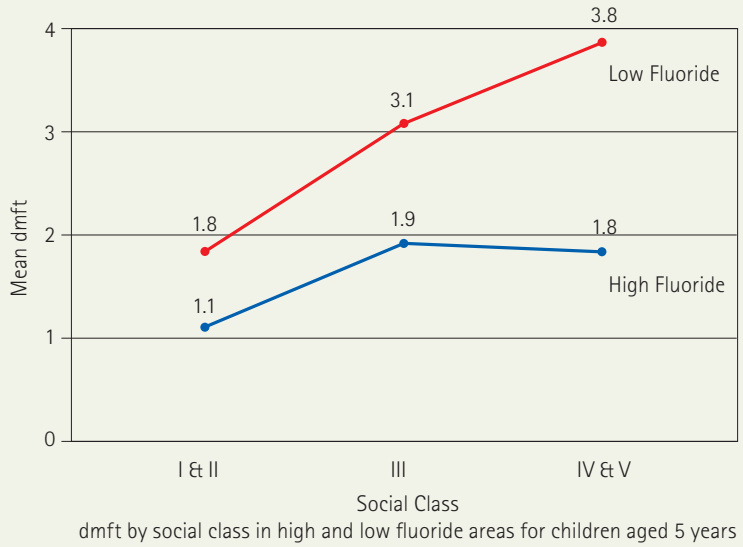
Both lines slope upwards. This tells us that young children living in poverty have higher levels of tooth decay than more affluent children. However, the red line (non-fluoridated communities) is steeper than the blue line (fluoridated communities) which tells us that fluoridation is reducing the effects of deprivation on tooth decay.

In addition, the red (non-fluoridated) line is always higher up the chart than the blue (fluoridated) line. This tells us that, where the level of deprivation is the same, children in non-fluoridated communities have more tooth decay than those in fluoridated communities. The difference is just over one tooth per child at `average' levels of deprivation, but importantly the difference increases as levels of deprivation increase. So, for example, at deprivation score 10 children in non-fluoridated communities have around two more decayed teeth per child than children in fluoridated communities. The link between poverty and tooth decay is weaker in fluoridated than non-fluoridated communities.

The York review looked at a number of UK studies investigating the relationship between tooth decay, social deprivation and water fluoridation (including the study described above). Five of the studies focussing on the dental health of 5-year-olds used the same classification of social class so York were able to combine these results [8-12]. The combined results are shown in Figure 2:

Figure 2

Tooth decay in 5-year-old children by social class and water fluoridation – average number of decayed, missing and filled teeth per child (dmft)



dmft by social class in high and low fluoride areas for children aged 5 years

Reproduced from York 2000 [3], by kind permission of the University of York Centre for Reviews and Dissemination

- Across all social classes, the number of teeth affected by decay is lower in the fluoridated than the non-fluoridated communities; and importantly,
- The teeth of 5-year-old children in the lowest social classes (IV and V) in the fluoridated communities are as healthy as those of children in the highest social classes (I and II) living in the non-fluoridated communities – demonstrating that water fluoridation can modify the usual link between poverty and severe tooth decay.

The constraints of studies in human populations mean that there is virtually no such thing as a perfect study; nevertheless it is important to strive to improve the quality of research. Therefore, following publication of the York Review in September 2000, the Department of Health asked the Medical Research Council (MRC) to set up a Working Group to advise on what further research was needed to improve the quality of evidence on fluoridation, much of which was considered by York to be of only low to moderate quality.

Review by the Medical Research Council

The 2002 review by the Medical Research Council (MRC) noted the findings of the York review, and also considered evidence from several relevant UK studies not included in the York review [13]. In terms of reductions in tooth decay, the results of the studies included in the MRC review were remarkably similar to those reported by York. However, the MRC review highlighted additional benefits such as reductions in both the prevalence of both toothache and dental treatment needing general anaesthetic, as well as the cost of dental treatment. Also included in the review were studies of reductions in tooth decay in very young children, in adults up to 75 years of age, and of the topical effect of water fluoridation on teeth already erupted at the start of fluoridation. These studies are important because as well

as confirming that water fluoridation reduces tooth decay, they also tell us something about:

- The effects of tooth decay on the quality of children's lives;
- Savings in the cost of dental treatment in fluoridated communities;
- The benefits of water fluoridation for adults;
- The importance of the 'topical' effect of fluoride, and hence the benefits of water fluoridation on teeth already present in the mouth at the start of fluoridation (see How fluoride works to prevent tooth decay Page 3).

Improved dental health for all age groups, from the very young...

The results of studies demonstrating the benefits of water fluoridation are given in Tables 1 – 12.

The study in Table 1 compared tooth decay in children as young as 3 years in fluoridated and non-fluoridated communities in Yorkshire. 3-year-olds in the fluoridated community had 59% less tooth decay than those in the non-fluoridated community.

Table 1: The effect of water fluoridation on average number of decayed, missing and filled teeth per 3-year-old child (dmft)

Reference	Year of survey	Fluoridated community	dmft	Non-fluoridated community	dmft	Difference in dmft	% difference in dmft
[14]	1989	Huddersfield	0.30	Dewsbury	0.74	0.44	59%

Tables 2 and 3 (5-year-olds and 14 to 15-year-olds respectively) show the average number of decayed, missing and filled teeth (dmft, or, for permanent teeth, DMFT) per child in fluoridated compared with similar non-fluoridated communities. The actual difference and the percentage difference between the two scores is shown in the right-hand columns.

Table 2: The effect of water fluoridation on the average number of decayed, missing or filled teeth per 5-year-old child (dmft)

Reference	Year of survey	Fluoridated community	dmft	Non-fluoridated community	dmft	Difference in dmft	% difference in dmft
[15]	1981	Newcastle	1.4	Northumberland	3.4	2.0	59%
[16]	1985	Newcastle	1.3	N. Manchester	3.3	2.0	61%
[17]	1987	Newcastle	1.8	Northumberland	3.9	2.1	54%
[18]	1987	Anglesey	0.8	Gwynedd (Mainland)	2.3	1.5	65%

Table 3. The effect of water fluoridation on the average number of decayed, missing or filled teeth per 14-15 year old child (DMFT)

Reference	Year of survey	Fluoridated community	DMFT	Non-fluoridated community	DMFT	Difference in DMFT	% difference in DMFT
[19]	1987	Birmingham	2.3	Bolton	3.8	1.5	40%

Tables 4 and 5 (5-year-olds and 14 to 15-year-olds respectively) show the percentage of children who are 'caries free' (i.e. have no tooth decay at all) in fluoridated compared with non-fluoridated communities.

Table 4: The percentage of 5-year-old children who are caries free in fluoridated and non-fluoridated communities.

Reference	Year of survey	Fluoridated community	Proportion (%) of children who are caries free	Non-fluoridated community	Proportion (%) of children who are caries free	Difference in proportion (%) of children who are caries free
[15]	1981	Newcastle	55	Northumberland	31	24
[16]	1985	Newcastle	62	N. Manchester	29	33
[17]	1987	Newcastle	50	Northumberland	32	18
[18]	1987	Anglesey	67	Gwynedd (Mainland)	48	19

Table 5: The percentage of 14-15 year old children who are caries free in fluoridated and non-fluoridated communities.

Reference	Year of survey	Fluoridated community	Proportion (%) of children who are caries free	Non-fluoridated community	Proportion (%) of children who are caries free	Difference in proportion (%) of children who are caries free
[19]	1987	Birmingham	32	Bolton	19	13

The study presented in Tables 3 and 5 focuses on the important benefits of fluoridation for adolescents. It shows that 14-year-olds in fluoridated communities had 40% fewer teeth affected by decay than 14-year-olds in non-fluoridated communities. In addition, in the fluoridated communities 13% more teenagers had no experience of tooth decay at all.

The Hardwick et al study (Table 6) clearly demonstrates that water fluoridation benefits teeth that are already present in the mouth when fluoridation starts [20]. This means that not only children and teenagers benefit, everyone does!

Table 6: The effect of water fluoridation on caries increment over a 4-year period in children aged 12 at start of fluoridation as expressed as average number of new decayed, missing and filled teeth per child (DMFT)

Reference	Year of survey	Fluoridated community	DMFT Increment over a 4-year period	Non-fluoridated community	DMFT Increment over a 4-year period	Difference in DMFT Increment	% Difference in DMFT Increment
[20]	1974/9	Alsager, Middlewich and Nantwich	3.76	Northwich	4.85	1.09	22.4%

Adults with their own teeth have much to gain from water fluoridation. In general more adults are keeping more of their own teeth into old age, and the studies presented in Table 7 demonstrate that adults living in fluoridated communities keep more of their own teeth longer and have much less trouble with them than those in non-fluoridated communities.

Table 7: The effect of water fluoridation on adult dental health

Reference	Year of survey	Fluoridated community	Non-fluoridated community	Age of subjects	Findings
[21]	1968/9	Hartlepool	York	15 – 65 years	Fluoridation reduced caries experience, tooth mortality, and the need for partial dentures in all 5-year age bands between 15 and 65 years.
[22]	1979 – 1989	Review, several studies included			In adults, including older adults, fluoridation reduced caries by between 15 and 35%.
[23]	Early 1980s	Iowa *8 communities naturally fluoridated* 3 communities artificially fluoridated	Iowa 6 non-fluoridated communities	Average age: 75.2 Fluoridated 74.1 Non fluoridated	Significant benefits resulted for those with 30 – 40 years of exposure to fluoridated water which suggested that fluoridation was beneficial even though exposure started in adulthood.
[24]	1989/90	Ireland Communities fluoridated since mid-1960s	Ireland Communities never fluoridated	16 – 65+ years	• In fluoridated areas the percentage of adults with no natural teeth was lower– e.g. in 45-54 year olds only 10.8% in fluoridated communities compared with 29.5% in non-fluoridated, had no natural teeth. • In fluoridated communities adults had more natural teeth – e.g. in 45-54 year olds had 16.4 natural teeth in fluoridated communities compared with only 10.7 in non-fluoridated - a 34% difference.
[25]	1986/1987	Anglesey	Gwynedd mainland	Antenatal patients up to 32 years	Lifelong residents of fluoridated Anglesey had on average 30% fewer decayed, missing or filled teeth.

... to the very old

Professor Robin Heath, former Director of Dental Care for the Elderly at the Royal London Hospital, is convinced of the benefits of water fluoridation. He says:

'Fluoridation of drinking water provides a safe, cheap and practical method of reducing dental disease, and reducing the consequent pain and severe problems that can result from tooth loss in old age.'

Improved quality of life

The studies in Tables 8, 9, 10, 11 and 12 show that fluoridation reduces:

- the risk of toothache;
- the need for tooth extractions and general anaesthesia;
- the prevalence of dental abscess.
- the prevalence of severe tooth decay.

Experience of toothache

Table 8 shows the difference in toothache experience between children from fluoridated and non-fluoridated communities. In three out of four studies, children from non-fluoridated communities were more than twice as likely to have had toothache during their lives.

Table 8: The experience of toothache among 5-year-old children

Reference	Year of survey	Fluoridated community	% Prevalence	Non-fluoridated community	% Prevalence	Difference in % Prevalence
[15]	1981	Newcastle	12%	Northumberland	27%	15%
[16]	1985	Newcastle	9%	N. Manchester	24%	15%
[17]	1987	Newcastle	18%	Northumberland	27%	9%
[18]	1987	Anglesey	5%	Gwynedd (mainland)	13%	8%

General anaesthetics carry significant risks, and have to be given in hospital

Tooth extractions

Tables 9 and 10 look at tooth extractions and general anaesthetic among 5-year-old children. In the four studies reported in Table 9, children from non-fluoridated communities were substantially more likely to have had at least one tooth extracted. In such young children tooth extraction is generally performed in hospital under a general anaesthetic with all its attendant risks – a distressing experience for all concerned, and one which is often mentioned by adults as the beginning of a lifelong fear of dental treatment. The studies in Table 10 show that 5-year-olds in non-fluoridated communities are much more likely to have had a general anaesthetic for tooth extraction than those in fluoridated communities.

Table 9: The experience of tooth extractions among 5-year old children

Reference	Year of survey	Fluoridated community	% Prevalence	Non-fluoridated community	% Prevalence	Difference in % Prevalence
[17]	1981	Newcastle	8%	Northumberland	23%	15%
[16]	1985	Newcastle	6%	N. Manchester	18%	12%
[17]	1987	Newcastle	8%	Northumberland	18%	10%
[18]	1987	Anglesey	6%	Gwynedd (mainland)	9%	3%

Table 10: The experience of general anaesthetic for tooth extractions among 5-year-old children

Reference	Year of survey	Fluoridated community	% Prevalence	Non-fluoridated community	% Prevalence	Difference in % Prevalence
[15]	1981	Newcastle	7%	Northumberland	21 %	14 %
[16]	1985	Newcastle	7%	N. Manchester	12%	5%
[17]	1987	Newcastle	9%	Northumberland	17%	8%
[18]	1987	Anglesey	5%	Gwynedd (mainland)	8%	3%

Severe tooth decay with abscess in a young child

Abscesses

The study in Table 11 illustrates that 5-year-olds in non-fluoridated Northumberland were five times more likely to suffer dental abscesses than 5-year-olds in fluoridated Newcastle.

Table 11: The prevalence of dental abscesses in 5-year-old children

Reference	Year of survey	Fluoridated community	% Prevalence	Non-fluoridated community	% Prevalence	Difference in % Prevalence
[17]	1987	Newcastle	1%	Northumberland	5%	4%

Severe tooth decay

Table 12 shows the results of three studies focussing on particularly high levels of tooth decay (five or more teeth affected per child). These studies found that children in non-fluoridated communities were several times more likely to experience such problems.

Table 12: The prevalence of severe tooth decay (5 or more teeth affected) among 5-year- old children

Reference	Year of survey	Fluoridated community	% Prevalence	Non-fluoridated community	% Prevalence	Difference in % Prevalence
*[16]	1985	Newcastle	1%	N. Manchester	10%	9%
[17]	1987	Newcastle	16%	Northumberland	31%	15%
[18]	1987	Anglesey	4%	Gwynedd (mainland)	20%	16%

* In this study high caries was defined as 10 or more teeth affected.

Use of NHS resources: cost of dental treatment

A number of studies have compared the cost of dental treatment needed by children in fluoridated and non-fluoridated communities. Costs have usually been calculated according to the NHS General Dental Service fee scale, which is based on the average time taken to complete specific items of treatment. Table 13 shows that 5-year-old children in non-fluoridated communities have been found to need treatment costing 61% more than that needed by those in fluoridated communities.

Table 13: Cost of dental treatment needed by 5-year-old children

Reference	Year of survey	Year of fee-scale	Fluoridated community	Cost	Non-fluoridated community	Cost	% Difference
[17]	1987	1986	Newcastle	£5.00	Northumberland	£12.75	61%

Clearly, water fluoridation in areas of high need would free up scarce NHS resources (both financial and human) to be used for other health care needs. Water fluoridation has been shown to be highly cost-effective in areas where tooth decay rates are high, and water from a single water treatment works serves a population of at least 200,000. (See Section 11 on costs and cost effectiveness.)

Other key points of note from these additional studies reviewed by the Medical Research Council are:

- In all of the studies, children from the fluoridated communities had better teeth - with fewer teeth affected by decay;
- A greater proportion of children in fluoridated areas had no tooth decay at all;
- Fluoridation saves around 2 teeth per child - similar to the difference reported by York;
- Children in fluoridated communities had between 42% and 65% fewer decayed, missing and filled teeth than those in similar non-fluoridated communities.

If introduced in regions with the worst dental health such as the North West of England, Yorkshire, the West of Scotland, Northern Ireland, and Inner London, water fluoridation could significantly improve health and well being for all, but particularly children and young people living in less prosperous communities.

National league table for 5-year-olds' dental health

The most recent survey of 5-year-olds' teeth in England, and Wales was co-ordinated by the British Association for the Study of Community Dentistry (BASCD) in 2001/2002 [26]. In Scotland the most recent national survey of the dental health of such young children was 1999/2000 [27], and in Northern Ireland 1998 [28]. These studies show that:

- Inequalities in dental health in Britain remain wide; for example, there is an almost eight-fold difference in dental health between the best and the worst English Primary Health Care Trusts (PCTs).
- The average number of decayed, missing and filled teeth ranged from 0.49 per child in Daventry PCT - one of the most affluent districts in the country, to 3.87 per child in Rochdale PCT - among the most socially deprived districts. (See Table 15 for data by PCT).
- Areas with the best teeth in the country include fluoridated Birmingham and the West Midlands, and more affluent areas such as Kent & Medway.

Areas with the worst dental health are the less prosperous, non-fluoridated areas including large parts of the north of England, parts of Inner London, parts of Wales, the West of Scotland and Northern Ireland.

Table 14 Ranked table compiled using data from national surveys[1] co-ordinated by the British Association for the Study of Community Dentistry (ranked by Health Authority).

Rank	Health Authority	[2]Mean dmft	Fluoridation status[3]	[4] % of Pop on F supplies
1	KENT & MEDWAY SHA	0.84	NF	0
= 2	ESSEX SHA	0.96	Natural[5]	
= 2	WEST MIDLANDS SOUTH SHA	0.96	Fluoridated	65
4	BIRMINGHAM, SOLIHULL & BLACK COUNTRY SHA	0.98	Fluoridated	97
5	SURREY & SUSSEX SHA	1.04	NF	0
6	AVON, GLOUCESTERSHIRE & WILTSHIRE SHA	1.07	Natural[5]	
7	HAMPSHIRE & ISLE OF WIGHT SHA	1.14	Natural	0
8	SHROPSHIRE & STAFFORDSHIRE SHA	1.15	Partial	35
9	TRENT SHA	1.16	Partial	22
10	DORSET & SOMERSET SHA	1.17	NF	0
11	SOUTH EAST LONDON SHA	1.18	NF	0
12	LEICESTERSHIRE, NORTHAMPTONSHIRE & RUTLAND SHA	1.20	NF	0
13	THAMES VALLEY SHA	1.23	NF	0
14	BEDFORDSHIRE & HERTFORDSHIRE SHA	1.25	Partial	12
15	SOUTH WEST LONDON SHA	1.26	NF	0
16	NORFOLK, SUFFOLK & CAMBRIDGESHIRE SHA	1.29	Natural[5]	
17	BORDERS HB	1.39	NF	0
18	SOUTH WEST PENINSULA SHA	1.46	NF	0
19	NORTH CENTRAL LONDON SHA	1.48	NF	0
20	N & E YORKSHIRE & NORTHERN LINCOLNSHIRE SHA	1.49	NF	8
21	SHETLAND HB	1.58	NF	0
22	NORTHUMBERLAND, TYNE & WEAR SHA	1.68	Fluoridated	47
23	NORTH EAST LONDON SHA	1.72	Natural[5]	
24	CHESHIRE & MERSEYSIDE SHA	1.77	Partial	6
25	NORTH WALES HA	1.86	NF	0
26	GRAMPIAN HB	1.89	NF	1
27	FIFE HB	1.94	NF	0
28	SOUTH YORKSHIRE SHA	1.98	NF	0
29	DUMFRIES & GALLOWAY HB	2.03	NF	0
30	CO DURHAM & TEES VALLEY SHA	2.08	Partial	20
31	CUMBRIA & LANCASHIRE SHA	2.12	Partial	6
32	DYFED POWYS HA	2.14	NF	0
33	LOTHIAN HB	2.24	NF	0
34	IECHYD MORGANNWG HA	2.27	NF	0
= 35	BRO TAF HA	2.28	NF	0
= 35	NORTH WEST LONDON SHA	2.28	NF	0

DoH target for 2003

Rank	Health Authority	[2]Mean dmft	Fluoridation status[3]	[4] % of Pop on F supplies
37	AYRSHIRE & ARRAN HB	2.37	NF	0
38	SOUTHERN HSSB	2.43	NF	0
39	FORTH VALLEY HB	2.45	NF	0
40	WEST YORKSHIRE SHA	2.46	NF	0
= 41	TAYSIDE HB	2.47	NF	0
= 41	GREATER MANCHESTER SHA	2.47	NF	0
43	HIGHLAND HB	2.65	NF	0
44	ORKNEY HB	2.68	NF	0
= 45	GWENT HA	2.73	NF	0
= 45	LANARKSHIRE HB	2.73	NF	0
= 45	ARGYLL & CLYDE HB	2.73	NF	0
48	WESTERN HSSB	2.91	NF	0
49	EASTERN HSSB	2.97	NF	0
50	NORTHERN HSSB	3.30	NF	0
51	WESTERN ISLES HB	3.46	NF	0
52	GREATER GLASGOW HB	3.51	NF	0

1 England & Wales Health Authorities data from national 2001/2002 survey [26],Scotland Health Boards data from 1999/2000 survey [27],Northern Ireland Health and Social Services Boards data from 1998 survey [28].
2 Mean dmft = average number of decayed missing or filled teeth per 5-year-old.
3 Fluoridated = 40% or more of population receiving fluoridated water supplies (NF=not fluoridated).
4 Pop on F supplies % = percentage of population receiving fluoridated water supply.
5 Naturally occurring fluoride levels varying between 0.21 and 1.05 ppm – difficult to quantify accurately and therefore not designated as 'Fluoridated'.

Table 15 Compiled using data from national surveys[1] co-ordinated by the British Association for the Study of Community Dentistry. Data ranked by health authority, including data for Primary Care Trusts where available (not all districts examined enough children in each PCT to allow the dmft for the PCT to be calculated).

Tooth decay in 5-year-old children in the United Kingdom showing detail by Primary Care Trust where available.

Rank	Health Authority/PCT	[2]Mean dmft	Fluoridation status[3]	[4] % of Pop on F supplies
1	KENT & MEDWAY SHA	0.84	NF	0
Including:	Maidstone & S.W.Kent PCT	0.62	NF	0
	Maidstone & Malling PCT	0.77	NF	0
	Canterbury & Coastal PCT	0.81	NF	0
	Ashford PCT	0.83	NF	0
	Dartford Gravesham & Swanley PCT	0.83	NF	0
	Medway & Swale PCT	1.02	NF	0

Rank	Health Authority/PCT	[2]Mean dmft	Fluoridation status[3]	[4] % of Pop on F supplies
= 2	ESSEX SHA	0.96	Natural[5]	
Including:	Maldon & Chelmsford PCT	0.91	NF	
	Billericay, Basildon & Thurrock PCT	1.37	Variable low levels	
= 2	WEST MIDLANDS SOUTH SHA	0.96	Fluoridated	65
Including:	Redditch & Bromsgrove PCT	0.57	Fluoridated	91
	North Warwickshire PCT	0.64	Fluoridated	100
	South Warwickshire PCT	0.65	Fluoridated	68
	Rugby PCT	0.69	Fluoridated	100
	South Worcestershire PCT	0.87	Fluoridated	32
	Coventry PCT	0.93	Fluoridated	85
	Wyre Forest PCT	1.16	Partially	14
	Herefordshire PCT	1.75	NF	0
4	BIRMINGHAM, SOLIHULL & BLACK COUNTRY SHA	0.98	Fluoridated	97
Including:	Castle & Beacon PCT	0.64	Fluoridated	100
	Dudley South PCT	0.69	Fluoridated	61
	South Birmingham PCT	0.78	Fluoridated	100
	Solihull PCT	0.81	Fluoridated	100
	Wednesbury & West Bromwich PCT	0.84	Fluoridated	100
	North Birmingham PCT	0.88	Fluoridated	100
	Rowley Regis & Tipton PCT	0.90	Fluoridated	100
	Wolverhampton City PCT	0.94	Fluoridated	100
	Walsall Area PCT	1.00	Fluoridated	100
	Oldbury & Smethwick PCT	1.01	Fluoridated	100
	East Birmingham PCT	1.19	Fluoridated	100
	Heart of Birmingham PCT	1.57	Fluoridated	100
5	SURREY & SUSSEX SHA	1.04	NF	0
Including:	East Elmbridge & Mid Surrey PCT	0.90	NF	0
	Mid Sussex PCT	0.94	NF	0
	Woking PCT	1.00	NF	0
	Brighton & Hove PCT	1.02	NF	0
	Guildford & Waverley PCT	1.15	NF	0
	Adur, Arun & Worthing PCT	1.20	NF	0
	Western Sussex PCT	1.25	NF	0
6	AVON, GLOUCESTERSHIRE & WILTSHIRE SHA	1.07	Natural[5]	
Including:	Swindon PCT	0.59	NF	
	North Wiltshire PCT	1.45	NF	
	West Wiltshire PCT	1.63	NF	
7	HAMPSHIRE & ISLE OF WIGHT SHA	1.14	Natural	0
Including:	Winchester PCT	0.97	NF	0
	Southampton City PCT	1.23	NF	0
	Isle of Wight PCT	1.32	NF	0
	Portsmouth City PCT	1.37	NF	0

Rank	Health Authority/PCT	[2]Mean dmft	Fluoridation status[3]	[4] % of Pop on F supplies
8	SHROPSHIRE & STAFFORDSHIRE SHA	1.15	NF	35
Including:	Cannock Chase PCT	0.52	Fluoridated	100
	East Staffordshire PCT	0.62	Fluoridated	100
	South West Staffordshire PCT	0.63	Fluoridated	53
	Burntwood, Lichfield & Tamworth PCT	0.64	Fluoridated	100
	Staffordshire Moorlands PCT	1.07	NF	0
	Shropshire County PCT	1.32	Partial	8
	Newcastle-under-Lyme PCT	1.47	NF	0
	South Stoke PCT	1.47	NF	0
	Telford & Wrekin PCT	1.89	NF	0
	North Stoke PCT	2.13	NF	0
9	TRENT SHA	1.16	NF	22
Including:	West Lincolnshire PCT	0.56	Fluoridated	100
	South West Lincolnshire PCT	0.58	Partial	20
	Derbyshire Dales & South Derbyshire PCT	0.78	Partial	20
	Erewash PCT	0.82	0	0
	Bassetlaw PCT	0.83	Fluoridated	100
	Gedling PCT	0.86	NF	0
	Rushcliffe PCT	0.86	NF	0
	Greater Derby PCT	0.88	NF	0
	Chesterfield PCT	1.05	NF	0
	Ashfield PCT	1.11	Fluoridated	100
	North Eastern Derbyshire PCT	1.12	Variable	?
	Amber Valley PCT	1.18	NF	0
	East Lincolnshire PCT	1.18	NF	0
	Newark and Sherwood PCT	1.19	NF	0
	Broxtowe & Hucknall PCT	1.20	NF	0
	Mansfield PCT	1.21	Fluoridated	100
	High Peak & Dales PCT	1.42	NF	0
	Central Derby PCT	2.04	NF	0
	Nottingham City PCT	2.23	NF	0
10	DORSET & SOMERSET SHA	1.17	NF	0
Including:	Taunton Deane PCT	1.03	NF	0
	Mendip PCT	1.15	NF	0
	South Somerset PCT	1.26	NF	0
	Somerset Coast PCT	1.27	NF	0
11	SOUTH EAST LONDON SHA	1.18	NF	0
Including:	Lewisham PCT	0.95	NF	0
	Bromley PCT	1.12	NF	0
	Southwark PCT	1.17	NF	0
	Bexley PCT	1.21	NF	0
	Lambeth PCT	1.22	NF	0
	Greenwich PCT	1.40	NF	0
12	LEICESTERSHIRE, NORTHAMPTONSHIRE & RUTLAND SHA	1.20	NF	0
Including:	Daventry PCT	0.49	NF	0
	Melton Rutland & Harborough PCT	0.80	NF	0
	Northampton PCT	0.89	NF	0

Rank	Health Authority/PCT	[2]Mean dmft	Fluoridation status[3]	[4] % of Pop on F supplies
	Northamptonshire Heartlands PCT	0.96	NF	0
	Southern Leicester PCT	1.04	NF	0
	Hinckley & Bosworth PCT	1.13	NF	0
	Charnwood & NW Leicestershire PCT	1.25	NF	0
	Leicester City West PCT	1.70	NF	0
	Eastern Leicester PCT	2.40	NF	0
13	THAMES VALLEY SHA	1.23	NF	0
Including:	South East Oxfordshire PCT	0.62	NF	0
	Wokingham PCT	0.80	NF	0
	Bracknell PCT	0.83	NF	0
	North East Oxfordshire PCT	0.83	NF	0
	South West Oxfordshire PCT	0.84	NF	0
	Milton Keynes PCT	0.97	NF	0
	Wycombe PCT	1.02	NF	0
	Aylesbury PCT	1.11	NF	0
	Newbury PCT	1.16	NF	0
	Windsor, Ascot and Maidenhead PCT	1.27	NF	0
	Oxford City PCT	1.48	NF	0
	Cherwell Vale PCT	1.53	NF	0
	Slough PCT	2.04	NF	0
	Reading PCT	2.30	NF	0
14	BEDFORDSHIRE & HERTFORDSHIRE SHA	1.25	NF	12
Including:	Bedfordshire Heartlands PCT	0.73	Partial	22
	Bedford PCT	1.04	Fluoridated	100
	North Herts & Stevenage PCT	1.24	NF	0
	Luton PCT	2.07	NF	0
15	SOUTH WEST LONDON SHA	1.26	NF	0
Including:	Croydon PCT	1.06	NF	0
	Kingston PCT	1.14	NF	0
	Sutton and Merton PCT	1.32	NF	0
	Wandsworth PCT	1.62	NF	0
16	NORFOLK, SUFFOLK & CAMBRIDGESHIRE SHA	1.29	Natural[5]	
Including:	Suffolk Central & South PCT	0.89	Variable	?
	South Cambridgeshire PCT	0.90	Variable	?
	East Cambridgeshire PCT	0.98	Variable	?
	Suffolk Coastal PCT	1.03	Variable	?
	Ipswich PCT	1.04	Variable	?
	Huntingdonshire PCT	1.05	Variable	?
	Suffolk West PCT	1.06	Variable	?
	Great Yarmouth PCT	1.07	Variable	?
	Fenland PCT	1.19	Variable	?
	West Norfolk PCT	1.25	NF	0
	Lowestoft & Waveney PCT	1.26	Variable	?
	South Peterborough PCT	1.32	Variable	?
	Broadland PCT	1.37	Variable	?
	Cambridge City PCT	1.55	NF	0
	South Norfolk PCT	1.63	Variable	?

Rank	Health Authority/PCT	[2]Mean dmft	Fluoridation status[3]	[4] % of Pop on F supplies
	North Peterborough PCT	1.65	Variable	?
	Breckland PCT	1.71	Variable	?
	Norwich City PCT	1.75	NF	0
	North Norfolk PCT	1.88	Variable	?
17				
	BORDERS HB	1.39	NF	0
18				
	SOUTH WEST PENINSULA SHA	1.46	NF	0
19				
Including:	NORTH CENTRAL LONDON SHA	1.48	NF	0
	Enfield PCT	1.16	NF	0
	Haringey PCT	1.55	NF	0
	Barnet PCT	1.75	NF	0
20				
Including:	N & E YORKSHIRE & NORTHERN LINCOLNSHIRE SHA	1.49	NF	8
	North Lincolnshire PCT	1.08	Fluoridated	75
	North East Lincoln PCT	1.28	Partial	15
	Selby & York PCT	1.30	NF	0
	Craven, Harrogate & Rural PCT	1.42	NF	0
	Hambleton & Richmondshire PCT	1.83	NF	0
	Scarborough, Whitby & Ryedale PCT	1.93	NF	0
21	SHETLAND HB	1.58	NF	0
22	NORTHUMBERLAND, TYNE & WEAR SHA	1.68	Fluoridated	47
Including:	North Tyneside PCT	1.17	Fluoridated + variable	50 + 50 variable low
	Gateshead PCT	1.31	Fluoridated	Virtually 100
	Newcastle PCT	1.60	Fluoridated	100
	Northumberland PCT	1.81	NF	33
	South Tyneside PCT	2.05	NF	0
	Sunderland PCT	2.05	NF	0
23	NORTH EAST LONDON SHA	1.72	Natural[5]	0
Including:	Havering PCT	0.91	NF	0
	Barking & Dagenham PCT	1.15	NF	0
	Waltham Forest PCT	1.15	NF	?
	Redbridge PCT	1.58	Natural variable	0
	City & Hackney PCT	1.68	NF	0
	Tower Hamlets PCT	2.50	NF	0
	Newham PCT	2.87	NF	0
24	CHESHIRE & MERSEYSIDE SHA	1.77	Partial	6
Including:	Central Cheshire PCT	0.91	Fluoridated	52
	Eastern Cheshire PCT	1.13	NF	0
	Halton PCT	1.21	NF	0
	Southport & Formby PCT	1.24	NF	0
	Cheshire West PCT	1.30	NF	3
	Bebington & West Wirral PCT	1.30	NF	0
	Warrington PCT	1.30	NF	0
	Ellesmere Port & Neston PCT	1.70	NF	0
	South Sefton PCT	1.92	NF	0

Rank	Health Authority/PCT	[2]Mean dmft	Fluoridation status[3]	[4] % of Pop on F supplies
	St Helens PCT	2.14	NF	0
	Birkenhead & Wallasey PCT	2.20	NF	0
	South Liverpool PCT	2.29	NF	0
	Central Liverpool PCT	2.30	NF	0
	North Liverpool PCT	2.30	NF	0
	Knowsley PCT	2.86	NF	0
25	NORTH WALES HA	1.86	NF	0
26	GRAMPIAN HB	1.89	NF	1
27	FIFE HB	1.94	NF	0
28	SOUTH YORKSHIRE SHA	1.98	NF	0
Including:	Sheffield South West PCT	1.37	NF	0
	Sheffield West PCT	1.45	NF	0
	Doncaster Central PCT	1.56	NF	0
	Rotherham PCT	1.89	NF	0
	Doncaster East PCT	2.02	NF	0
	Doncaster West PCT	2.12	NF	0
	Sheffield South East PCT	2.23	NF	0
	Sheffield North PCT	2.27	NF	0
	Barnsley PCT	2.44	NF	0
29	DUMFRIES & GALLOWAY HB	2.03	NF	0
30	CO DURHAM & TEES VALLEY SHA	2.08	Partial	20
Including:	Hartlepool PCT	0.86	Fluoridated	100
	Darlington PCT	2.16	NF	0
	North Tees PCT	2.53	NF	0
31	CUMBRIA & LANCASHIRE SHA	2.12	Partial	6
Including:	West Cumbria PCT	1.30	Fluoridated	100
	Fylde PCT	1.39	NF	0
	West Lancashire PCT	1.39	NF	0
	Chorley & South Ribble PCT	1.57	NF	0
	Carlisle & District PCT	1.65	NF	0
	Eden Valley PCT	1.76	NF	0
	Morecambe Bay PCT	2.03	NF	0
	Wyre PCT	2.26	NF	0
	Blackburn with Darwen PCT	2.39	NF	0
	Burnley, Pendle & Rossendale PCT	2.58	NF	0
	Blackpool PCT	2.62	NF	0
	Hyndburn & Ribble Valley PCT	2.67	NF	0
	Preston PCT	2.88	NF	0
32	DYFED POWYS HA	2.14	NF	0
33	LOTHIAN HB	2.24	NF	0
34	IECHYD MORGANNWG HA	2.27	NF	0

Rank	Health Authority/PCT	[2]Mean dmft	Fluoridation status[3]	[4] % of Pop on F supplies
= 35	BRO TAF HA	2.28	NF	0
				0
= 35	NORTH WEST LONDON SHA	2.28	NF	0
Including:	Harrow PCT	1.52	NF	0
	Hillingdon PCT	1.73	NF	0
	Hounslow PCT	2.13	NF	0
	Kensington & Chelsea PCT	2.19	NF	0
	Ealing PCT	2.59	NF	0
	Brent PCT	2.68	NF	0
	Hammersmith & Fulham PCT	2.68	NF	0
	Westminster PCT	3.04	NF	
				0
37	AYRSHIRE & ARRAN HB	2.37	NF	
				0
38	SOUTHERN HSSB	2.43	NF	
				0
39	FORTH VALLEY HB	2.45	NF	
				0
40	WEST YORKSHIRE SHA	2.46	NF	0
Including:	Airdale PCT	1.83	NF	0
	Wakefield West PCT	1.91	NF	0
	Eastern Wakefield PCT	2.06	NF	0
	Calderdale PCT	2.18	NF	0
	North Kirklees PCT	2.87	NF	
= 41	TAYSIDE HB	2.47	NF	0
				0
= 41	GREATER MANCHESTER SHA	2.47	NF	0
Including:	Trafford South PCT	1.45	NF	0
	Stockport PCT	1.67	NF	0
	Trafford North PCT	2.01	NF	0
	Ashton, Leigh & Wigan PCT	2.14	NF	0
	Salford PCT	2.37	NF	0
	Bury PCT	2.43	NF	0
	Tameside & Glossop PCT	2.55	NF	0
	South Manchester PCT	2.56	NF	0
	North Manchester PCT	2.58	NF	0
	Bolton PCT	2.61	NF	0
	Heywood & Middleton PCT	2.85	NF	0
	Central Manchester PCT	2.87	NF	0
	Oldham PCT	2.96	NF	0
	Rochdale PCT	3.87	NF	0
43	HIGHLAND HB	2.65	NF	0
44	ORKNEY HB	2.68	NF	0
= 45	GWENT HA	2.73	NF	0
= 45	LANARKSHIRE HB	2.73	NF	0
= 45	ARGYLL & CLYDE HB	2.73	NF	0

Rank	Health Authority/PCT	[2]Mean dmft	Fluoridation status[3]	[4] % of Pop on F supplies
48	WESTERN HSSB	2.91	NF	0
49	EASTERN HSSB	2.97	NF	0
50	NORTHERN HSSB	3.30	NF	0
51	WESTERN ISLES HB	3.46	NF	0
52	GREATER GLASGOW HB	3.51	NF	

1 England & Wales Health Authorities data from national 2001/2002 survey [26], Scotland Health Boards data from 1999/2000 survey [27], Northern Ireland Health and Social Services Boards data from 1998 survey [28].
2 Mean dmft = average number of decayed missing or filled teeth per 5-year-old.
3 Fluoridated = 40% or more of population receiving fluoridated water supplies. NF= not fluoridated.
4 Pop on F supplies % = percentage of population receiving fluoridated water supply.
5 Naturally occurring fluoride levels varying between 0.21 and 1.05 ppm – difficult to quantify accurately and therefore not designated as 'Fluoridated'.

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Dental Fluorosis

Key points

- Dental fluorosis appears as markings of the enamel surface of teeth.
- In most cases fluorosis appears as barely visible pearly white flecks on the surface of the teeth, and is undetectable except by an expert.
- The more severe cosmetically unacceptable forms are uncommon in the UK.
- The risk of fluorosis can be reduced by simply following dentists' advice on the use of fluoride toothpastes and fluoride supplements by children.

Very mild dental fluorosis (TF1) giving teeth an attractive `pearlised' appearance

What is dental fluorosis?

Dental fluorosis appears as markings of the enamel surface of teeth (enamel defects). It is caused by ingesting excessive fluoride during the period when the teeth are developing in the gums, before they erupt into the mouth. For the cosmetically important permanent front teeth, the key developmental period extends from birth to 6 years, though some suggest a more precise `critical period' at 22 – 26 months of age [1].

In most cases dental fluorosis appears as barely visible pearly white flecks on the surface of the tooth, and is undetectable except by an expert.

In the UK the likely overall prevalence of all types of enamel defects has been estimated at around 40% - about half of which will be dental fluorosis – mainly the mildest forms [2]. The more severe forms, though uncommon in the UK, are generally more unsightly and cosmetically unacceptable.

Dental fluorosis (TF3) the lower end of the range of severity classified by York review as being 'of aesthetic concern'

Dental fluorosis is not a new condition, the relationship between dental fluorosis and fluoride intake has been recognised for over 70 years. However, it should be noted that:

- There are around 90 different causes of enamel defects, of which 3-4 causes - including fluorosis - are common;
- Few cases of dental fluorosis are unsightly; the mildest forms of fluorosis give teeth a `pearlised' appearance. Indeed, one study has shown that adolescent children think that teeth with the mildest forms of fluorosis are more attractive than those without fluorosis [3];
- The diagnosis of dental fluorosis is not straightforward, and this has made it difficult to estimate the true prevalence of the condition in the UK.

It is important to keep the issue of dental fluorosis in perspective. An important point to keep in mind when considering dental fluorosis is that it is primarily a *cosmetic* issue, and not a health problem. Indeed, as noted above, research shows that in its milder forms dental fluorosis may not even be considered a cosmetic

issue by some, and that teeth exhibiting mild fluorosis can be considered to be more attractive than those without fluorosis. Furthermore, in the same study the children with fluorosis had, on average, significantly less tooth decay than those without fluorosis [3]. It is therefore important when considering fluoride to balance the risk of the *possible* cosmetic disadvantage of dental fluorosis against the known benefits to dental health, and that tooth decay is itself very unsightly, and poses a recognisable *health risk* to significant numbers of young children in less privileged parts of the UK.

Dental fluorosis occurs in both fluoridated and non-fluoridated areas. We need to make appropriate use of fluoride in order to protect against tooth decay and minimise the possibility of dental fluorosis.

The findings of recent reviews

The York review

The University of York systematic review considered 88 studies of the relationship between water fluoridation and dental fluorosis [4]. The studies were conducted in 30 countries, and included some studies of water fluoride levels of up to 5 parts per million (i.e. 5 times higher than the level recommended for water fluoridation). The review noted that there is a 'dose response' relationship between fluoride level in water and the amount of dental fluorosis in the population – that is, as the amount of fluoride in the water increases, the amount and severity of dental fluorosis in the population increases. This is nothing new; indeed, the beneficial effects of fluoride were first discovered because people tended to have 'mottled teeth' in areas where the natural fluoride levels were very high.

York estimated the prevalence of fluorosis (all levels of severity) to be 48% in fluoridated areas and 15% in non-fluoridated areas. However, their estimates of *cosmetically important* levels of severity were 12% in fluoridated areas and 6% in non-fluoridated areas.

Review by the Medical Research Council

The Medical Research Council noted the findings of the York review; however they also considered several studies relevant to the UK that were not included in the York review [5]. These studies suggest that in the UK the prevalence of cosmetically important dental fluorosis is probably lower than that estimated by York.

In 2000 a study by Tabari *et al* estimated the prevalence of cosmetically important fluorosis in fluoridated Newcastle to be 3% and non-fluoridated Northumberland to be 0.5% [6]. Furthermore, a study looking at cosmetically significant fluorosis in several European cities, [7] estimated the prevalence to be between 0 and 4% (see table 1 below). Only Cork had a fluoridated water supply.

Table 1 Prevalence of cosmetically significant fluorosis

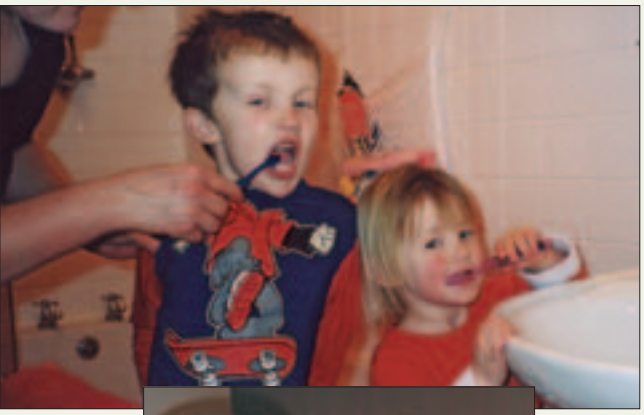
	Number of children photographed	Prevalence of cosmetically significant fluorosis
Cork, Ireland (Fluoridated)	325	4%
Knowsley, UK	314	1%
Haarlem, Netherlands	303	4%
Athens, Greece	283	0%
Almada, Portugal	210	1%
Reykjavik, Iceland	296	1%
Oulu, Finland	315	0%

Source Cochran et al [7]

Reducing the risk of dental fluorosis

Dental fluorosis develops as a result of excessive intake of fluoride by young children at the time of enamel formation. Therefore, after the age of seven the risk of cosmetically important fluorosis ceases to exist. The British Dental Association, and other specialist organisations believe that an important factor associated with the development of cosmetically significant dental fluorosis in the UK is young children routinely swallowing fluoride toothpaste.

To reduce the possibility of excessive fluoride intake by young children, parents are advised to supervise their children's tooth brushing, and use only a smear or small pea sized amount of paste on the brush. Children under seven years of age who are at low risk of tooth decay, living in a fluoridated area, or receiving fluoride supplements should use lower fluoride toothpaste [8]. (Children at low risk include those with little evidence of tooth decay, no history of tooth decay among siblings, and good oral hygiene suggesting regular use of fluoride toothpaste.)



Brushing should be done no more than twice a day and children should be encouraged to spit out afterwards. Toothpastes containing 1000 to 1500 ppm are more effective and should be used by all children over seven years of age and adults. Fluoride drops or tablets should be given to young children *only on the advice of a dentist or doctor,* and when they are used, they should be given at a different time of day to brushing [9].

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Fluoridation and General Health

4

Key points

- Epidemiological studies and independent reviews of the relevant medical and scientific literature have consistently failed to find evidence that fluoride in water at or around one part per million has any effect on the health of the body other than reducing tooth decay.
- Water fluoridation has been practised for almost 60 years, and, in addition, people have drunk naturally fluoridated water for generations. Worldwide, over 400 million people consume fluoridated water, including the residents of 46 of the 50 largest US cities.
- Neither the York review, nor the Medical Research Council and other expert panels, found any evidence of adverse health effects.

Improvements to health

Oral health and general health are strongly linked. Eating, speaking and most social activities are dependent to some extent on good oral health. Fluoridation improves a population's oral health, and as a consequence its general health [1].

Tooth decay and its treatment are, at best, unpleasant for otherwise healthy individuals. However, for certain groups tooth decay or its treatment can present far more serious risks. Individuals suffering certain physical or mental disabilities are particularly vulnerable, and the cardiac status of children and adults with heart problems may be seriously affected by dental disease. Fluoridation of water supplies in socially deprived areas where tooth decay rates are generally high would significantly reduce decay rates and hence reduce the general health risks that the most vulnerable youngsters in those communities face.

No evidence of harmful effects

The main purpose of fluoridation is to reduce tooth decay which it does very effectively and, from all the available evidence, very safely. However, opponents of fluoridation claim that it might cause serious general health problems. It is important therefore for health agencies advocating fluoridation for the purpose of improving dental health to satisfy themselves that it is safe.

How nature showed the way

Fluoride is not a 'new' chemical in drinking water. It is naturally present at varying concentrations in all water supplies. In the United Kingdom natural concentrations are typically lower than the 1 part per million (1ppm) which is recommended for dental health. However, some water supplies - for example in Hartlepool in the North East of England - have always had a natural fluoride concentration at about 1ppm - and supplies in parts of Essex used to contain even higher concentrations - up to nearly 6ppm - until the switch was made to different water sources.

Good oral health is important for eating, speaking, and smiling

In the early 1900s scientists were trying to find out why people living in certain areas had a particular type of mottling of the teeth. Eventually the link between the mottling and very high concentrations of fluoride in drinking water was made, and they called the mottling *dental fluorosis*. However, they also noticed that the people affected had remarkably low levels of tooth decay. Soon, they were able to establish that at one part per million, fluoride in water caused mottling of only minor cosmetic significance but did bring with it the benefit of improved dental health. This early work led to the suggestion that it might be possible to reproduce the benefits of nature by artificially adjusting the natural fluoride levels in drinking water to around 1ppm. So, starting with Grand Rapids in Michigan in 1945, a series of studies of artificial fluoridation in the United States and Canada were set up, and quickly provided evidence that this was indeed the case. The key question to ask, of course, is whether fluoride at this level could or does cause harm to other parts of the body. Again, the early research suggested that there was not a problem.

As described above, some communities have had more than a lifetime's exposure to naturally fluoridated water. Because the laws of chemistry dictate that fluoride ions in solution in water are identical whether they occur naturally in the water or are added artificially, it has long been believed that there is no difference in absorption of fluoride from naturally and artificially fluoridated water. However, to establish conclusively whether there was any difference, the UK Government asked the University of Newcastle to undertake a study. The results confirmed that there is no significant difference in the absorption of fluoride from naturally and artificially fluoridated water [2]. This confirmation is important because it means that evidence from populations such as Hartlepool, where water supplies have been naturally fluoridated at the right level for dental health (1 part of fluoride per million parts of water) for hundreds of years, and which have shown no increased risk of any adverse health effects, can be applied to populations receiving artificially fluoridated supplies.

In addition, artificial fluoridation has now been practised throughout the world for almost 60 years. Around 400 million people in at least 53 countries drink optimally fluoridated water - including two-thirds of the population of the United States. There is therefore a wealth of experience and evidence about the health effects of drinking fluoridated water.

How the facts have refuted allegations of harm

Despite a lack of scientific evidence, opponents of fluoridation have blamed it for a seemingly almost endless list of diseases. Numerous searching reviews of the safety of fluoridation have been unable to find any adequate grounds for these allegations of harm.

The most recent UK reviews of the evidence have been undertaken by the University of York's NHS Centre for Reviews and Dissemination (CRD) [3], and the Medical Research Council [4]. The York CRD review, published in September 2000, included 33 studies of a possible link between water fluoridation and possible adverse health effects. No evidence of a link with *any* adverse health effect – including cancer, bone fractures and Down's Syndrome - was found. However, York identified the need for more good quality research, so the Government asked the Medical Research Council to suggest where it might be possible to strengthen the evidence base.

The Medical Research Council (MRC) Water Fluoridation Working Group sought to move the debate forward and concentrated its efforts on those areas where there might be plausible scientific grounds for an association with ill health – bone health and cancer.

Bone health

Approximately half of the fluoride we take in is rapidly excreted in the urine; however almost all of the fluoride retained in our bodies is deposited in the bones and teeth. It is plausible therefore that any adverse effects from fluoride intake might occur in our bones and teeth. We have noted that too much fluoride ingested at the time that the tooth enamel is forming might result in cosmetically unsightly dental fluorosis. Only one condition - skeletal fluorosis - is known to result from long-term ingestion of exceptionally high concentrations of fluoride in water.

Skeletal fluorosis

Skeletal fluorosis is a bone disease characterised by failure of the bone to mineralise properly. The bones tend to be weaker than normal bones, and, typically, the bones of the legs become deformed due to weight bearing. Calcification extends into tendons and ligaments, making them stiff, and less mobile. The condition is very different from the forms of arthritis common in the UK. Indeed, there are no reports of skeletal fluorosis in the UK or the US associated with fluoride concentrations at 1ppm in drinking water. The condition is very rare in both countries, and only one indigenous case has ever been reported in the UK [5].

Skeletal fluorosis is a widespread problem in several developing countries such as India and Pakistan, and has also been reported sporadically in other parts of the world. These areas tend to have high fluoride exposures, mainly from high fluoride levels in drinking water (up to 18 mg/L in 15 states of India), and hot climates (resulting in increased water consumption). In these developing countries dietary deficiencies and lack of safe water supplies also contribute to the much higher occurrence of crippling bones diseases than is seen in developed countries.

Other possible effects on bone health

There is a large body of evidence from populations drinking *naturally fluoridated* water that it has no adverse effect on our bones [6-8]. However, as hip fracture is the most important of the potential effects of fluoride on bone in developed countries, a number of studies have

investigated fluoride exposure and hip fracture risk. Results vary: some studies have shown a slight protective effect, others have shown a slight increase in fracture rates, while still others found no effect. The York review [3] conducted a meta-analysis (analysing the pooled results) of several studies on bone fracture and water fluoridation. They found no effects, except for studies of 10 years or longer, in which case a protective effect of water fluoridation on fracture risk was shown.

Gaps in the evidence

The laws of chemistry dictate that fluoride ions in solution in water are identical whether they occur naturally in the water or are added artificially. It has therefore long been believed that absorption of fluoride is similar from naturally and artificially fluoridated water [9, 10]. That being the case, the health impact on residents of areas in which fluoride occurs naturally has been applied to those of areas in which drinking water is artificially fluoridated. However, this reasoning has been strongly disputed by opponents of fluoridation, and the Medical Research Council Review therefore recommended new research to investigate the bioavailability and absorption of fluoride from naturally fluoridated and artificially fluoridated drinking water, looking at the impact of water hardness [4]. Consequently, the UK Government commissioned the study of the absorption by humans of fluoride in water described briefly earlier in this chapter [2]. The study carried out by the University of Newcastle, and reviewed by internationally recognised experts, confirms that there is no significant difference in the absorption of fluoride from naturally and artificially fluoridated water. It confirms that evidence from the many studies of populations such as Hartlepool where water fluoride levels have always been naturally at the right level for dental health (1 part of fluoride per million parts of water), and which have shown no increased risk of hip fracture or other adverse health effects, can be applied to populations receiving artificially fluoridated supplies. These results therefore give further reassurance that water fluoridation has no adverse effects on bone health.

Cancer

There have been many epidemiological studies examining whether or not there could be any link between fluoride in water and cancer. Probably the earliest, published over fifty years ago, was conducted in the UK [11]. It was a simple comparison of death rates, for 1930-39, in South Shields (fluoride naturally present in water at l.4ppm) and Tynemouth (fluoride less than 0.25ppm). The author concluded that the death rates from *'malignant disease'* in the two communities were *'approximately the same'*.

Nowadays however little weight can be placed on Weaver's analysis as it did not take into account other relevant differences between the communities, such as the proportions of males and females and the proportions of people in different age groups. These factors have important effects on cancer rates, and, because of the public health implications of cancer, many further investigations of the possibility of any link with fluoridation have been carried out over the years.

The early studies looked at the possible association of fluoride with cancers of all types and these are discussed later in this chapter. However, because fluoride accumulates in bone and has an effect on bone formation, particular attention has been given to bone cancer - especially osteosarcoma.

Osteosarcoma

Osteosarcoma - primary bone cancer - is very rare; not all bone cancers are osteosarcoma, most are secondary from cancer in other organs. There are only about 125 new cases of osteosarcoma per year in England and Wales [4].

In 1990, the independent Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment (COC) - which assesses and gives advice to the Government on carcinogenic risk to humans - concluded that there was no evidence that fluoride causes bone cancer in humans, even in people in whom long term exposure to excessive levels of fluoride had caused skeletal fluorosis. In 2000 the York review could find no clear association between osteosarcoma and fluoridation, and in 2002 the Medical Research Council agreed with York that, overall, the evidence does not suggest that artificially fluoridated water increases the risk of cancer. However, because osteosarcoma, is a difficult cancer to study, and because its causes are poorly understood, the Medical Research Council review suggested that *if new studies are undertaken,* exposure to fluoride should be included along with the other possible risk factors.

The Medical Research Council report commented, *'further data are expected from an extension of the preliminary report of McGuire et al*

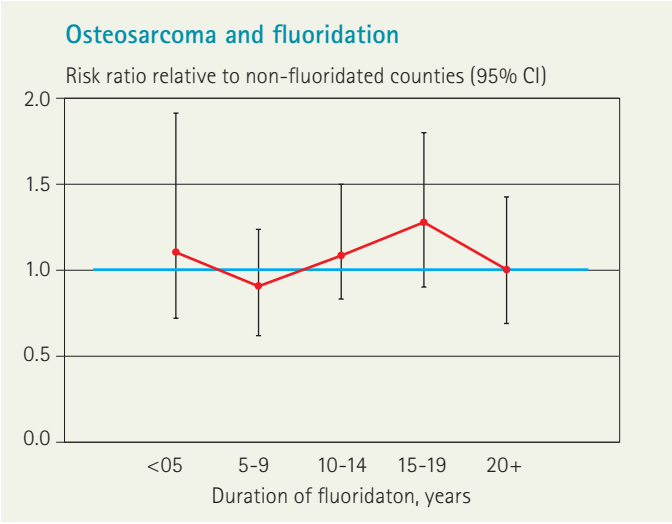
[osteosarcoma case control study]' [12]. Professor Chester Douglass of Harvard University presented preliminary results, as yet unpublished, from that and a separate National Cancer Institute study by Hoover et al, at a symposium held at the Royal College of Physicians, London, in November 2002. These two large case-control studies showed no association between fluoride exposure and osteosarcoma.

Population studies of cancer

Analyses of cancer statistics in the US, the UK and elsewhere have not shown any differences in total cancer rates between fluoridated and non-fluoridated populations, or between populations with water supplies naturally high or low in fluoride. Some studies have looked specifically at bone cancer or at osteosarcoma, and have not observed any association with water fluoridation [13, 14].

An important study by Hoover et al [13], which included 2.3 million cancer deaths, was not included in the York Review's main analysis because it grouped non-fluoridated areas together with areas fluoridated within the most recent five years. However, the MRC working group considered that, since cancers take many years to develop, this grouping was appropriate, and that the results of the Hoover study are very important for the evaluation of the effects of fluoridation because the large numbers involved made it possible to detect small effects. The Hoover study singled out osteosarcomas for detailed analysis and found no relationship with fluoridation. Figure 1 shows the risk of osteosarcoma in fluoridated compared with non-fluoridated US counties. The horizontal line at 1.0 is the theoretical line of identical risk. As can be seen, the actual risk over a 20+ year period hovers above and below the line of identical risk. The bar lines indicate that, statistically, the risk of osteosarcoma is no different in fluoridated compared with non-fluoridated for any of the 5-year periods. The Hoover study did find some evidence suggestive of a relationship with fluoridation and the *occurrence* of renal cancer. However, in contrast, the data for renal cancer deaths showed evidence of an opposite relationship. Overall, the Hoover study identified no trends in cancer cases or *deaths* that could be attributed to the consumption of fluoridated drinking water.

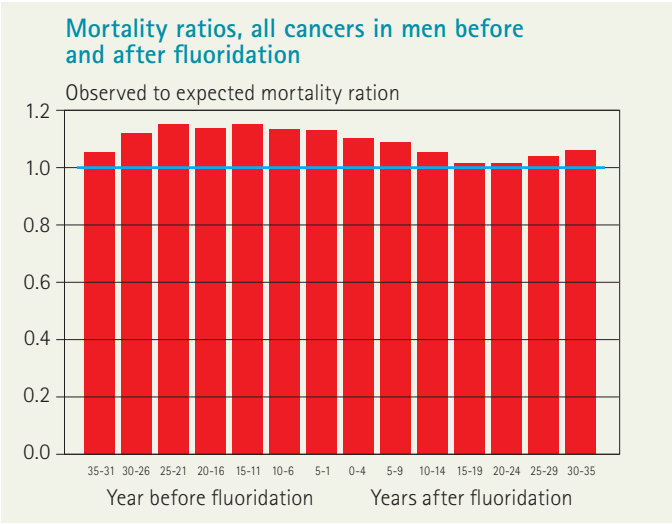
Figure 1 NCI study, Hoover et al 1991



Osteosarcoma and fluoridation. 91 incident osteosarcomas in fluoridated counties. Risk ratios relative to non-fluoridated counties, adjusted for age, calendar time, geographic area, and sex. (Adapted from Hoover et al 1991.)

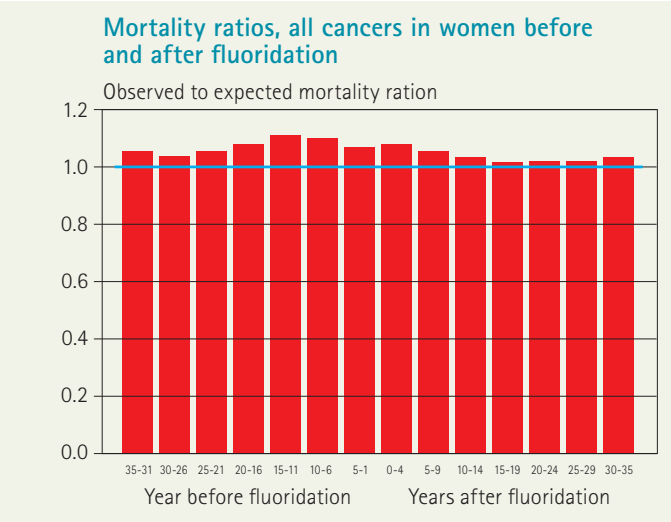
Figures 2 and 3 show the pattern of cancers deaths in 1.2 million men (Figure 2) and 1.1 million women (Figure 3) for a period 35 years before and 35 years after fluoridation compared with cancer deaths in similar, but non-fluoridated, populations. Again, the horizontal line at 1.0 is the theoretical line of no difference. As can be seen, up to 35 years of fluoridation did not increase the risk of death from cancer for either men or women compared with the risk before fluoridation, or compared with non-fluoridated populations.

Figure 2 NCI study, Hoover et al 1991



Mortality ratios, all cancers in men before and after fluoridation. Mortality relative to non-fluoridated counties, adjusted for age, calendar-time, and geographic region. (1.2 m deaths.) (Adapted from Hoover et al 1991.)

Figure 3 NCI study, Hoover et al 1991



Mortality ratios, all cancers in women before and after fluoridation. Mortality relative to non-fluoridated counties, adjusted for age, calendar-time, and geographic region. (1.1 m deaths.) (Adapted from Hoover et al 1991.)

Cancer studies with data for fluoride exposure in individuals

There are few cancer studies where data on fluoride exposure were estimated for individuals rather than populations. However, three small case control studies of osteosarcoma have been reviewed by the Australian National Health and Medical Research Council [12, 15-17]. None of these studies found any evidence of fluoride increasing the risk of cancer.

Evaluation of existing information

Overall, the available evidence suggests there is no association between artificially fluoridated water and cancer in humans. The results of studies to date rule out more than a very small effect of fluoridation on cancer risk for up to about 35 years of exposure. Furthermore, studies of cancer rates in populations drinking naturally fluoridated water, which provide information on lifetime exposure, provide a high level of reassurance concerning safety. (See the section on the Knox report below.)

The Knox report

A Working Party convened by the UK Department of Health and Social Security and led by Professor George Knox reported in 1985 on its evaluation of analyses of cancer data available at that time, including some commissioned for the Working Party itself [18]. The team concluded that:

'We have found nothing in any of the major classes of epidemiological evidence which could lead us to conclude that either fluoride occurring naturally in water, or fluoride added to water supplies, is capable of inducing cancer, or of increasing the mortality from cancer. This statement applies both to cancer as a whole and to cancer at a large number of specific sites. In this we concur with the great majority of scientific investigators and commentators in this field. The only contrary conclusions are in our view attributable to errors in data, errors in analytical technique, and errors in scientific logic.

The evidence permits us to comment positively on the safety of fluoridated water in this respect. The absence of demonstrable effects on cancer rates in the face of long-term exposures to naturally elevated levels of fluoride in water: the absence of any demonstrable effect on cancer rates following the artificial fluoridation of water supplies: the large human populations observed: the consistency of the findings from many different sources of data in many different countries: lead us to conclude that in this respect the fluoridation of drinking water is safe.

The routine monitoring of public health has been an important feature of many fluoridation programmes, and has contributed to the confidence with which we can assert the safety of fluoridation with respect to cancer. We recommend that such monitoring should continue.'

Conclusion

Public health authorities around the world have taken seriously the suggestion that fluoridation might increase cancer rates. In 1990 the independent Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment (COC) which assesses carcinogenic risk to humans, and gives advice to the UK Government, examined the available evidence and concluded that there was no evidence of carcinogenic to humans from fluoride.

The MRC review used material included in the York Review, and 'other significant reviews' to assess the risk of cancer from fluoridation. As has been noted above, the MRC agreed with York that, overall, the evidence does not suggest a link between artificially fluoridated water and the risk of any cancer. The Working Group commented that there is no evidence on the effects on cancer risk from artificial fluoridation for more than 40 years, and recommended an updated analysis of UK population data on artificial fluoridation and cancer rates that would detect any effect after long exposure. However, as stated earlier,

the recent Government-commissioned study of the absorption by humans of fluoride in water confirms that there is no significant difference in the absorption of fluoride from naturally and artificially fluoridated water; therefore, evidence from studies of populations drinking naturally fluoridated water which have shown no increased risk of cancer or any other adverse health effects, can be applied to populations receiving artificially fluoridated supplies. These studies give further reassurance that water fluoridation does not increase the risk of cancer. The results of the absorption study are expected to be published in full in due course.

Other health concerns

It has been suggested that water fluoridation causes a variety of unwanted health effects other than those mentioned above. Many of these claims have not been substantiated. Below is a brief summary of what is known about the most important of these possible effects.

Allergy and immunological effects

It has been claimed that many allergic reactions are caused by fluoride in drinking water. However these claims have been investigated and reviewed by experts and all concluded that there is no credible evidence to support claims that fluoride is allergenic [4, 19-21].

Effects on reproduction

On the question of whether fluoridation affects reproduction, the Medical Research Council's 2002 review said:

> *'Adverse effects of fluoride intake on reproductive performance, such as reduced lactation, have been demonstrated in many species. However, these studies have used dietary concentrations very much higher than those in the fluoridated drinking water of humans (National Research Council, 1993).*
>
> *Fluoride has also been implicated in a number of adverse outcomes relating to fertility and pregnancy, but there is insufficient evidence to establish a link between decreased fertility and fluoride exposure (National Health and Medical Research Council, 1999). The York Review found no evidence of reproductive toxicity in humans (McDonagh et al, 2000).*
>
> *The plausibility of fluoride affecting the reproductive capacity of humans at the intakes experienced from fluoridated drinking water is low.'*

Birth defects

Fluoride reaches the unborn baby and is incorporated into its tissues; it could therefore plausibly cause birth defects. However, studies in areas of India and Africa that have high levels of naturally fluoridated water have not shown an increase in birth defects [7]. In 1957, an investigator linked an excess of Down's Syndrome to fluoridation. However, later studies by other investigators provided strong evidence against this suggestion [3, 7].

On this question, the Medical Research Council's 2002 review concluded:

> *'Human and experimental animal data suggest that drinking even high levels of fluoride in water does not cause birth defects.... Further work on this aspect is not considered to be of high priority.'*

One recent study has concluded *'that there is no evidence that fluoridation has had any influence on the rate of congenital abnormalities or stillbirths in the North East of England'* [22]. Another which looked at all pregnancies that were recognized to be affected by Down Syndrome in England and Wales over a five year period found no convincing evidence of an association between water fluoridation and Down Syndrome [23].

Renal effects

The kidney is exposed to relatively high fluoride concentrations and therefore the potential for it to be harmed by fluoride exists. However, several large community-based studies have found no increase in kidney disease associated with long-term exposure to drinking water with fluoride concentrations of up to eight times the optimal for dental health [7, 20]. The Medical Research Council's 2002 review concluded that further research of this question is not high priority.

Gastrointestinal tract

High concentrations of fluoride can be irritating to the stomach. However, at optimal drinking water fluoride concentrations (1 part per million) this is not a problem [7, 20]. Again, the Medical Research Council's 2002 review concluded that further research of this question is not high priority.

Intelligence

Two Chinese studies have found a positive association between *high levels* of fluoride in drinking water and reduced children's intelligence/IQ. However at fluoride

concentrations that are more comparable to the levels in fluoridated water in the UK, the Chinese studies found no reduction in children's IQ [24, 25]. The Medical Research Council's 2002 review concluded that further investigation of this aspect was of low priority.

Thyroid disease

The York Review found two studies which found no significant association between water fluoride level and goitre [26, 27], and one, unpublished, study that found an association between combined high fluoride/low iodine levels and goitre [28]. Again, the Medical Research Council's 2002 review concluded that further investigation of this aspect was of low priority.

Miscellaneous effects

The Medical Research Council's 2002 review concluded that further targeted research on several other possible health outcomes such as effects on the pineal gland, dementia, and Sudden Infant Death Syndrome, was of low priority *'unless and until critical literature reviews are undertaken that demonstrate specific research needs'*.

Conclusion

Water fluoridation has been practised for almost 60 years, and, in addition, people have drunk naturally fluoridated water for generations. Worldwide, over 400 million people consume fluoridated water, including the residents of 46 of the 50 largest US cities. Given the number of research reports reviewed by York, the Medical Research Council and other expert panels, it seems to us inconceivable that any adverse health effects would not by now have been uncovered. As previously mentioned, the recent University of Newcastle study of the absorption of fluoride from naturally and artificially fluoridated water confirms that there is no significant difference in the absorption of fluoride from naturally and artificially fluoridated water. The study confirms that evidence from the many studies of populations throughout the world where water fluoride levels have always been naturally at the right level for dental health (1 part of fluoride per million parts of water), and which have shown no increased risk of any adverse health effects, can be applied to populations receiving artificially fluoridated supplies. These results therefore give further reassurance as to the safety of water fluoridation.

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5 Legal Aspects and Decision Making

Key points

- In England local strategic health authorities are responsible for deciding whether fluoride should be added to the water supplies consumed by their populations.
- If formal consultation demonstrates local support, the strategic health authority may then request the relevant water supplier to make the necessary technical arrangements.
- Recent changes to the legislation for England and Wales mean that, in future, water suppliers will be obliged to fluoridate supplies when asked to do so by a strategic health authority in England, or, in Wales, the National Assembly.
- New regulations on the detailed requirements on consultations are in preparation.

Flawed legislation

In the United Kingdom decisions about fluoridation have always been made locally. Prior to 1974 decisions were made by local authorities. Responsibility passed to the NHS when local government and the NHS were reorganised in 1974. The 1985 Water (Fluoridation) Act (subsequently incorporated into the Water Industry Act 1991) [1, 2], made health authorities in England and Wales and Health Boards in Scotland responsible. In Northern Ireland, the relevant legislation entrusts the decision to area health and social services boards, and ultimately to the Department of the Environment.

In theory, the 1985 Act made decision-making on fluoridation a straightforward process. In practice however, the Act proved to be defective as it allowed water suppliers to refuse health authorities' requests for fluoridation – even where strong local support for fluoridation had been demonstrated. As a result, no new fluoridation schemes were started under its provisions.

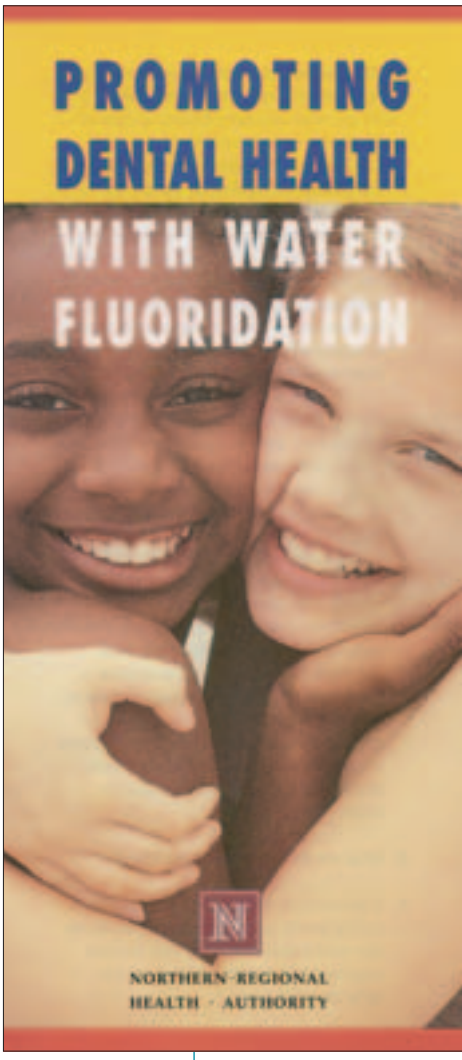
The wording of the relevant clause stated that, when requested by a health authority, the water supplier *'may, while the application remains in force, increase the fluoride content of the water supplied by them within that area'* (our emphasis). Following unsuccessful attempts to implement fluoridation under the Act by many health authorities across the UK (as outlined below), in 1998 a judicial review confirmed that the 1985 Act did indeed give water companies discretion on whether or not to fluoridate [3]. As a result of the legislation failing to deliver what had been intended Parliament passed new legislation in 2003 [4].

Futile attempts to implement fluoridation

As has been discussed in Section 2 of this report, severe tooth decay is a particular problem among young children in disadvantaged communities, and tooth extraction is the most common form of treatment in such young children. Therefore, in light of the proven benefits of water fluoridation, and the absence of evidence of harm, many health authorities have been doing their best to make the 1985 Act work. Between 1987 and 1992, parts of the UK where they have sought to use the Act to obtain or extend fluoridation include:

- The former North Western Health Region;
- The former Mersey Health Region;
- The former Northern Health Region;
- The former Yorkshire Health Region;
- The former Trent Health Region;
- The former West Midlands Region;
- The former Wessex Health Region;
- Scotland;
- Wales;
- Northern Ireland.

In all cases, where the formal consultation and decision-making processes have been concluded and written applications made to the appropriate



Leaflet used during the 1994 public consultation about fluoridation in the North East

water suppliers, either a negative or a non-committal response has been received. Perhaps the most interesting and well documented example is in the North East of England where Northumbrian Water has refused fluoridation applications from eight health authorities – despite the support of the general public, 19 of the 24 local authorities concerned, and 10 of the 11 Community Health Councils, and the fact that the company already fluoridates supplies for around 1 million of its customers.

In 1998 a judicial review of Northumbrian Water's decision not to fluoridate supplies at the request of Newcastle and North Tyneside Health Authority (and the seven other health authorities of the region) confirmed that the 1985 Act did give water companies discretion on whether or not to fluoridate [3, 5].

Ruling against the Health Authority, the judge, Mr Justice Collins, said,

> *'In the exercise of its discretion, the respondent water company was entitled to reject the applicant health authority's proposal to extend the artificial fluoride in its water supplies. It did not have a public body duty and was entitled to take the interests of its shareholders into account'. He went on to say `with some regret' that it was open to the water company to adopt the attitude that it had.*

Justice Collins indicated that a change in the law would be necessary to rectify the situation. And, indeed, the *`shortcomings in the effectiveness of the legislation'* had been acknowledged earlier that year by the, then, Public Health Minister, Tessa Jowell. In a Commons debate she described the situation as *'a mess'* [6], and promised action by the Government to find a *`workable'* way forward. As outlined later in this Section, in November 2003 the necessary legislation to remove the water suppliers right to refuse to fluoridate was passed by Parliament [7].

Scotland

In Scotland the 1985 Water (Fluoridation) Act, and subsequent guidance issued as NHS Circular No 1991(GEN)16, remain in force. The Act and guidance give Health Boards the power to decide whether or not to apply for fluoridation of supplies in their area, and set out the procedure to be followed in using that power. Publicity and consultation are an important part of the process.

Scotland now has its own Parliament, with health among its devolved powers. A further major difference between England and Scotland is that Scottish water supplies are under public, not private, ownership which since February 2001 has been a single water authority – Scottish Water. Unlike the privatised water industry in England and Wales, Scottish Water remains a publicly owned organisation directly answerable to the Scottish Parliament.

Northern Ireland

The recent Water Act (2003) does not cover Northern Ireland. Water supplies in Northern Ireland are not privatised and the 'may/shall' wording issue that has dogged fluoridation in England and Wales has not affected the province.

Legislation enabling fluoridation of the public water supplies in Northern Ireland was updated in 1987. The Water Order (1987) empowers the Department of the Environment (NI), on application from a Health Board, to fluoridate the water supplied within the area (or part of the area) of that Board [8]. Before making an application to fluoridate, Boards are required to:

- Publish details of their proposal;
- Consult district councils for the area affected by the proposal;
- Obtain the approval of the Department of Health and Social Services.

There are currently no water fluoridation schemes in Northern Ireland. A consultation exercise took place in 1996/7 with all four Health Boards proposing schemes. Twenty-five out of the 26 district councils opposed the schemes. Although the support of the councils is not required by the Order, in practice it was not possible to proceed in the face of this level of opposition.

The publication of the interim report of the North-South Children's Oral Health Survey[9] has reactivated the fluoridation debate within the Department of Health (NI) but the defeat of 1996/7 has left deep wounds. It remains to be seen whether progress made on starting new schemes in England will have any effect on the situation in Northern Ireland.

New legislation

Since 1996, the National Alliance for Equity in Dental Health (an alliance of over 100 leading health and voluntary organisations including the British Dental Association, the British Medical Association, and the British Fluoridation Society) has worked with Water UK (the water industry's trade organisation) to bring about the 2003 change in the law. Whilst remaining neutral on

fluoridation *per se,* Water UK made clear that it wanted the Government to act to enable the long-standing impasse between the industry and the NHS over fluoridation to be resolved. In Spring 2003 Water UK issued a news release stating that the industry strongly supported a proposed amendment to the Water Industry Act 1991. The news release left no doubt that the water industry as a whole believed that water fluoridation is *'a health issue'* and that *'current discretion for water companies to agree to an application from a health authority should be removed'*. In the news release Water UK Chief Executive, Pamela Taylor said:

> *'The current situation is frustrating for everyone with an interest in this important issue. Water UK wants to see the stalemate resolved and decision-making placed securely with health professionals, where it belongs.'*

Such a statement from the industry made it clear to all concerned that without new legislation there could be no progress on fluoridation; however, equally importantly, it made clear that the industry as a whole welcomed the proposed change, and would support the Government's efforts to change the law – provided that the position of water companies is *'properly safeguarded in respect of operating arrangements, costs and indemnities'*.

From the outset the Alliance campaign had been actively supported by several Members of Parliament, and in December 2002 Andy Burnham, Labour MP for Leigh, tabled an Early Day Motion calling for an amendment to the Water Bill that would require water companies to fluoridate supplies where health authorities have demonstrated that there is strong local support. His motion was signed by 149 MPs.

On the 9th of July 2003, encouraged by the water industry's attitude, and the support of backbench MPs on all sides of the Commons, the Government put down an amendment to the Water Bill then being discussed in the Lords[7]. In a free, unwhipped, vote Peers supported the Government's amendment by a convincing 153 votes to 31, and the amendment was incorporated into the Bill. At the Commons Committee Stage the amendment was supported by 14 votes to 6, and on Monday 10 November 2003 in a free vote MPs voted overwhelmingly (284 votes to 181) in support of fluoridation. The Water Act 2003 became law on 20th November 2003 [4]. On fluoridation, Section 58 says, inter alia,

> *'If requested to do so by a relevant authority, a water undertaker shall enter into arrangements with the relevant authority to increase the fluoride content of the water supplied by that undertaker to premises specified in the arrangements'*.

The replacement of the word '**may**' by the word '**shall**' was the critically important change.

Section 58 also put new emphasis on the requirement for consultation before any new fluoridation scheme is requested (or an existing scheme terminated). A new section on consultation confirmed that Regulations are to be drawn up about the process to be followed on consultation and assessment of public opinion. Furthermore, indicating how important public consultation is, such regulations must be *'laid before, and approved by a resolution of, each House of Parliament'* or, in the case of Wales, *'The power of the Assembly to make regulations ...shall be exercisable by statutory instrument'*.

The Government has always indemnified water companies in respect of liabilities that they may incur in respect of fluoridation, and the new Act provided for Regulations to be drawn up governing future indemnities.

The way forward: public information and consultation

The 1985 Act and associated guidance (HC(87)18) required as a *statutory minimum* that health authorities:

- publish their proposals on two consecutive weeks in newspapers with the largest circulation in the relevant areas, mentioning by name all the districts to be fluoridated and inviting comments; and
- consult the relevant local authorities and community health councils.

The consultation period had to last for at least three months, and health authorities had to publicly consider the views which emerged.

However, the guidance made clear that a health authority might consult any other bodies, or use other means of sounding out local opinion it considered appropriate to *'ensure that no significant section of the population can reasonably complain that they did not have an opportunity to learn about the proposals'*. A good public information and consultation strategy has long been considered the cornerstone of decision-making about water fluoridation proposals, and,

in practice, health authorities have tended to go beyond the required minimum in order to maximise public involvement in the process.

As already noted, in the early to mid-1990s, health authorities in the North East and West Midlands of England mounted *very vigorous information campaigns* in support of fluoridation and sought the maximum possible response from relevant local organisations and the public. Successful publicity techniques used in one or both of these campaigns, included:

- pre-consultation *information campaigns* (through the media and through leaflets and posters widely distributed to dental surgeries, GP practices, health centres, clinics, hospital out-patient departments, libraries) on the state of local dental health, inequalities between different geographical areas or sections of the community, and the options for reducing those inequalities;
- offers to make *presentations on the state of dental health* to elected representatives, community organisations, parents' groups, schools and other interested bodies;
- at the commencement of the publicity and consultation exercise, *circulation to local authorities, Community Health Councils, MPs and town or parish councils of an information pack* containing copies of the formal consultation document supported by detailed background information and scientific evidence of the dental benefits and safety of fluoridation;
- an *initial press conference to announce the proposals,* followed up by a series of news releases and editorial features to explain the issues in greater detail and deal with queries and concerns which are raised during the three month consultation period;
- a willingness to supply *well-informed spokespersons for radio and television programmes and debates;*
- extensive circulation of a *summary version of the consultation document in leaflet form* on a door-to-door basis (subject to feasibility and cost) as well as to dental surgeries, GP practices, health centres, clinics, hospitals, libraries, council offices, schools, colleges and other public places;
- insertion of *advertising features in major local newspapers* to summarise the key points from the consultation document;
- *poster displays* in NHS premises;
- independently conducted *opinion surveys* asking a demographically representative sample of the population concerned whether they think fluoride should be added to water to reduce tooth decay;
- *briefing materials* distributed widely to health care professionals in order to enable them to respond to their patients' questions about fluoridation;
- establishment of a *free telephone information line* for people to obtain further information;
- provision of *speakers* on request for public meetings arranged by local community organisations to discuss the merits of fluoridation.

Future consultations

We believe that requirements for undertaking future consultation exercises on fluoridation should include all or most of the above publicity techniques to ensure that people are well informed about what is being proposed. However, other techniques that might also be included are:

- *focus groups* comprising a cross section of people from the communities affected, or a cross section of users of dental services or parents of children;
- consultation meetings with the *water company's customer liaison panel;*
- *inter-active web sites* through which people can seek information and/or record their views.

The new Act makes clear that the bodies responsible for future consultations about fluoridation will be, in England, Strategic Health Authorities (SHAs), and, in Wales, the Assembly. In recent times the NHS has developed considerable expertise in involving the public in large-scale consultation exercises which have informed the establishment of the Commission for Patient and Public Involvement in Health, and SHAs have played an important role in these consultations. They are therefore both knowledgeable about the health needs of their populations, and experienced in the process of engaging local stakeholders in consultations and drawing out the issues.

At the time of writing, the new Regulations governing fluoridation consultations were in preparation. The Government's declared intention to strengthen and make more explicit the publicity and consultation process by developing regulations that will:

- provide SHAs with appropriate guidance relating to public consultations about proposals for new fluoridation schemes;
- ensure that such guidance is based on best practice and the most up-to-date methods, satisfies the requirements of the water industry, and, as far as possible, meets the concerns

of other interested bodies such as local authorities, professional and consumer groups;
- ensure that consultations provide communities with evidence-based information such that all can understand and are given an opportunity to participate;
- ensure that consultations are capable of ascertaining the wishes of the population as a whole – particularly those in less privileged communities who have most to gain from fluoridation, but who often do not participate in the democratic process;
- lay down the process that must be followed by SHAs, and the requirements that must be satisfied before new fluoridation schemes can go ahead.

The concept of involving local communities in policy-making has developed enormously since the late 1990s in both local government and the health service [10-12]. As a result improved methods of conducting public consultations have been developed. Simple ballots or referendums are no longer considered adequate to ensure that consultations range sufficiently widely to take in all shades of opinion – particularly on issues as complex as water fluoridation. Instead, a basket of consultation methods would be necessary [13]. Future consultations on fluoridation proposals should therefore use modern validated methods which provide a credible means of assessing the views of the local population.

In addition, since the 1990s, the statutory mechanisms for involving the local community in health policy have altered. Community Health Councils have been abolished, and the Commission for Patient and Public Involvement has been set up at a national level to ensure that patients and the public have a strong voice in all matters that affect their health and health services. Under the Commission's auspices, Patient and Public Involvement Forums are being established across England, attached to, but independent of, every NHS Trust and Primary Care Trust. They will be made up of patients and members of the public who will have powers to influence local health issues. The 'Our Health' network is also being created, to provide a two-way channel of communication between the PPI Forums and the communities they serve.

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Technical and Scientific Aspects of Water Fluoridation

Key points

- Worldwide there are many thousands of fluoridation schemes in operation – the earliest dating from 1945. Water suppliers have therefore accumulated a wealth of practical experience in managing the fluoridation process safely and efficiently.
- The practice of adjusting the natural level of fluoride in drinking water to improve dental health began in 1945 in the city of Grand Rapids in the USA. Since then hundreds of millions of people worldwide have regularly consumed artificially fluoridated water – including nowadays around 350million, over 160 million of them in the USA.
- The fluoride ion produced from artificial fluoridation behaves identically to the fluoride ion naturally present in water supplies, which means that, chemically, there is no difference between artificial and natural fluoridation.
- Water fluoridation has an excellent safety record.

Understanding the chemistry of fluoride in water

Fluoride occurs naturally in all water supplies. Artificial water fluoridation is the process of adjusting the naturally occurring fluoride in water supplies to a level that is known to benefit teeth: 1 part of fluoride to one million parts of water (1 ppm)[i] . This is a level that occurs naturally in many places throughout the world. In the UK, for example, the water supply for Hartlepool has a natural fluoride content a little higher than this at around 1.2 ppm, and in some parts of Essex it was higher still.

Fluorides are abundant in the earth's crust and are present in the environment largely due to volcanic and industrial activity. Fluoride is present in water supplies as a result of having been dissolved out of the rocks and soils over which the water has travelled. There are two normal forms of fluoride, *inorganic* and *organic;* however, in dentistry, medicine and public health, only the inorganic form (which yields the fluoride ion) is important. Inorganic fluoride also occurs in two different forms: *ionic fluoride,* and *nonionic fluoride.* Importantly however, it is the concentration of *ionic fluoride* in solution that is referred to (generally in parts per million - ppm) when we talk of the fluoride concentration of a water supply. The concentration of fluoride in water is analysed by the *fluoride ion specific electrode* which measures free fluoride ions, not fluoride bound to metal ions such as calcium, magnesium, iron or aluminium [1].

The natural fluoride concentration of ground waters is affected by the availability and solubility of fluoride-containing minerals and the porosity of rocks and soils over which the water passes, in addition to temperature, pH, and the presence of other minerals such as calcium, aluminium and iron which may combine with the fluoride ion. Ground waters in the United States have been reported to have fluoride concentrations of up to 67 parts per million, and in parts of India and Africa much higher concentrations have been reported. Most surface waters contain much lower fluoride concentrations - usually less than 0.1 ppm, but reaching 1.0 ppm in some rivers in the UK, Spain, Canada, Japan, and Finland [1].

[i] Parts per million (ppm) is the same as milligrams per litre (mg/l or mgl^{-1})

In parts of some undeveloped countries where the climate is hot, and safe water supplies are unavailable, very high natural levels of fluoride in drinking water can cause damage to the bones and teeth of humans and animals if consumed over many years. (Such water supplies are often also contaminated with unsafe levels of other natural chemicals including arsenic, iron and salts.) However, in developed countries with temperate climates such as the UK, USA and Canada, there is no evidence of harm to human health from waterborne fluoride - even in populations where the level of fluoride in drinking water is in excess of that known to be optimal for dental health - 1 part of fluoride for every one million parts of water (1 ppm) [2]. Many studies of the health of populations in temperate climates drinking water with natural fluoride concentrations up to 8 ppm have found no evidence of harmful effects [3].

Expert review of the chemistry and uptake of fluoride in drinking water

The laws of chemistry dictate that fluoride ions in solution in water are identical whether they occur naturally in the water or are added; therefore scientists have believed since artificial water fluoridation first began in the United States in 1945, that the body's uptake of fluoride from water is the same whether the fluoride level is naturally elevated or artificially adjusted. However, opponents of water fluoridation increasingly claim that the body's uptake of fluoride from naturally fluoridated water is different from that of artificially fluoridated water, and that artificially fluoridated water is in some way harmful.

Because of such claims, and to improve our understanding of the chemistry of water fluoridation, in 2002 experts at WRc-NSF were asked to provide an independent expert review of the chemistry and uptake (bioavailability) of fluoride in drinking water. The full report of the WRc-NSF study [4] is available on the British Fluoridation Society website (www.bfsweb.org/wrcreport.pdf). Below is a lay summary of the report that has been reviewed and approved by the authors of the original study.

Study aims

The aim of the study was to answer the following key questions:

1. Are there differences in uptake of fluoride naturally present and that added to the water supply?
2. Does water hardness affect the uptake of fluoride in humans?
3. Does fluoride at around 1 part per million (1 ppm) affect the uptake of other constituents of water e.g. Aluminium?
4. Does fluoride at around 1 ppm affect the possibility of interactions either between the constituents of water, or between water and the pipes through which it travels?
5. Do other components of the artificially added fluoride compounds increase the toxicity of water?

Study method

Questions 1 to 4 were addressed by calculating the outcome of chemical reactions between fluoride and other water constituents and interpreting the results in terms of bioavailability (uptake). The outcome of chemical reactions (the 'speciation' of the resulting mixture of chemicals dissolved in water) were calculated using the accepted scientific method of *'chemical equilibrium and mass balance modelling'*. The potential effects on bioavailability (uptake) were then assessed based upon the results.

In drinking water there are many chemical reactions taking place at any one time, and although it is possible to model all of these reactions simultaneously, the models become complicated and can give results that are difficult to interpret. The WRc-NSF scientists thought that the results for each individual substance would be more clear-cut; therefore to keep the chemical models simple and to make the results easier to understand, separate models were constructed to address each question.

Question 5 was addressed by investigating the impurities that would be added based on product specifications and actual product quality data for fluoridation chemicals.

Results

1. Added fluoride was shown to be identical to 'natural' fluoride.

Natural fluoridation

All waters contain fluoride at some concentration as a result of having been dissolved out of the rocks over which the water has travelled such as fluorspar (natural calcium fluoride - CaF_2). When minerals such as fluorspar dissolve in water the molecules split up to produce calcium and fluoride ions - shown in the equation below as $2F^-$

$$CaF_2 \rightarrow Ca^{2+} + 2F^-$$

Artificial fluoridation

In the UK only two fluoride compounds are permitted for the adjustment of fluoride levels to improve dental health (water fluoridation). They are hexafluorosilicic acid (H_2SiF_6) which is a liquid, and sodium hexafluorosilicate (Na_2SiF_6) which is a crystalline powder. However, in practice the powder, sodium hexafluorosilicate, is used far less commonly than the liquid, hexafluorosilicic acid.

When hexafluorosilicic acid is added to water it splits up releasing fluoride ions (shown in the equation below as $6F^-$), the overall reaction being:

$$H_2SiF_6 + 4H_2O \leftrightarrow 6F^- + Si(OH)_4 + 6H^+$$

With sodium hexafluorosilicate the reaction is:

$$Na_2SiF_6 + 4H_2O \leftrightarrow 6F^- Si(OH)_4 + 2Na^+ + 4H^+$$

Is the fluoride the same in natural and artificially fluoridated water?

To check whether the fluoride added to water is the same as that which is naturally present, it was necessary to establish the extent to which the hexafluorosilicate ion (SiF_6^{2-}) splits up to form fluoride ion (F^-) and silicic acid ($Si(OH)_4$) – a process known as the *dissociation reaction*. The calculation covered the range of pH levels normally encountered in water supplies (a pH below 7 indicates acidity, a pH in excess of 7 indicates alkalinity), and the 'worst case' in terms of the relevant chemical reactions (by using the smallest value hydrolysis constant). The results showed that, effectively, all of the hexafluorosilicate would dissolve to form free fluoride ion (F^-).

Next, the rate at which the *dissociation reaction* takes place was calculated to check whether the process of splitting will take place within the timescale relevant to water treatment and distribution (hours to days). The conclusion was that the process is complete by the time the water reaches the consumers tap.

In other words the fluoride ion produced from artificial fluoridation will behave identically to the fluoride ion naturally present in water supplies, which means that, chemically, there is absolutely no difference between artificial and natural fluoridation.

2. The effects of calcium and magnesium (water hardness) and sodium on fluoride availability were calculated.

The hardness of water is determined by the amount of dissolved calcium and magnesium. A typical ratio of 1:5 magnesium to calcium was used to calculate the proportion of free fluoride ion in relation to the concentration of calcium and magnesium.

Water hardness may be expressed in a variety of units. In the UK it is commonly expressed in terms of milligrams per litre (mg/l) as calcium, or mg/l as calcium carbonate ($CaCO_3$). The hardness in mg/l calcium carbonate, is 2.5 times the hardness in mg/l as calcium.

Water hardness is often classified by descriptive words as shown in Table 1.

Table 1 Classification of water hardness

Description of water	Hardness in mg/l as calcium carbonate	Hardness in mg/l as calcium
Soft	up to 50	Up to 20
Moderately soft	50 – 100	20 - 40
Slightly hard	100 – 150	40 - 60
Moderately hard	150 – 200	60 - 80
Hard	200 – 300	80 - 120
Very hard	over 300	Over 120

The hardness of water supplies in the UK covers a wide range, and some examples are given in Table 2 below. It should be noted however that these figures are approximate, and that even within quite small geographical areas there can be large differences in water hardness; also, hardness can vary seasonally.

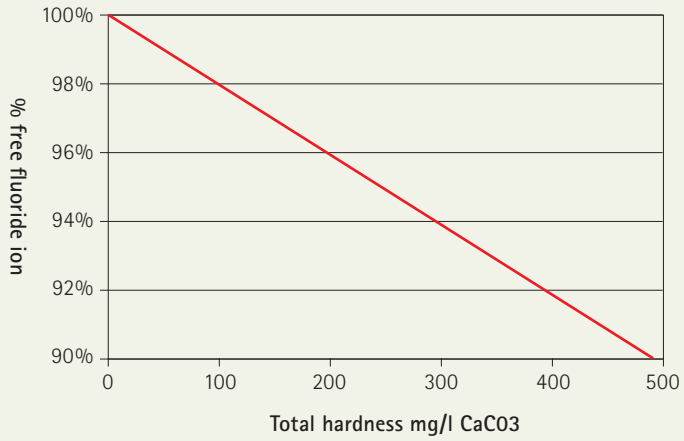
Table 2 The hardness of some UK water supplies

Location	Total hardness in mg/l as calcium carbonate approximate
Glasgow	20
Birmingham	50
Newcastle	120
London	300
Hartlepool	450

In the WRc-NSF study calculations were made for water hardness in the range 0 to 500 mg/l calcium carbonate which more than covers the range that occurs in the UK. The results of the calculations are shown in Figure 1.

Figure 1 Effect of water hardness on fluoride ion concentration

(Note that the scale on the vertical axis starts at 90%)



- It can be seen that even with extremely hard waters, 90% or more of the total fluoride is present as free fluoride ion. The amount of calcium and magnesium present that would be bound to fluoride would be very small indeed – for example, in water with 1 ppm fluoride, less than 0.05% of the calcium would be present as calcium fluoride.
- It was therefore concluded that the effect of water hardness on the uptake of fluoride would be very small.
- Using a similar approach it was calculated that in the presence of 100 mg/l sodium (a relatively high concentration in drinking water) 99.998% of the fluoride would be present as free fluoride ion.

3. Possible interactions with aluminium, iron, copper and lead were calculated

The interactions between fluoride and the dissolved trace metals aluminium, iron, copper, and lead were examined in a similar way to that described for calcium and magnesium above.

Aluminium

Aluminium is naturally present in some waters but occurs in drinking water predominantly through the use of aluminium sulphate in the process of water treatment to remove cloudiness. The added aluminium forms aluminium hydroxide, removing suspended material and some dissolved substances. The precipitated aluminium hydroxide is removed by settlement and filtration. The residual aluminium concentration passing into supply should not exceed 0.05 mg/l (the maximum permitted is 0.2mg/l). However, aluminium hydroxide can accumulate as a deposit within distribution systems (e.g. in dead ends).

Calculations were made using a total available fluoride concentration of 1 ppm. The results showed that fluoride forms strong complexes with aluminium. The fluoride complexes accounted for a substantial proportion of the dissolved aluminium only at pH values less than 7. This indicates that, in the presence of slightly acidic water, fluoride could dissolve aluminium deposits within the distribution system. However, since virtually all UK water supplies are likely to have pH values of greater than 7, this is unlikely to be a problem in practice.

Iron

Iron is present naturally in many water sources. It is removed during water treatment. Iron in water supplies may also be derived from corrosion of iron mains, but any concentrations present in water do not present any risk to health. Iron compounds are used in water treatment to remove cloudiness. As for aluminium, the residual iron concentration passing into supply should not exceed 0.05 mg/l (the maximum permitted is 0.2mg/l). However, concentrations above this level do occur and iron hydroxide can accumulate as a deposit within distribution systems (e.g. in dead ends).

Calculations were made using a total available fluoride concentration of 1 ppm. The results showed that less than 0.005% of the iron is present as fluoride complexes; which means that the presence of fluoride at 1 ppm has essentially no effect on the solubility of iron. Therefore fluoride will not affect the bioavailability of iron.

Copper

Traces of copper, which are not significant to health, occur naturally in many water sources and higher concentrations may occur at consumers' taps as a consequence of copper pipes. The concentrations present in water do not present any risk to health. The maximum level permitted is 3 mg/l, though in practice the levels in supplies are very much less than this.

Under all the conditions examined by the WRc-NSF scientists, the reaction with fluoride accounted for less than 0.1% of the dissolved copper. It was found that even under conditions of low pH and low alkalinity (pH 6, alkalinity 10 mg/l as $CaCO_3$) the presence of 1 ppm fluoride would only increase copper solubility by 0.05%. Therefore fluoride will not affect the bioavailability of copper.

Lead

Lead is not normally present in water sources but may be present at consumers' taps if lead pipes are present.

Calculations were made using a total available fluoride concentration of 1 ppm, and at a range of pH values and alkalinity. Under all the conditions examined the reactions with fluoride accounted for less than 0.5% of the dissolved lead. Even under conditions of low pH and low alkalinity it was found that the presence of 1 mg/l fluoride would only increase lead solubility by 0.5%. Therefore fluoride will not affect the bioavailability of lead.

A different, more detailed study, by scientists in the United States examined in great depth the possibility of lead concentrations in drinking water being increased following fluoridation using hexafluorosilicate. A sophisticated model that considered all possible reactions together was used [5]. They considered the possible reactions of lead with fluoride, and found that the lead fluoride complexes accounted for less than 1% of the total dissolved lead – i.e. essentially the same result as reported by the WRc-NSF scientists. The US scientists found that the concentration of lead fluorosilicate ($PbSiF_6$) would be vanishingly small - one molecule in 1000 litres of water at pH 6. They also showed that the small pH drop caused by fluoridating with hexafluorosilicic acid has an insignificant effect on dissolving lead. Overall they concluded that,

> *'No credible evidence exists to show that water fluoridation has any quantitatable effects on the solubility, bioavailability, bioaccumulation or reactivity of lead(0) or lead(II) compounds.'*

4. Interactions with other chemical reactions and the distribution system were considered.

It has been shown in Sections 2 and 3 above that, with the exception of aluminium, the major and minor chemicals present in water do not react to any significant extent with fluoride. This means that at the concentrations relevant to fluoridation, the fluoride ion could not cause significant interactions between other compounds (e.g. by forming chemical bridges).

The WRc-NSF scientists found very little published information on the effects of fluoridation on distribution system corrosion. This they thought was probably because any such effects are negligible and do not cause any problems in practice. They found that while fluoridation using hexafluorosilicic acid will cause a reduction in both pH and alkalinity, the low dose used in practice, means that such effects are likely to be negligible except in very soft, poorly buffered[i], waters. Calculations show, for example, that fluoridation to 1ppm using hexafluorosilicic acid would reduce the pH from 7.00 to 6.70 in a soft poorly buffered water (alkalinity 20 mg/l as $CaCO_3$). In harder water (alkalinity 200 mg/l as $CaCO_3$) the pH would only drop to 6.96. Fluoridation using sodium hexafluorosilicate will only slightly reduce pH and alkalinity. The WRc-NSF scientists noted that Urbansky and Schock[5] who modelled the effects on pH and buffer capacity support this conclusion.

In practice however, water suppliers add alkali to adjust the pH to an appropriate value before the water leaves the water treatment works; therefore virtually all UK public water supplies have pH greater than 7. The WRc scientists concluded that it seems unlikely that fluoridation would have a noticeable effect on corrosion.

5. The quantities of trace metals added with fluoridation chemicals were calculated both for the minimum specification (worst case) and actual quality of fluoridation chemicals.

The impact fluoridation has on trace metals concentrations in drinking water was determined by considering the specifications for fluoridation chemicals (the 'worst case'), and by calculations based upon actual product quality.

[i] Poorly buffered water is water with little capacity to resist a change of pH if acid or alkali is added. In fresh waters the alkalinity (carbonate and bicarbonate) provides the buffer capacity. Hard waters almost invariably have high alkalinity and consequently greater buffer capacity.

European standards for water treatment chemicals under European Union legislation (ENs) are published by the British Standards Institution as BS ENs. Water treatment chemicals which conform to a BS EN may be used without the approval of the Authorities, provided that any national conditions of use are observed – in the case of fluoridation chemicals, they have to be used in accordance with the UK Code of Practice [6].

European standards for hexafluorosilicic acid and sodium hexafluorosilicic acid have recently been adopted and published by the British Standards Institution: BS ENs 12174 [7], and 12175 [8]. These standards are listed in the latest List of Approved Products [9]. The standards lay down requirements for product purity that are summarised in Tables 3 and 4. Using hexafluorosilicic acid as an example, it can be seen from Table 3 that to meet European and British Standards, the product must contain no more than 400mg per kg (400 parts per million) of arsenic, 40 mg per kg of cadmium, 10 mg per kg of mercury, 400 mg per kg of lead and so on.

On the face of it the presence of such toxic substances in a product to be added to drinking water supplies may be alarming to the lay reader. However, it is important to be aware that:

- To achieve the optimal concentration of one part of fluoride per million parts of water, the product is diluted approximately 170,000 times;
- Because of the high dilution factor the levels of any impurities added as a result of fluoridation are very small indeed, and have no discernible impact on the toxicity of drinking water. For example, fluoridation using hexafluorosilicic acid will generally *add less than 1% of the maximum permitted levels of trace metals to water supplies* (see below); and finally,
- Like fluoride, some of these substances (eg arsenic) are naturally present in many water supplies; however, stringent European and British drinking water quality regulations - which are rigorously enforced - ensure that maximum permitted levels are far too low to be harmful (see below).

Table 3 European standard BS EN 12175 for hexafluorosilicic acid

(mg/kg is the same as parts per million).

Parameter	Units	Value
H_2SiF_6	% m/m	spec. ±5
Free acid (HF)	mg/kg product max.	1.5
Phosphate (P_2O_5)	mg/kg product max.	0.75
As (arsenic)	mg/kg H_2SiF_6 max.	400
Cd (cadmium)	mg/kg H_2SiF_6 max.	40
Cr (chromium)	mg/kg H_2SiF_6 max.	400
Hg (mercury)	mg/kg H_2SiF_6 max.	10
Ni (nickel)	mg/kg H_2SiF_6 max.	400
Pb (lead)	mg/kg H_2SiF_6 max.	400
Sb (antimony)	mg/kg H_2SiF_6 max.	80
Se (selenium)	mg/kg H_2SiF_6 max.	80

Table 4 European standard BS EN 12174 for sodium hexafluorosilicate

(mg/kg is the same as parts per million).

Parameter	Units	Value
Na_2SiF_6	% m/m min.	98
Moisture	% m/m product max.	0.3
Insolubles	% m/m product max.	0.5
As (arsenic)	mg/kg product max.	400
Cd (cadmium)	mg/kg product max.	40
Cr (chromium)	mg/kg product max.	400
Hg (mercury)	mg/kg product max.	10
Ni (nickel)	mg/kg product max.	400
Pb (lead)	mg/kg product max.	400
Sb (antimony)	mg/kg product max.	80
Se (selenium)	mg/kg product max.	80

Table 5 Impurities added by dosing hexafluorosilicic acid (mg/kg is the same as parts per million, and micrograms per litre (µg/l) is the same as parts per billion).

Element	Maximum permitted level in product, mg/kg H_2SiF_6	µg/l (micrograms per litre) added at 1 mg/l fluoride dose	Parametric Value (permitted level) in micrograms per litre (µg/l)	% of permitted level added
As (arsenic)	400	0.51	10	5.1
Cd (cadmium)	40	0.05	5	1.0
Cr (chromium)	400	0.51	50	1.0
Hg (mercury)	10	0.01	1	1.0
Ni (nickel)	400	0.51	20	2.5
Pb (lead)	400	0.51	10	5.1
Sb (antimony)	80	0.10	5	2.0
Se (selenium)	80	0.10	10	1.0

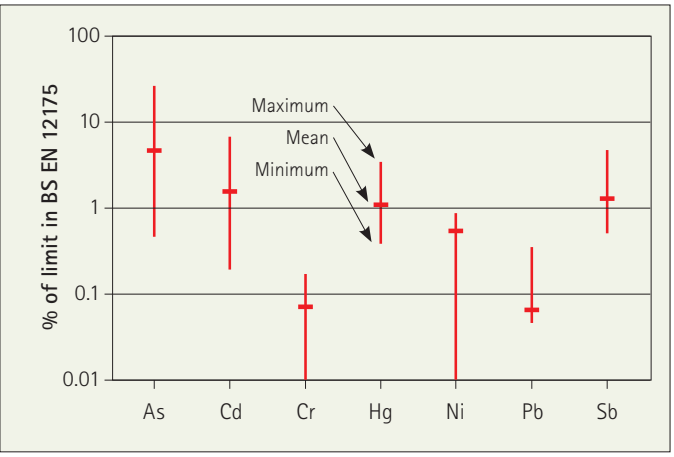
The maximum concentration of a contaminant that could be added to drinking water as a result of adding a fluoride dose of 1 ppm was calculated. These are shown in Tables 5 and 6, with the European permitted levels (Parametric Values) for comparison. Using arsenic and lead as examples, it can be seen that at a dose of 1 mg/l as F, the highest that would be used in practice, only about 5% of the permitted level for these parameters could be added by a product that contained the maximum permitted levels of trace metals (see shaded areas in Table 5).

Table 6 Impurities added by dosing sodium hexafluorosilicate (mg/kg is the same as parts per million, and micrograms per litre (µg/l) is the same as parts per billion).

Element	Maximum permitted level in product, mg/kg H_2SiF_6	µg/l (micrograms per litre) added at 1 mg/l fluoride dose	Parametric Value (permitted level) in micro-grams per litre (µg/l)	% of per-mitted level added
As (arsenic)	400	0.67	10	6.7
Cd (cadmium)	40	0.07	5	1.3
Cr (chromium)	400	0.67	50	1.3
Hg (mercury)	10	0.02	1	1.7
Ni (nickel)	400	0.67	20	3.3
Pb (lead)	400	0.67	10	6.7
Sb (antimony)	80	0.13	5	2.7
Se (selenium)	80	0.13	10	1.3

In practice, trace metal contents are lower than the limits in the BS EN standards permit. Figure 2 shows a summary of data on hexafluorosilicic acid supplied by Hydro Chemicals, based on monthly analyses over the period January 1996 to June 2000[i]. (The vast majority of fluoridation plants in the UK use hexafluorosilicic acid as the fluoridating agent.)

Figure 2 Summary of quality of hexafluorosilicic acid



The maximum trace metal concentrations found were approximately 20% of the limit in the BS EN standard (data for selenium were not available). Therefore, because of dilution, using hexafluorosilicic acid for fluoridation will generally add less than 1% of the maximum permitted levels of trace metals. The permitted limits in drinking water are based on values derived by the World Health Organization as being safe for a lifetime's exposure (consumption of 2 litres of water per day over 70 years).

Conclusions

- In terms of chemistry and bioavailability (uptake) there is no difference between added and 'natural' fluoride.
- The effect of calcium and magnesium (water hardness) and sodium – on the chemical reactions and hence uptake of fluoride is very small.
- Fluoride forms strong bonds with aluminium so effects on uptake are theoretically possible in the presence of slightly acidic water. However, since virtually all UK water supplies are likely to have pH values of greater than 7, this is unlikely to be a problem in practice.
- The presence of fluoride at a concentration of 1 ppm will have practically no effect on the chemical reactions and uptake of iron, copper or lead.
- There is no plausible mechanism by which fluoride could interact with other chemical reactions in drinking water; fluoridation will therefore have negligible impact on the corrosiveness of water in the distribution system.
- The traces of impurities added as a result of fluoridation are very small and would have no measurable impact on the toxicity of drinking water.

The manufacture and regulation of the chemicals used for water fluoridation

Permitted chemicals

Drinking water safety is taken very seriously in the UK. Very strict European and UK regulations govern what can be added to public water supplies. As has been described in the previous section, European standards for water treatment chemicals under European Union legislation (ENs) are published by the British Standards Institution as BS ENs. Only water treatment chemicals which conform to a BS EN may be used without the approval of the Authorities, provided that any national conditions of use are observed – in

[i] Bob Hassall, Hydro Chemicals (UK) Limited, Personal Communication, June 2000.

the case of fluoridation chemicals, they have to be used in accordance with the UK Code of Practice [6]. The Drinking Water Inspectorate (DWi) which is part of the Department for Environment Food and Rural Affairs (DEFRA) is responsible for enforcing the standards, and does so by undertaking regular checks.

Only two compounds of fluoride are permitted for artificial fluoridation in the UK [10, 11]:

- Hexafluorosilicic acid (H_2SiF_6) also known as fluorosilicic acid
- Disodium hexafluorosilicate (Na_2SiF_6) also known as sodium fluorosilicate

These compounds achieve the desired concentration of fluoride (1 part per million) reliably and safely, and must meet Department of Environment purity specifications [6].

How the chemicals are produced

The chemicals used for water fluoridation are specifically manufactured to exacting quality standards; they are important co-products of the manufacture of phosphate fertilisers. The manufacturing process involves recovery of the product from a vapour phase which ensures a high degree of purity. The end result is a valuable and useful resource that meets very high quality specifications.

The manufacturing process

The vast majority of fluoridation plants in the UK use hexafluorosilicic acid, which is a liquid, as the fluoridating agent.

Fluorspar *Cryolite* *Apatite*

The raw materials

Fluoride is found in a solid form in minerals such as fluorspar, cryolite and apatite (pictured above from left to right). Fluorspar (also called fluorite) is found in most parts of the world. It is a mineral containing between 30 to 98 percent calcium fluoride. Cryolite is a compound of aluminium, sodium, and fluoride. Because of its low melting point, it is preferred for industrial use, but is not a major source of fluoride for water fluoridation. Apatite is a deposit of a mixture of calcium compounds, including calcium phosphates, calcium fluorides, and calcium carbonates. Apatite contains between 3 to 7 percent fluoride and is the main source of fluorides used in water fluoridation.

To obtain *hexafluorosilicic acid (H_2SiF_6):*

- The fluoride-containing rock is ground up and treated with sulphuric acid producing hydrofluoric acid gas (HF);
- The HF gas then begins a purification process involving washing, cooling, condensation, and finally distillation (rectification);
- The HF is then reacted with silica to produce hexafluorosilicic acid with a concentration of 37 to 42 per cent.

By neutralising hexafluorosilicic acid with sodium carbonate and precipitating the solid matter, manufacturers can readily convert liquid hexafluorosilicic acid into the powder *disodium hexafluorosilicate (Na_2SiF_6).*

As has been discussed in detail in the previous section, trace elements such as lead and arsenic are present in minute quantities in fluoride compounds. This is because fluoride compounds are derived from naturally occurring minerals, and such trace elements are always present in minerals of this type. However, maximum levels of these trace elements – including arsenic (and lead) are laid down as standards and details are incorporated in the product specifications in the Code of Practice [6].

It is likely that few people realise that arsenic occurs naturally in some drinking waters – or that in the UK some natural levels are above the permitted level of 10 parts per billion and therefore must be reduced to comply with Water Quality Regulations [12]. Fortunately the levels of such unwanted trace elements in the fluoride compounds are minute, and become immeasurable when diluted thousands of times to achieve 1 part per million of fluoride

in water. Fluoridation therefore makes no measurable contribution to the concentration of these substances in the water supplies.

Common misconceptions

It is often claimed by opponents of fluoridation that the aluminium and phosphate fertiliser industries have a vested interest in promoting water fluoridation. It is perhaps worthwhile addressing those claims here.

The phosphate fertiliser industry

Apatite is the raw material used in the manufacture of phosphate fertilizers, and Fluorine for the manufacture of fluorides for water fluoridation is recovered from this process. The manufacturing process of fluorosilicic acid for water fluoridation involves recovery of the product from a vapour phase, which ensures a high degree of purity. The product is therefore manufactured in *tandem* with the production of phosphoric acid, and can be described as a co-product. It would, however, be equally valid to describe phosphate fertilizers as co-products of the manufacture of fluorosilicic acid, since each are valuable products.

Prior to 1987 when hexafluorosilicic acid was produced in the UK for water fluoridation, manufacture was intermittent to match market need and represented only about 10% of the total Fluorine that could be extracted from the process. Since production in the UK ceased, chemicals companies have imported supplies of hexafluorosilicic acid to service the established market. The product is Quality Assured to BS5750, and as already stated, the specification conforms to that given in the Department of the Environment's Code of Practice on Technical Aspects of Fluoridation of Water Supplies.

The aluminium industry

The basis of the claims that the aluminium industry promotes fluoridation in order to dispose of its toxic waste seems to be based on a tenuous link more than 40 years ago in the USA. In the 1940s, The Aluminium Company of America (ALCOA) acquired a chemical manufacturing plant which produced fluoride compounds by the method described above (not as a waste product of aluminium production). ALCOA was then using sodium fluoride as a catalyst in the aluminium smelting process, but soon replaced sodium fluoride with less costly fluoride compounds. ALCOA sold the chemical plant in the early 1950s; their last sales of sodium fluoride were in 1952[i].

Nowadays, the aluminium industry is the largest *user* of fluoride compounds, and has no interest in promoting water fluoridation whatsoever.

Summary

Only two compounds of fluoride are permitted for artificial fluoridation in the UK: hexafluorosilicic acid (H_2SiF_6) and disodium fluorosilicate (Na_2SiF_6). These compounds are manufactured to exacting quality standards and must meet Department of the Environment purity specifications. Fluoride compounds used for water fluoridation are not now, and have never been, obtained as industrial waste.

Safety at the water treatment works

The Department of the Environment Code of Practice ensures that safety is the prime consideration when fluoride is added to water [6]. Water companies in the UK have almost 50 years experience in the successful operation of fluoridation schemes, and around the world there are thousands of highly successful fluoridation schemes in operation. In the United States alone – the country with the largest number of people drinking water with added fluoride - there are over 14,000 individual water systems operating fluoridation schemes.

A wealth of practical experience

Water suppliers have accumulated a wealth of practical experience in managing the fluoridation process safely and efficiently. In the UK, the first schemes were introduced on an experimental basis in Anglesey, Watford, Kilmarnock and Andover in the mid-1950s.

The first large-scale scheme started in Birmingham and Solihull in 1964. Another followed a few years later in Newcastle. In all operations concerning the process of fluoridation at the water treatment plant, the emphasis is very much on safety[ii]. The aim throughout is to make absolutely certain that only the right amount of fluoride is added to the water.

UK water companies that operate fluoridation schemes

UK water companies that are currently operating fluoridation schemes include:

- Anglian Water
- Northumbrian Water
- Severn Trent Water
- South Staffordshire Water Plc
- United Utilities Water

[i] Source NIDR US Public Health Service 1993

[ii] The UK requirements for safety are considered to be among the most rigorous in the world (personal communication Tom Reeves, USPHS, CDC 5 May 2003.)

UK water suppliers that have in the past operated fluoridation schemes include:

- Department of the Environment for Ireland
- Thames Water
- Welsh Water
- Yorkshire Water

Code of practice

Strict operational criteria are laid down in the 1987 *'Code of Practice on Technical Aspects of Fluoridation of Water Supplies'* issued by the Department of the Environment [6]. These are designed to ensure that:

- The average fluoride content of the water leaving the treatment works in a calendar month is maintained between 0.9 and 1.1 parts per million, calculated for those periods when the fluoridation plant is in operation;

Fluoride monitor

- The fluoride content of the water leaving the treatment works is maintained between 0.8 and 1.2 parts per million for at least 90% of the time when the fluoridation plant is in operation; and,
- The fluoride content of the water leaving the treatment works shall not exceed 1.5 parts per million at any time.

How fluoride is added to the water supply

During the process of water treatment at the Water Treatment Works a solution of fluoride is injected into water under close control.

Although the physical layout of the fluoridation equipment will vary between treatment works, the essential principles of the design and operation are determined by the need to meet the operational and Health and Safety criteria laid down in the Code of Practice. These will be common to all fluoridation plants and include:

a Bulk storage tanks suitably constructed, located, and labelled, to receive deliveries and store the fluoride liquid;
b Working storage (Day Tank) which holds only enough fluoride for one day's operation;

Day tank

c An injection pump to deliver fluoride into the water at the rate required at a point beyond which good mixing will be achieved before the water leaves the water treatment works;
d A continuous recording fluoride monitor, linked to an appropriate alarm system and automatic plant shut down to prevent over-dosing;
e A programme of regular supervision, sampling and reporting; and,
f Regular servicing and maintenance.

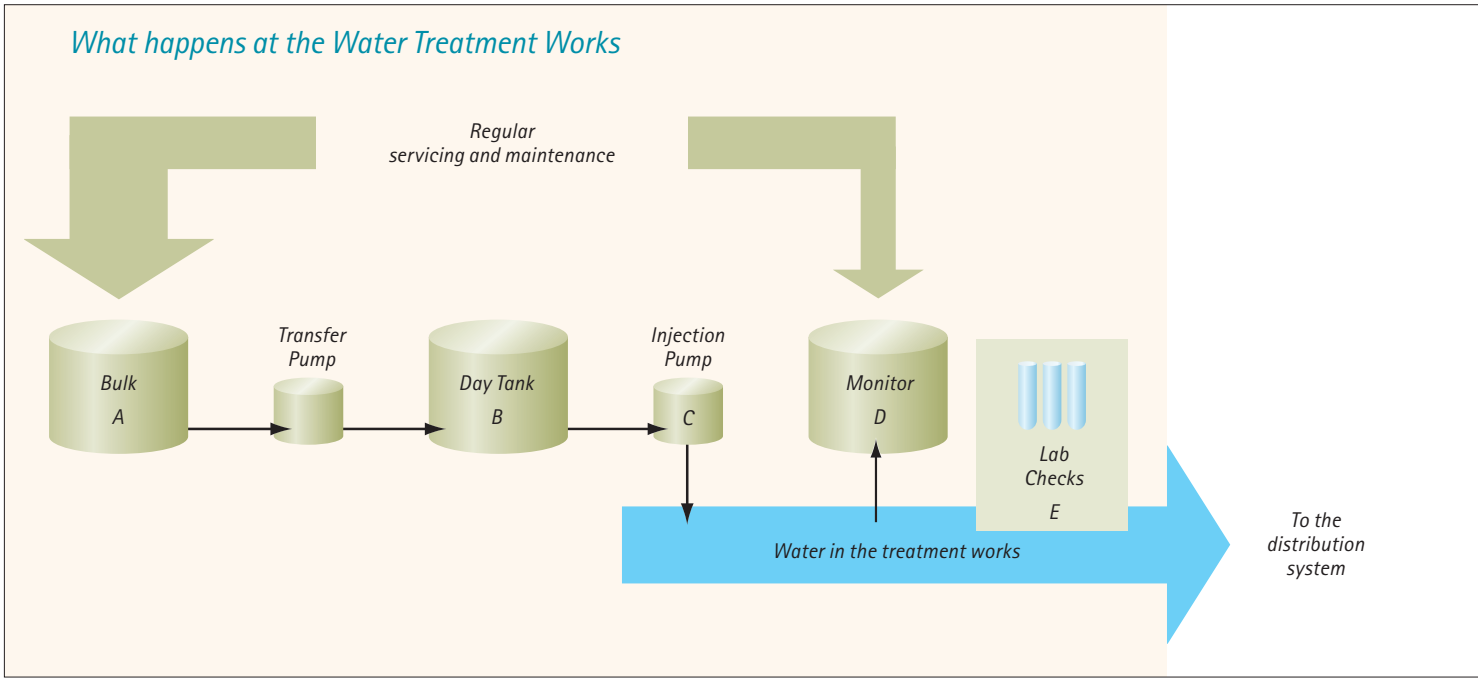
What happens at the Water Treatment Works

One day's supply at a time

The fluoride is delivered by tanker and kept in a bulk storage tank (A in the diagram). Every day, the right amount needed for one day's operation is transferred to a separate smaller `Day Tank' (B in the diagram). Both tanks are specially constructed from acid resistant material, and the day tank can hold a maximum of only one day's supply at a time.

Pump operating at a maximum capacity

A second safety feature is the injection pump that transfers the fluoride liquid from the day tank into the mains (C in the diagram). The pump is automatic and its pumping rate is proportional to the flow of water. Even when operating at maximum capacity, it is only capable of adding fluoride at the rate required in relation to the flow of water through the mains. If the water flow reduces or stops, the pump will also stop; furthermore should the pump break down or malfunction, the result would be the addition



of *less* than the required amount of fluoride, not more.

Monitoring 24 hours a day

The third safety feature is the continuous recording fluoride monitor (D in the diagram) - every second of every day the fluoride level in the water is monitored at a sampling point which is some distance from the injection pump, but before water leaves the Treatment Works and enters the distribution system. The process is automatic and is carried out by equipment which itself is regularly checked to ensure its accuracy. If at any time the fluoride level should exceed the permitted level, a warning is sounded in the control room and the whole plant is automatically shut down. The monitor itself also incorporates a fail-safe shut down of the fluoridation plant should the monitor or controller become faulty.

Laboratory checks

Finally, there is a double check in the laboratory, with samples taken regularly from several taps in the local distribution system for testing and analysis (E in the diagram). Reports are sent to the directors of public health of the districts covered by the fluoridation scheme. This is in addition to the general sampling and monitoring required under water quality regulations [12]

Additional monitors and the need to update the code of practice

The safety features described above are *required;* all water companies operating fluoridation plant must comply, and the Drinking Water Inspectorate carries out regular checks on their performance in this respect.

In addition to the required safety arrangements described above, some water companies have installed additional monitors in their fluoridation plants. Water UK, the body that represents the whole of the UK water industry, has suggested that the Code of Practice should be reviewed and updated from time to time (see Water UK policy statement at the end of this section). The Code was originally published in 1987 and was prepared by a multidisciplinary working group of experts from the Department of the Environment, the water industry and the NHS. At the time of printing, the Drinking Water Inspectorate was leading a review of the 1987 Code; an updated 2004 edition was expected imminently.

The record on safety

Many of the chemicals used to treat our water supplies are highly toxic in their concentrated forms, so the possibility always exists for accidents resulting in harm to people working with the chemicals. Of course the water industry takes its Health and Safety responsibilities very seriously, and fortunately serious accidents involving water treatment chemicals are rare. Happily, since fluoridation began in the UK in the in the mid-1950s, there have been no such accidents involving fluoride.

Worldwide there are many thousands of fluoridation schemes in operation – the earliest dating from 1945. Water suppliers have therefore accumulated a wealth of practical experience in managing the fluoridation process safely and efficiently. The practice of adjusting the natural level of fluoride in drinking water to improve dental health began in 1945 in the city

of Grand Rapids in the USA. Since then hundreds of millions of people worldwide have regularly consumed fluoridated water – including nowadays around 350million, over 160 million of them in the USA.

Water fluoridation has an excellent safety record. However, some serious spillage and overfeed incidents have been reported in the United States, though these are extremely rare [13]. In the USA many fluoridation plants serve very small communities such as schools and relatively undeveloped remote villages. Training and supervision of water plant operators in such locations tends to be less stringent than in the highly regulated UK water industry, and equipment such as continuous recording fluoride monitors is not the norm. Such incidents are always investigated, and often found to have resulted from lack of operator training and supervision, and bad or poor equipment design. In order to minimise the risk of such accidents, for many years the US Public Health Service Division of Oral Health at the Centers for Disease Control and Prevention (CDC) has played a major role in providing educational material and training courses for States and water companies to assist them to develop and maintain standards of competence among their water plant operators.

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Water UK policy position on fluoridation of water supplies

Date: 5 July 2001
Updated September 2002

Current legislation is unsatisfactory. Decisions relating to fluoridation must be recognised as a health issue and statutory changes should be introduced to clarify policy and procedure on fluoridation for the water industry.

Water UK's aim is to ensure that:

- The present legislative position is recognised as unsatisfactory;
- If the Government wishes to promote fluoridation there should be a change through primary legislation such that
- If the Government, Health Authorities and customers so wish, water companies can be required to increase the fluoride content of the water they supply, and
- Companies' positions in respect of their operating arrangements, costs and indemnities are properly safeguarded.

Fluoride is a health issue

- Water operators have a primary duty to provide a sufficient and wholesome supply of water.
- The decision whether to fluoridate a water supply should be entirely a health issue. Health professionals are the only people in a position to make a decision about public health measures. The current discretion on water operators whether to accede to an application from a Health Authority should be removed.
- Water operators are contractors in the arrangement, who can be required to use the water supply network to deliver a product on behalf of the relevant local Health Authorities.

Decision-making

- There should be absolute clarity in the decision making process. The respective roles and responsibilities of the Health Authorities, national and local Government and water operators need to be spelled out.
- Whilst Health Authorities are the only bodies qualified to decide on the merits of fluoridation schemes we suggest that:
  - the decision making process must be absolutely clear;
  - the process should include improved provision for consulting with the population to be affected;
  - there should be a model consultation process agreed at the national level. Whilst the water industry should have an input to the design of the model process, (which may also include local government) it should not play a part in the consultation itself;
  - a parallel consultation between the Health Authority and water operator should take place, to ensure that fluoridation plant is installed to the required standards of the water operator;
  - subject to the results of the consultation with the water operator the final decision should be taken by the Health Authority in public and in a transparent and understandable way;
  - Health Authorities requiring fluoridation schemes should nevertheless be required to liaise with water operators to ensure that the present and future operations of the water operator are not compromised through the fluoridation of the water supply.

Public Relations

- The industry requires the support of public relations work led by Government and Health Authorities to make it absolutely clear who 'owns' (the Government, Health Authorities, or both) the issue of fluoridation.
- The industry's stance must remain neutral but it will provide information to customers and organisations as appropriate on the technical issues of fluoridating water supplies.
- The Health Authorities must take the lead in producing information on areas covered by fluoridation agreements and answering general enquiries and complaints from the public.

Indemnity

- Health Authorities must be responsible for all costs incurred by water operators as a consequence of the decision to implement a fluoridation scheme including:
  - costs of all works and plant required to fluoridate and the ongoing costs of operating and maintaining plant to nationally agreed standards and monitoring costs;
  - costs of management time and lost opportunity costs;
  - training of personnel, Health and Safety issues etc;
  - full legal indemnity - ie absolute indemnity on civil liability and indemnity on strict criminal liability as far as public policy allows;
  - in the event of bulk supply, common carriage or cross border supply the costs to de-fluoridate should also be recoverable;
  - supplying water to customers who

cannot for any valid reason drink water which is fluoridated
- the action of customers and others opposed to fluoridation (including the costs of debt recovery).

- The industry also requires an undertaking from the Department of Health and DETR to provide technical help to resist claims from customers, even though the Health Authorities are primary movers.
- Indemnities should remain, even if fluoridation proposals are withdrawn.

Maintaining operational flexibility

- Operators are increasingly integrating supply systems to maintain reliable and efficient operations. This makes it increasingly difficult to implement fluoridation on a piecemeal basis.
- Operators must maintain the flexibility to supply water from a particular source to different areas as the needs arise. This may entail suspension of fluoridation of supplies in some circumstances.
- Operators must be able to supply fluoridated water to normally non-fluoridated areas on the basis of operational contingencies without incurring any liability.
- The introduction of a fluoridation scheme must not operate as a barrier to development of competition in the water industry.
- Need a model agreement.

Code of Practice on technical aspects

- The industry needs to be confident that the Code of Practice on the Technical Aspects of Fluoridation of Water Supplies reflects best practice based on up-to-date knowledge.
- We suggest that the current code of practice be withdrawn and replaced by:
  i) A DWI/WO/SO guidance letter setting out:
  a) the roles of the different agencies and water operators
  b) chemicals and specifications (linking to current drinking water regulation 25)
  c) dosage and allowable tolerances
  d) monitoring (validation and sampling regime over and above that required in the water quality regulations).

and

  ii) An industry code of practice setting out principles including:
  a) a commitment to the highest operating levels and the use of failsafe equipment
  b) storage and handling of chemicals
  c) injection process
  d) control of dose
  e) monitoring
  f) maintenance
  g) reporting requirements to Health Authorities.
  h) Health and Safety.

The Extent of Water Fluoridation

7

Key points

- Because fluoride occurs naturally in all water supplies, everyone is drinking water with some fluoride. Below 0.3 parts per million it is unlikely that any dental benefit is obtained.
- Approximately 10% of the UK population (i.e. around 6 million people) currently benefit from a water supply where the fluoride content has been adjusted or is naturally present at around the optimal level for dental health. The West Midlands is the most extensively fluoridated region.
- Worldwide around 400 million people benefit from a fluoridated water supply, with the US being one of the most extensively fluoridated countries.

Fluoridation in the UK

Approximately 6 million people in the UK receive water in which the fluoride content has been adjusted to the optimum level for dental health of around one part of fluoride per million parts of water, or that has a naturally occurring fluoride level of around this level[i]. This means that around one in ten of the total population of the UK is currently benefiting from water with a fluoride level that is capable of providing protection against tooth decay.

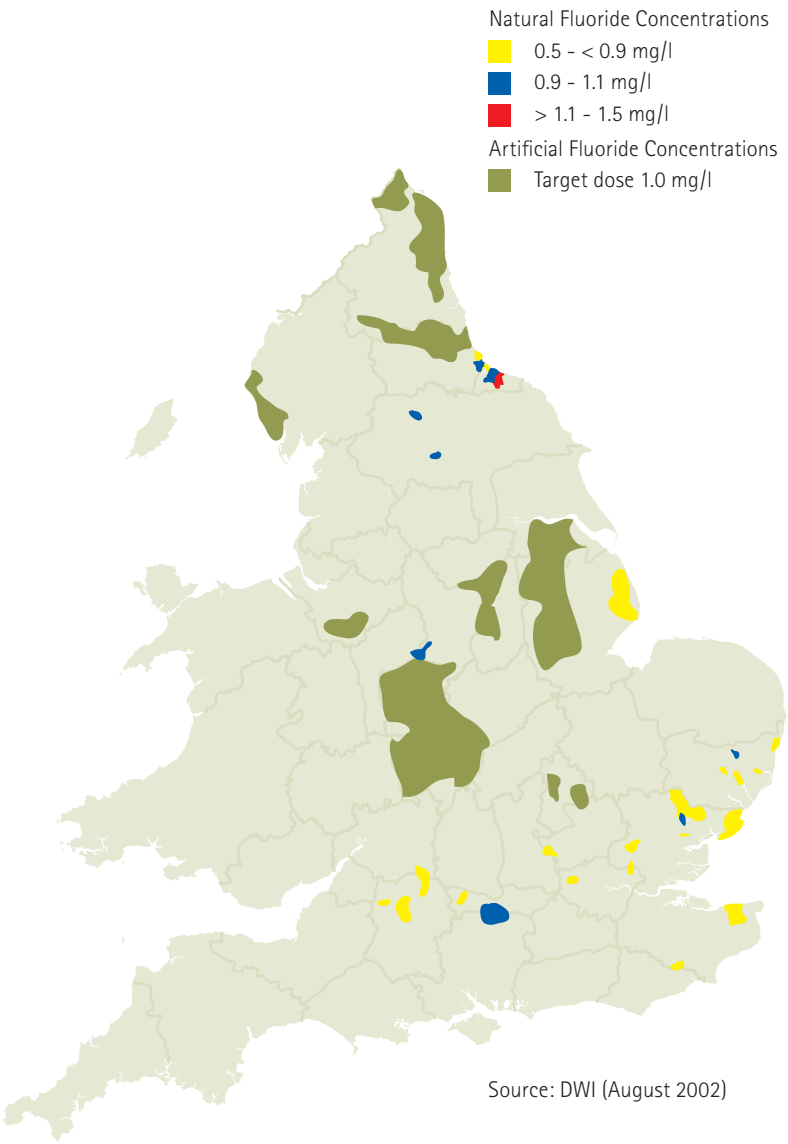
Sub-optimal fluoridation

In some areas people drink water containing what can be described as a 'sub-optimal' natural fluoride content of between 0.3 and 0.7 parts per million. This affords some protection against tooth decay but is below the level at which the optimal benefit is obtained. In some areas (for example parts of Essex, Wiltshire and Norfolk) naturally occurring fluoride levels can vary substantially between places and over time and it is very difficult to quantify this accurately.

Fluoridation across the regions

The map on this page has been produced by the Government Department of the Environment, Food and Rural Affairs[ii] from information supplied by water companies to the Drinking Water Inspectorate. It shows the concentration of fluoride in public drinking water in England and Wales.

Fluoride concentrations in water supplies, August 2002



Source: DWI (August 2002)

[i] This information has been compiled by the British Fluoridation Society in collaboration with the dental lead/Consultant in Dental Public Health for each Strategic Health Authority to whom we are most grateful.

[ii] Map reproduced by kind permission of DeFRA.

As can be seen on the map, the West Midlands is by far the most extensively fluoridated region. In fact, around 3½ million people in the West Midlands drink fluoridated water – some since 1964 when the first scheme was started in Birmingham. In the North East of England fluoridation schemes in Newcastle, North Tyneside and Gateshead serve approximately ½ million people and, in addition, in the town of Hartlepool around ¼ million people benefit from a water supply where the fluoride level is naturally at the optimum for dental health.

In England, there are 10 Strategic Health Authorities (out of 28) whose populations wholly or partly benefit from a fluoridated water supply and these are listed in Table 1. There are no fluoridated areas in Scotland, Wales or Northern Ireland – with the exception of a small pocket of naturally fluoridated water in rural Morayshire, Scotland.

Strategic Health Authorities

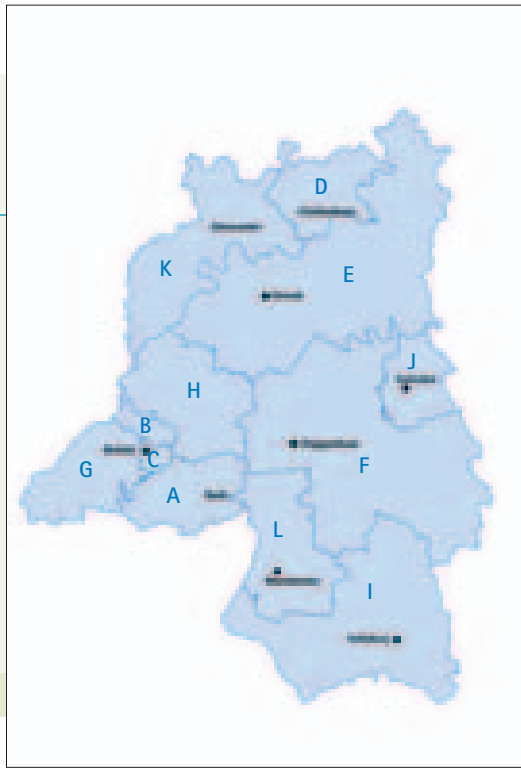
Table 1 Strategic Health Authorities in England in which part or all of the population benefits from fluoridated water

Strategic Health Authority	Total population	Population with fluoridated water supply	% of total population	Natural or adjusted
Bedfordshire & Hertfordshire	1,597,607	197,961	12%	Adjusted
Birmingham, Solihull & the Black Country	2,253,600	2,175,366	97%	Adjusted
Cheshire & Merseyside	2,342,941	136,700	6%	Adjusted
Co Durham & Tees Valley	1,130,907	220,867	20%	Natural & Adjusted
Cumbria & Lancashire	1,900,226	120,000	6%	Adjusted
North & East Yorkshire & Northern Lincolnshire	1,603,635	135,546	8%	Adjusted
Northumberland, Tyne & Wear	1,381,728	647,863	47%	Adjusted
Shropshire & Staffordshire	1,482,537	518,170	35%	Natural & Adjusted
Trent	2,580,579	536,276	21%	Adjusted
West Midlands South	1,524,100	940,212	62%	Adjusted
Totals		**5,628,961**		

The next section shows the overall national picture in more detail showing the proportion of people who benefit from an optimally fluoridated water supply for each of the 28 Strategic Health Authorities in England and Wales and their respective Primary Care Trusts.

Table 2 Avon, Gloucestershire and Wiltshire Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Bath and North East Somerset	A	168,857	*	*	Natural
Bristol North	B	210,325	0	0	
Bristol South and West	C	170,088	0	0	
Cheltenham and Tewkesbury	D	156,444	0	0	
Cotswold and Vale	E	187,831	0	0	
North Somerset	F	188,787	0	0	
Kennet and North Wiltshire	G	191,978	*	*	Natural
South Gloucestershire	H	244,909	0	0	
South Wiltshire	I	111,984	0	0	
Swindon	J	183,706	*	*	Natural
West Gloucestershire	K	218,086	0	0	
West Wiltshire	L	116,612	*	*	Natural
Totals		**2,149,607**	*	*	



* Supply source at Ashton Keynes (Wessex Water) contains naturally elevated fluoride levels and is distributed to PCTs in Wiltshire (Kennet & North Wiltshire, Swindon, Bath & North East Somerset, West Wiltshire). Population coverage not known.

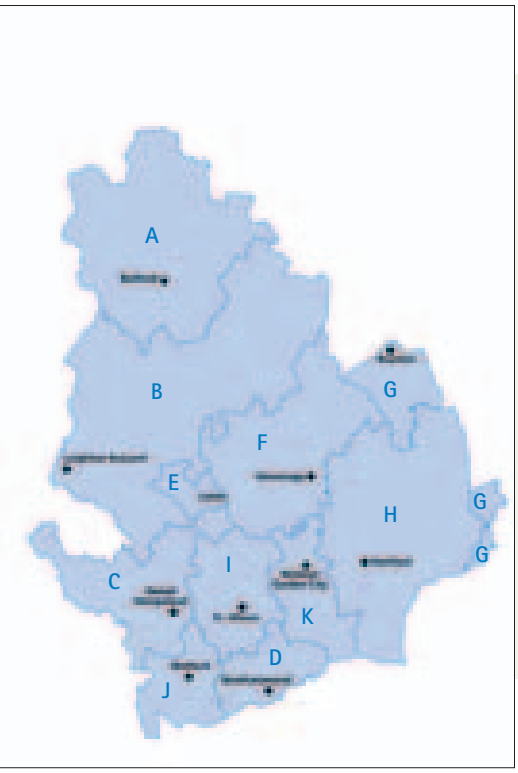


Table 3 Bedfordshire and Hertfordshire Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Bedford	A	147,829	147,829	100	Adjusted
Bedfordshire Heartlands	B	232,867	50,132	22	Adjusted
Dacorum	C	137,177	0	0	
Hertsmere	D	94,139	0	0	
Luton	E	184,294	0	0	
North Hertfordshire and Stevenage	F	179,745	0	0	
Royston, Bedford & Bishops Stortford	G	61,985	0	0	
South East Hertfordshire	H	171,365	0	0	
St Albans and Harpenden	I	129,128	0	0	
Watford and Three Rivers	J	161,527	0	0	
Welwyn Hatfield	K	97,551	0	0	
Totals		**1,597,607**	**197961**	**12**	

Table 4 Birmingham and the Black Country Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Dudley Beacon and Castle	A	104,600	104,600	100	Adjusted
Dudley South	B	200,600	122,900	61	Adjusted
Eastern Birmingham	C	227,700	227,700	100	Adjusted
Heart of Birmingham	D	270,900	270,900	100	Adjusted
North Birmingham	E	154,400	154,400	100	Adjusted
Oldbury and Smethwick	F	96,900	96,900	100	Adjusted
Rowley, Regis and Tipton	G	76,600	76,600	100	Adjusted
Solihull	H	199,600	199,600	100	Adjusted
South Birmingham	I	323,300	323,300	100	Adjusted
Walsall	J	253,300	253,300	100	Adjusted
Wednesbury & West Bromwich	K	109,300	109,300	100	Adjusted
Wolverhampton City	L	236,400	236,400	100	Adjusted
Totals		**2,253,600**	**2,175,900**	**97**	**Adjusted**

Table 5 Cheshire and Merseyside Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Bebington and West Wirral	A	118,951	0	0	
Birkenhead and Wallasey	B	193,264	0	0	
Central Cheshire	C	253,917	132,000	52	Adjusted
Central Liverpool	D	237,680	0	0	
Cheshire West	E	151,111	4,700	3	Adjusted
Eastern Cheshire	F	187,038	0	0	
Ellesmere Port and Neston	G	81,580	0	0	
Halton	H	118,185	0	0	
Knowsley	I	150,494	0	0	
North Liverpool	J	102,529	0	0	
South Liverpool	K	98,107	0	0	
South Sefton	L	168,764	0	0	
Southport and Formby	M	114,120	0	0	
St Helens	N	176,810	0	0	
Warrington	O	190,391	0	0	
Totals		**2,342,941**	**136,700**	**6**	**Adjusted**

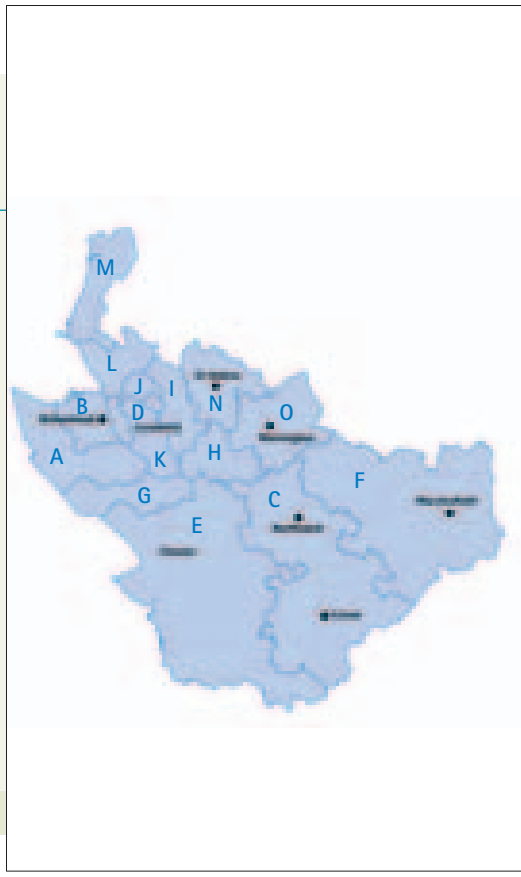
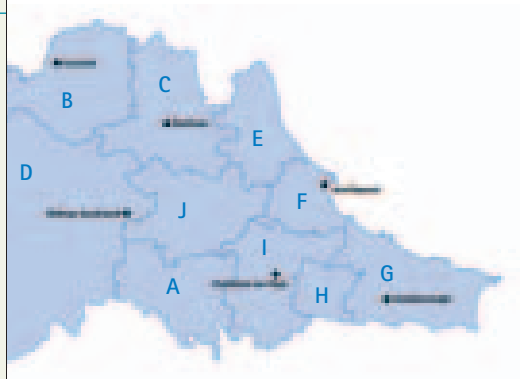


Table 6 County Durham and Tees Valley Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Darlington	A	97,849	0	0	
Derwentside	B	85,171	85,171	100	Adjusted
Durham and Chester-le-Street	C	140,644	0	0	
Durham Dales	D	85,531	0	0	
Easington	E	93,971	46,985	50	Natural
Hartlepool	F	88,711	88,711	100	Natural
Langbaurgh	G	97,028	0	0	
Middlesbrough	H	176,806	0	0	
North Tees	I	177,992	0	0	
Sedgefield	J	87,204	0	0	
Totals		**1,130,907**	**220,867**	**20**	**Natural & Adjusted**



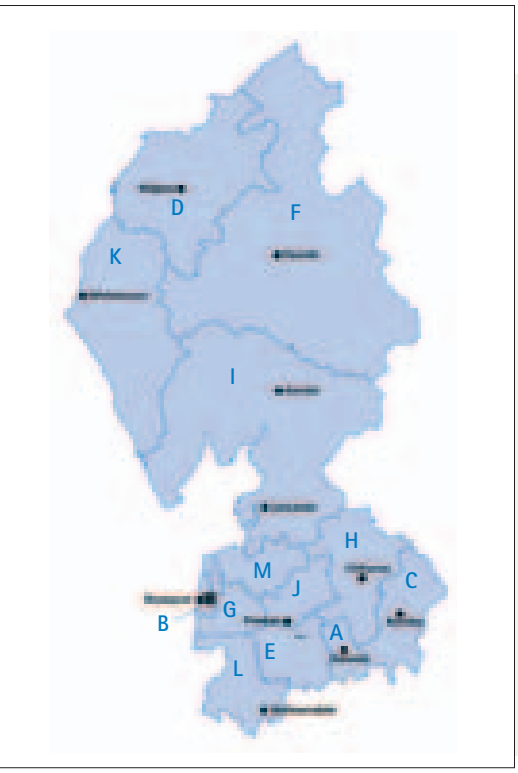


Table 7 Cumbria and Lancashire Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Blackburn With Darwen	A	137,556	0	0	
Blackpool	B	142,184	0	0	
Burnley, Pendle and Rossendale	C	244,449	0	0	
Carlisle and District	D	113,582	0	0	
Chorley and South Ribble	E	203,189	0	0	
Eden Valley	F	69,020	0	0	
Fylde	G	72,657	0	0	
Hyndburn and Ribble Valley	H	124,672	0	0	
Morecambe Bay	I	308,189	0	0	
Preston	J	140,065	0	0	
West Cumbria*	K	130,409	120,000	92	Adjusted
West Lancashire	L	108,541	0	0	
Wyre	M	105,713	0	0	
Totals		**1,900,226**	**120,000**	**6**	Adjusted

* Fluoridation intermittent since 1999 for technical reasons.

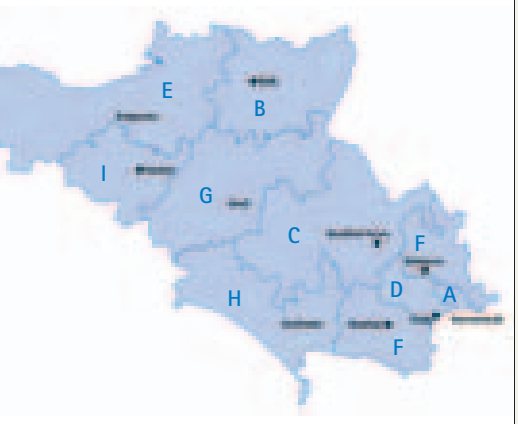


Table 8 Dorset and Somerset Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Bournemouth	A	147,140	0	0	
Mendip	B	106,714	0	0	
North Dorset	C	84,882	0	0	
Poole	D	177,766	0	0	
Somerset Coast	E	141,121	0	0	
South and East Dorset	F	146,810	0	0	
South Somerset	G	145,686	0	0	
South West Dorset	H	131,532	0	0	
Taunton Deane	I	101,955	0	0	
Totals		**1,183,606**	**0**	**0**	

Table 9 Essex Strategic Health Authority

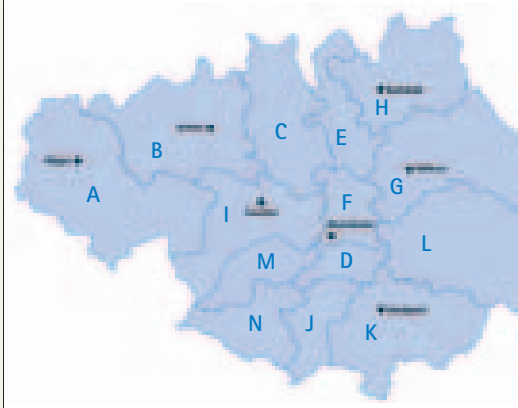
Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Basildon	A	102,623	0	0	
Billericay, Brentwood and Wickford**	B	131,718	variable low levels	variable low levels	Natural low levels
Castle Point and Rochford	C	165,218	0	0	
Chelmsford	D	133,719	0	0	
Colchester*	E	155,376	variable up to 1ppm	variable up to 1ppm	Natural up to 1ppm
Epping Forest**	F	120,964	variable low levels	variable low levels	Natural up to 1ppm
Harlow**	G	78,935	variable low levels	variable low levels	Natural up to 1ppm
Maldon and South Chelmsford	H	87,435	0	0	
Southend On Sea	I	160,344	0	0	
Tendring	J	136,487	130,000 variable levels	95%	Natural up to 1ppm
Thurrock	K	143,212	0	0	
Uttlesford**	L	70,928	variable low levels	variable low levels	Natural low levels
Witham, Braintree and Halstead*	M	125,628	variable up to 1ppm	variable up to 1ppm	Natural
Totals		**1,612,587**			

* Naturally occurring fluoride levels in some parts of these areas may reach optimal (1ppm). There is considerable natural variation in the level across the year.

** Naturally occurring fluoride levels in some parts of these areas can exceed 0.3ppm, but never reach optimal. There is considerable natural variation in the level across the year.

Table 10 Greater Manchester Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Ashton, Leigh and Wigan	A	301,207	0	0	
Bolton	B	261,329	0	0	
Bury	C	180,637	0	0	
Central Manchester	D	147,788	0	0	
Heywood and Middleton	E	73,378	0	0	
North Manchester	F	118,885	0	0	
Oldham	G	217,456	0	0	
Rochdale	H	131,546	0	0	
Salford	I	215,817	0	0	
South Manchester	J	125,779	0	0	
Stockport	K	284,582	0	0	
Tameside and Glossop	L	245,415	0	0	
Trafford North	M	92,686	0	0	
Trafford South	N	117,470	0	0	
Totals		**2,513,975**	**0**	**0**	



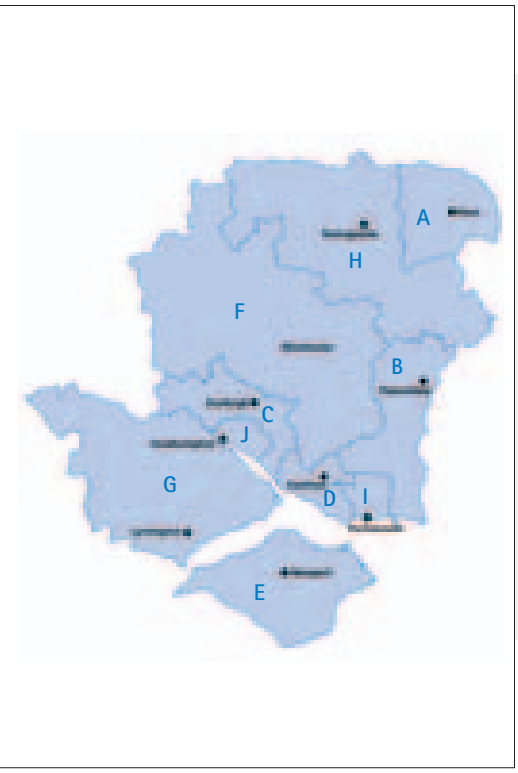


Table 11 Hampshire and Isle of Wight Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
East Hampshire	A	182,094	0	0	
Eastleigh and Test Valley South	B	149,837	0	0	
Fareham and Gosport	C	187,120	0	0	
Isle of Wight	D	132,908	0	0	
Mid-Hampshire	E	168,599	0	0	
New Forest	F	174,696	0	0	
North Hampshire	G	184,717	0	0	
Portsmouth City	H	180,268	0	0	
Blackwater Valley and Hart	I	182,242	0	0	
Southampton City	J	232,925	0	0	
Totals		**1,775,406**	**0**	**0**	

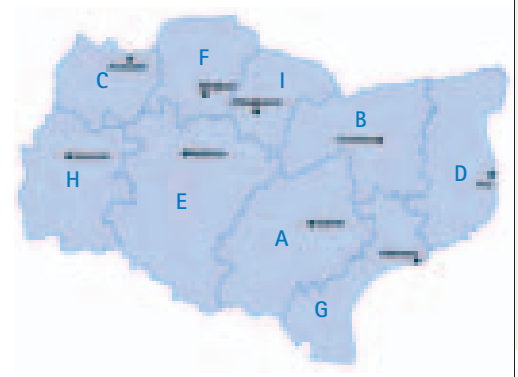


Table 12 Kent and Medway Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Ashford	A	102,527	0	0	
Canterbury and Coastal	B	167,886	0	0	
Dartford, Gravesham and Swanley	C	224,369	0	0	
East Kent Coastal	D	230,581	0	0	
Maidstone Weald	E	231,556	0	0	
Medway	F	258,894	0	0	
Shepway	G	94,515	0	0	
South West Kent	H	176,548	0	0	
Swale	I	87,607	0	0	
Totals		**1,574,483**	**0**	**0**	

Table 13 Leicestershire, Northamptonshire and Rutland Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Charnwood & NW Leicestershire	A	230,214	0	0	
Daventry & South Northants	B	101,006	0	0	
Eastern Leicester	C	173,316	0	0	
Hinckley and Bosworth	D	115,004	0	0	
Leicester City West	E	106,430	0	0	
Melton, Rutland and Harborough	F	137,726	0	0	
Northampton	G	208,645	0	0	
Northamptonshire Heartlands	H	283,758	0	0	
South Leicestershire	I	158,350	0	0	
Totals		**1,514,449**	**0**	**0**	

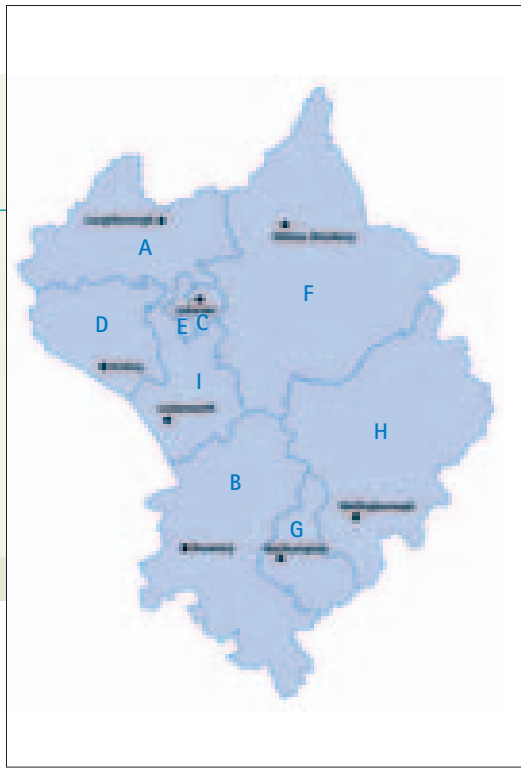
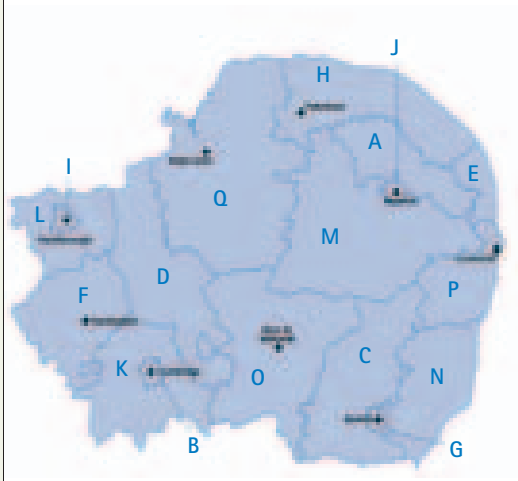


Table 14 Norfolk, Suffolk and Cambridgeshire Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Broadland	A	118,302	0.14-0.45	100	Natural
Cambridge City	B	108,466	0.07-0.17	100	Natural
Central Suffolk	C	97,953	0.11-0.8	100	Natural
East Cambridgeshire & Fenland	D	136,129	0.08-0.6	100	Natural
Great Yarmouth	E	90,889	0.15-0.43	100	Natural
Huntingdonshire	F	140,111	0.08-0.6	100	Natural
Ipswich	G	141,672	0.21-0.65	100	Natural
North Norfolk	H	97,168	0.11-0.43	100	Natural
North Peterborough	I	99,239	0.08-0.6	100	Natural
Norwich	J	121,145	0.14-0.22	100	Natural
South Cambridgeshire	K	129,562	0.08-0.6	100	Natural
South Peterborough	L	86,912	0.08-0.6	100	Natural
Southern Norfolk	M	200,492	0.13-0.45	100	Natural
Suffolk Coastal	N	98,237	0.21-0.65	100	Natural
Suffolk West	O	195,747	0.11-0.8	100	Natural
Waveney	P	121,238	0.15-0.93	100	Natural
West Norfolk	Q	154,724	0.07-0.16	100	Natural
Totals		**2,137,986**			



Naturally occurring fluoride levels in some areas may reach optimal but it is difficult to quantify this accurately.

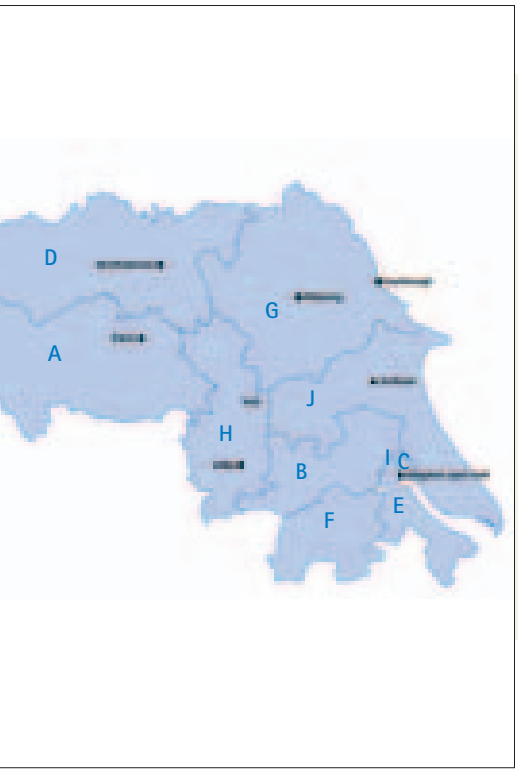


Table 15 North and East Yorkshire and Northern Lincolnshire Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Craven, Harrogate & Rural Dist	A	202,790	0	0	
East Yorkshire	B	169,845	0	0	
Eastern Hull	C	113,309	0	0	
Hambleton and Richmondshire	D	108,030	0	0	
North East Lincolnshire	E	159,214	23,822	15	Adjusted
North Lincolnshire	F	148,965	111,724	75	Adjusted
Scarborough, Whitby and Ryedale	G	157,007	0	0	
Selby and York	H	271,280	0	0	
West Hull	I	129,614	0	0	
Yorkshire Wolds and Coast	J	143,581	0	0	
Totals		**1,603,635**	**135,546**	**8**	Adjusted

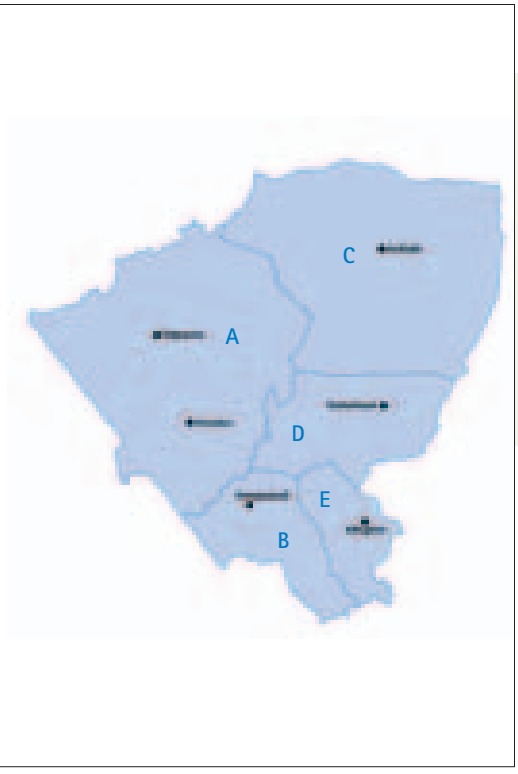
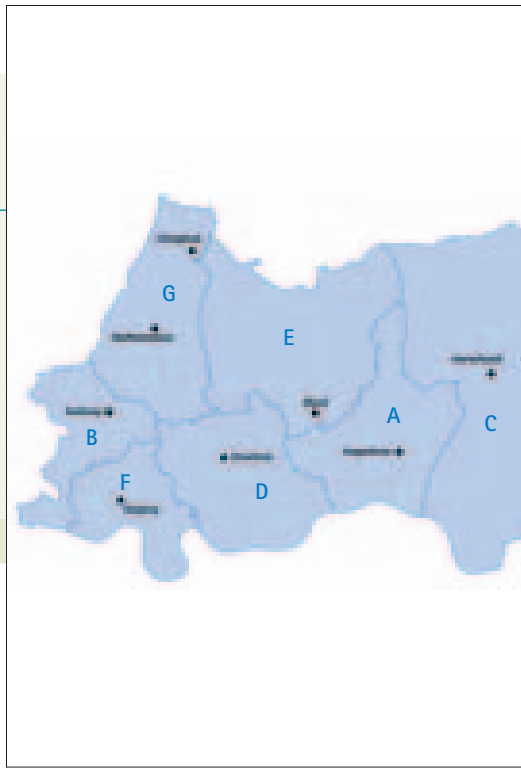


Table 16 North Central London Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Barnet	A	314,203	0	0	
Camden	B	198,008	0	0	
Enfield	C	274,330	0	0	
Haringey	D	216,812	0	0	
Islington	E	175,798	0	0	
Totals		**1,179,151**	**0**	**0**	

Table 17 North East London Strategic Health Authority

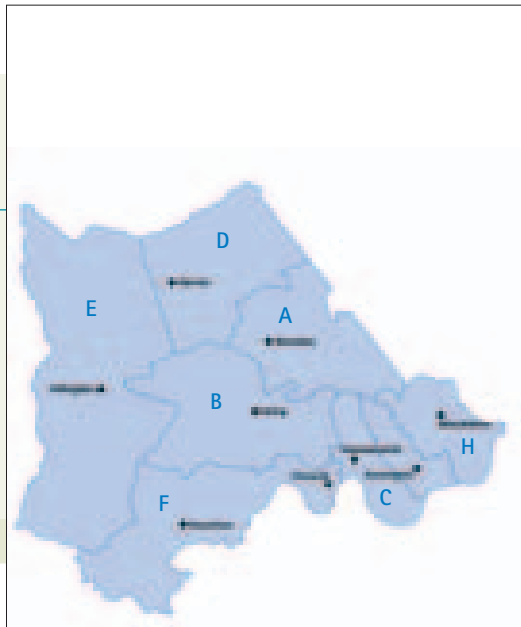
Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Barking and Dagenham	A	164,344	0	0	
Chingford, Wanstead & Woodford	B	120,355	0	0	
City and Hackney	C	210,480	0	0	
Havering	D	224,634	0	0	
Newham	E	244,280	0	0	
Redbridge	F	176,883	?	?	Natural
Tower Hamlets	G	196,567	0	0	
Walthamstow, Leyton & Leytonstone	H	160,662	0	0	
Totals		**1,498,205**	**0**	**0**	



The natural fluoride content of supplies around Redbridge may reach optimal, but it is difficult to quantify the number of people affected.

Table 18 North West London Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Brent	A	263,629	0	0	
Ealing	B	301,433	0	0	
Hammersmith and Fulham	C	165,058	0	0	
Harrow	D	207,389	0	0	
Hillingdon	E	240,346	0	0	
Hounslow	F	212,397	0	0	
Kensington and Chelsea	G	158,935	0	0	
Westminster	H	179,754	0	0	
Totals		**1,728,941**	**0**	**0**	



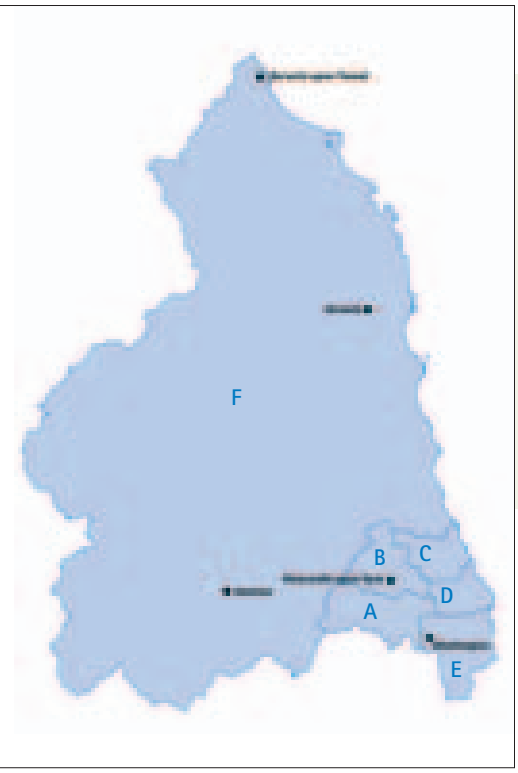


Table 19 Northumberland, Tyne and Wear Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Gateshead	A	191,133	191,000	virtually 100	Adjusted
Newcastle	B	259,470	259,470	100	Adjusted
North Tyneside*	C	191,999	191,999	50 & 50 variable low	Adjusted
Northumberland Care Trust	D	305,536	100,827	33	Adjusted
South Tyneside	E	152,785	0	0	
Sunderland Teaching	F	280,805	0	0	
Totals		**1,381,728**	**647,863**	**47**	Adjusted

* 100% of supply fluoridated, but only 50% at optimal; remaining 50% variable, but never more than 0.4ppm.

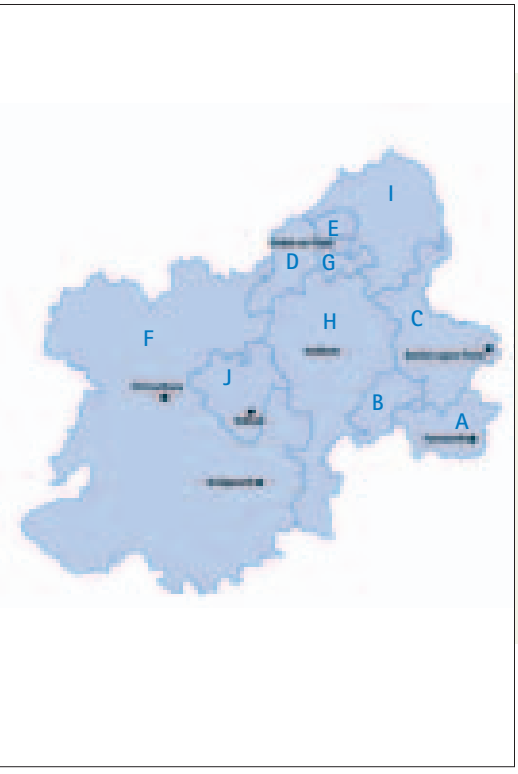


Table 20 Shropshire and Staffordshire Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Burntwood, Lichfield & Tamworth	A	151,500	151,500	100	Adjusted
Cannock Chase	B	127,800	127,800	100	Adjusted
East Staffordshire	C	112,700	112,700	100	Nat & Adjusted
Newcastle-Under-Lyme	D	102,000	0	0	
North Stoke	E	123,100	0	0	
Shropshire County	F	279,700	22,400	8	Adjusted
South Stoke	G	124,900	0	0	
South Western Staffordshire	H	195,800	103,800	53	Adjusted
Staffordshire Moorlands	I	106,800	0	0	
Telford and Wrekin	J	158,100	0	0	
Totals		**1,482,400**	**518,200**	**35**	**Nat & Adjusted**

Table 21 South East London Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Bexley	A	218,675	0	0	
Bromley	B	295,865	0	0	
Greenwich	C	214,597	0	0	
Lambeth	D	266,487	0	0	
Lewisham	E	249,428	0	0	
Southwark	F	245,357	0	0	
Totals		**1,490,409**	**0**	**0**	

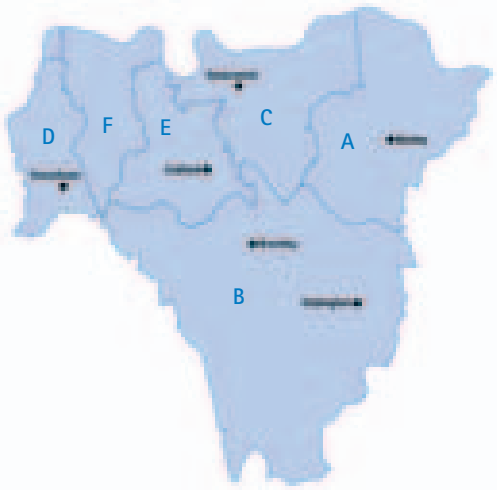
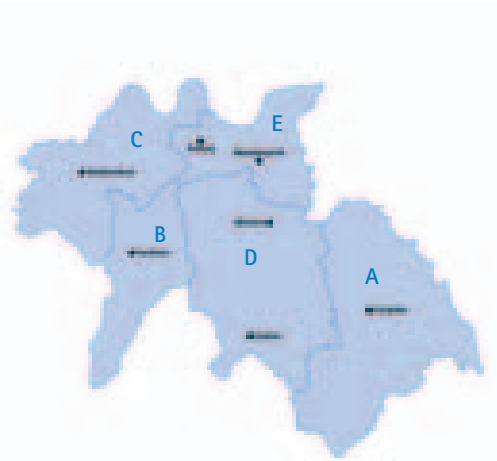


Table 22 South West London Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Croydon	A	331,406	0	0	
Kingston	B	147,356	0	0	
Richmond and Twickenham	C	172,474	0	0	
Sutton and Merton	D	368,480	0	0	
Wandsworth	E	259,864	0	0	
Totals		**1,279,580**	**0**	**0**	



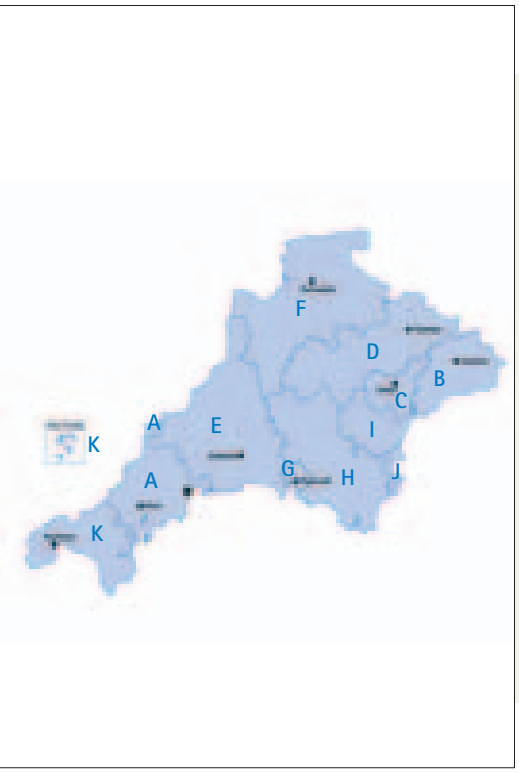


Table 23 South West Peninsula Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Central Cornwall	A	184,265	0	0	
East Devon*	B	117,674	variable low levels	variable low levels	Natural low levels
Exeter	C	130,206	0	0	
Mid Devon	D	92,204	0	0	
North and East Cornwall	E	156,064	0	0	
North Devon	F	146,216	0	0	
Plymouth	G	234,266	0	0	
South Hams and West Devon	H	109,761	0	0	
Teignbridge	I	105,290	0	0	
Torbay	J	129,848	0	0	
West of Cornwall	K	156,156			
Totals		**1,561,950**	**0**	**0**	

* Some bore hole supplies have elevated fluoride levels, but too low to be of dental benefit.

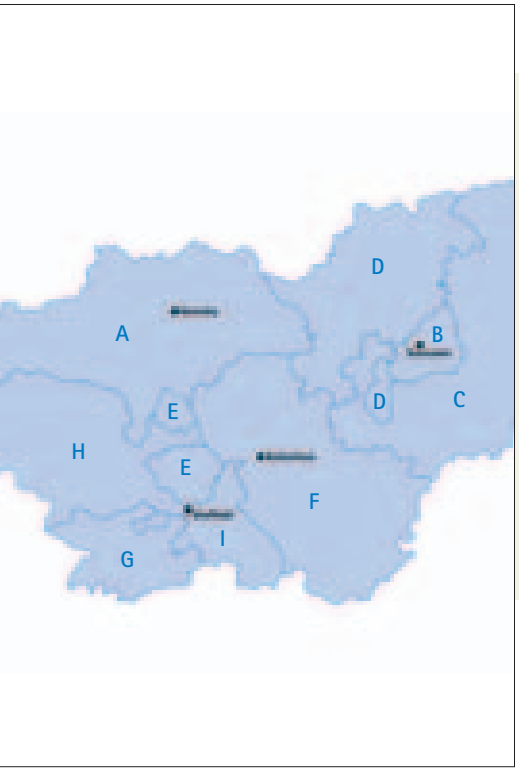


Table 24 South Yorkshire Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Barnsley	A	218,125	0	0	
Doncaster Central	B	70,401	0	0	
Doncaster East	C	110,122	0	0	
Doncaster West	D	104,970	0	0	
North Sheffield	E	117,114	0	0	
Rotherham	F	248,352	0	0	
Sheffield South West	G	124,598	0	0	
Sheffield West	H	107,094	0	0	
South East Sheffield*	I	164,239	?	?	Adjusted
Totals		**1,265,015**	**0**	**0**	

* Some parts of this area receive fluoridated supplies from Severn Trent Water Company.

Table 25 Surrey and Sussex Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Adur, Arun and Worthing	A	216,387	0	0	
Bexhill and Rother	B	87,368	0	0	
Brighton and Hove City	C	248,061	0	0	
Crawley	D	99,679	0	0	
East Elmbridge and Mid Surrey	E	260,806	0	0	
East Surrey	F	159,808	0	0	
Eastbourne Downs	G	166,311	0	0	
Guildford and Waverley	H	222,319	0	0	
Hastings and St Leonards	I	85,325	0	0	
Horsham and Chanctonbury	J	100,790	0	0	
Mid-Sussex	K	130,195	0	0	
North Surrey	L	199,554	0	0	
Sussex Downs and Weald	M	153,865	0	0	
Western Sussex	N	206,581	0	0	
Woking	O	199,939	0	0	
Totals		**2,536,988**	**0**	**0**	

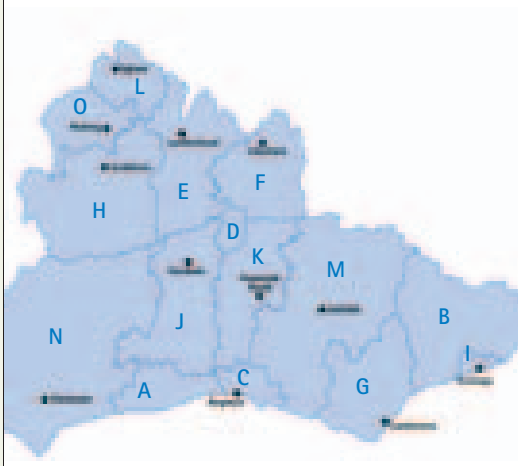
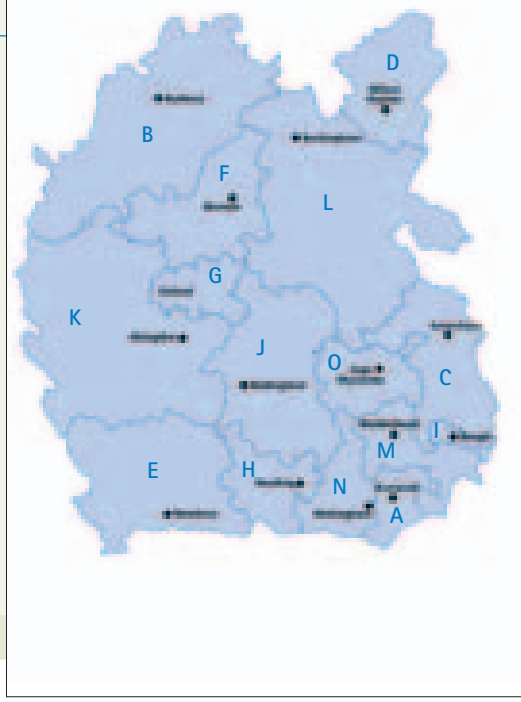


Table 26 Thames Valley Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Bracknell Forest	A	108,151	0	0	
Cherwell Vale	B	122,009	0	0	
Chiltern & South Buckinghamshire	C	159,751	0	0	
Milton Keynes	D	211,671	0	0	
Newbury and Community	E	93,090	0	0	
North East Oxfordshire	F	69,101	0	0	
Oxford City	G	154,597	0	0	
Reading	H	194,294	0	0	
Slough	I	119,059	0	0	
South East Oxfordshire	J	92,996	0	0	
South West Oxfordshire	K	190,520	0	0	
Vale of Aylesbury	L	176,322	0	0	
Windsor, Ascot and Maidenhead	M	143,891	0	0	
Wokingham	N	148,789	0	0	
Wycombe	O	134,621	0	0	
Totals		**2,118,862**	**0**	**0**	



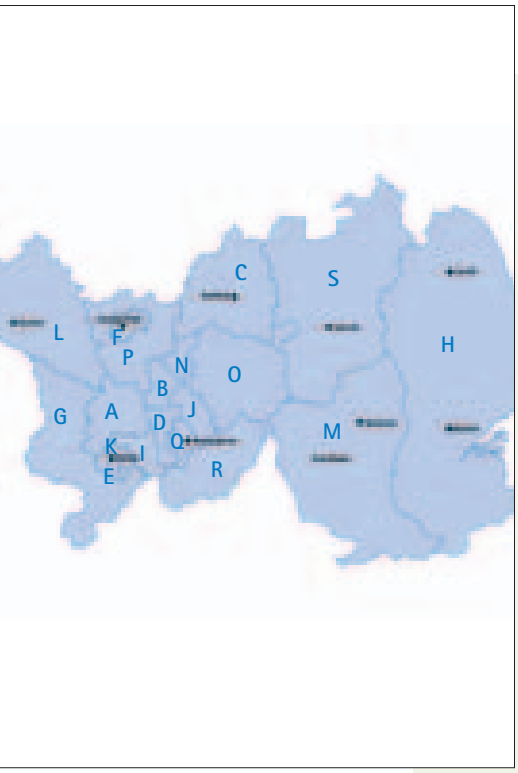


Table 27 Trent Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Amber Valley	A	116,564	0	0	
Ashfield	B	81,777	81,777	100	Adjusted
Bassetlaw	C	107,327	107,327	100	Adjusted
Broxtowe and Hucknall	D	136,951	0	0	
Central Derby	E	64,320	0	0	
Chesterfield	F	98,882	0	0	
Derbyshire Dales & S Derbyshire	G	107,461	22,000	20	Adjusted
East Lincolnshire	H	265,403	0	0	
Erewash	I	110,123	0	0	
Gedling	J	111,795	0	0	
Greater Derby	K	157,342	0	0	
High Peak and Dales	L	100,153	0	0	
Lincolnshire South West	M	160,683	32,137	20	Adjusted
Mansfield District	N	97,993	97,993	100	Adjusted
Newark and Sherwood	O	105,709	0	0	
North Eastern Derbyshire*	P	168,767	?	?	Adjusted
Nottingham City	Q	266,780	0	0	
Rushcliffe	R	105,507	0	0	
West Lincolnshire	S	217,042	217,042	100	Adjusted
Totals		**2,580,579**	**558,276**	**22**	**Adjusted**

* Some parts of this area receive fluoridated supplies from Severn Trent Water Company.

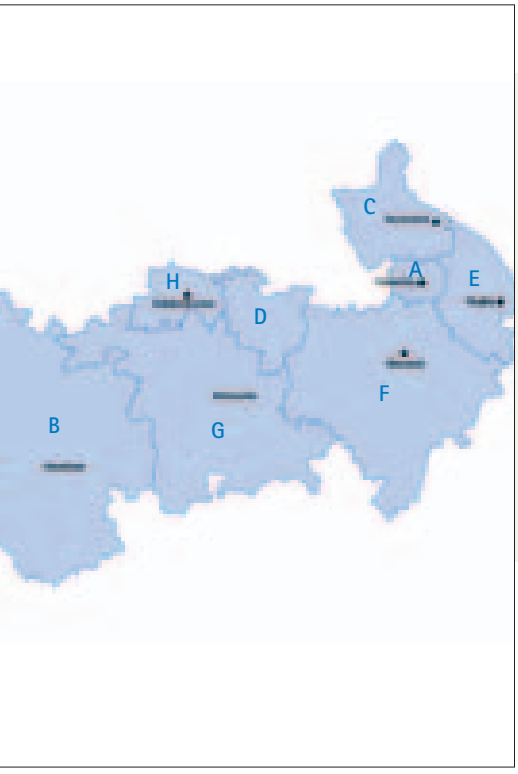
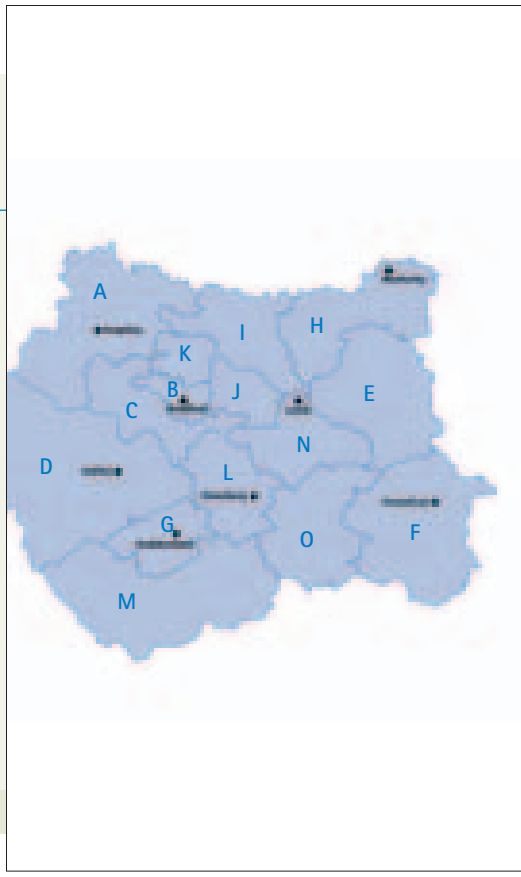


Table 28 West Midlands South Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Coventry	A	300,700	300,700	100	Adjusted
Herefordshire	B	174,900	0	0	
North Warwickshire	C	181,100	181,100	100	Adjusted
Redditch and Bromsgrove	D	166,700	152,300	91	Adjusted
Rugby	E	87,500	87,500	100	Adjusted
South Warwickshire	F	237,600	162,200	68	Adjusted
South Worcestershire	G	278,700	87,800	32	Adjusted
Wyre Forest	H	96,900	13,400	14	Adjusted
Totals		**1,524,100**	**985,000**	**65**	**Adjusted**

Table 29 West Yorkshire Strategic Health Authority

Primary Care Trust (PCT)		PCT population	PCT Population with fluoridated water supply	% of total population	Natural or adjusted
Airedale	A	116,192	0	0	
Bradford City	B	135,189	0	0	
Bradford South and West	C	132,310	0	0	
Calderdale	D	192,381	0	0	
East Leeds	E	162,757	0	0	
Eastern Wakefield	F	171,976	0	0	
Huddersfield Central	G	137,821	0	0	
Leeds North East	H	111,524	0	0	
Leeds North West	I	185,393	0	0	
Leeds West	J	108,892	0	0	
North Bradford	K	84,257	0	0	
North Kirklees	L	170,627	0	0	
South Huddersfield	M	80,460	0	0	
South Leeds	N	145,835	0	0	
Wakefield West	O	142,712	0	0	
Totals		**2,078,326**	**0**	**0**	



The information provided about the extent of fluoridation in the UK is an estimate of population coverage. Local water suppliers are able to provide their customers with water quality information (including fluoride concentration) for their own home supply. It is a good idea to establish accurate details of the home water supply fluoride concentration if a fluoride supplementation (e.g. tablets or drops) is being considered for young children. Depending on the water fluoride level, supplementation may not be advisable; parents should therefore seek their dentist's advice before starting. A list of water suppliers and their contact details, together with a map showing the approximate supply area covered by each is included on page 78 at the end of this Section. For further information visit Water UK's website at www.water.org.uk.

How fluoridation could be extended in the UK

In the late 1980s and early 1990s, many health authorities in areas where dental health was poor asked water suppliers to fluoridate their supplies, but had their requests refused (See section 6, *Legal aspects & decision making for further details).*

Dental public health experts recommend that targeted water fluoridation of large public water supplies – as opposed to universal or 'blanket' fluoridation – is the most cost-effective approach. In some non-fluoridated areas – such as the affluent Home Counties – most people who live there already have good dental health and would probably not benefit much further from water fluoridation. Elsewhere, rural areas with poor dental health, such as the Highlands of Scotland, do not have large enough public water supplies to make water fluoridation a cost effective option.

The British Dental Association argues that a modest increase in coverage of water fluoridation from the current 10% to 25-35% of the UK population to cover areas where dental health is worst and where single water supplies serve large population, would have a significant impact on dental health and dental inequalities.

Fluoridation worldwide

Throughout the world we estimate that approximately 350 million people drink artificially fluoridated water and that at least a further 50 million drink water whose natural fluoride level is at or around optimal (i.e. 1 part of fluoride for every million parts of water)[i]. However, it should be noted that for many countries we have not been able to obtain any information about fluoridation status so, in particular, the number of people benefiting

[i] The British Fluoridation Society and the US Public Health Service, Division of Oral Health, CDC, have collaborated in the compiling and verification of much of these data. Whilst the information included is the best estimate currently available, some information will be incomplete or may have errors which are unknown to the British Fluoridation Society or to the USPHS Division of Oral Health, CDC. We are grateful to the many colleagues throughout the world who responded to our request for information.

from naturally optimally fluoridated water is likely to be much higher than the 50 million reported. In some countries (particularly parts of India, Africa and China) drinking water can contain very high concentrations of naturally occurring fluoride. These levels are not considered optimal for dental or general health.

Countries using adjusted fluoridation schemes include the UK, Chile, South Korea, Singapore, Spain, Ireland, the United States, Canada, Brazil, Malaysia, Vietnam, Australia, and New Zealand. Other countries (for example South Africa and Japan) have enacted the necessary legislation and plan to introduce schemes in the imminent future. Contrary to opponents claims, fluoridation has not been banned anywhere.

The countries worldwide where at least some of the population is known to benefit from fluoridated water – either natural or adjusted – are listed on page 75 at the end of this Section. For each country, the estimated number and proportion of the population served is given.

The position in Europe

In Western Europe, approximately 12 million people benefit from an artificially fluoridated water supply (UK 6 million; Ireland 2.3 million; Spain 4 million). In Ireland, fluoridation of all sizable public water systems is mandatory.

A water fluoridation scheme serving approximately 0.2 million people in the Swiss canton of Basle was in operation from 1962 until as recently as April 2003. A fluoridated salt programme served the remainder of the Swiss population – and the Swiss Government has now opted to switch from fluoridated water to fluoridated salt in Basle[i].

As well as Switzerland, many other European countries including France, Austria, Germany, Hungary, Slovakia and Belarus use fluoridated salt widely. However, in densely populated parts of the UK, where relatively few water sources serve large populations, water fluoridation is considered the most effective means of preventing tooth decay on a community-wide scale.

The Netherlands was amongst the pioneering fluoridating countries and by 1973 around 5 million people (30% of the population) were benefiting from fluoridated water. However, in their attempts to modify inadequate legislation, the Government were forced into battle with anti-fluoridation activists and this eventually resulted in fluoridation being withdrawn. This was in spite of strong support from the health departments at the time [1]; indeed, after water fluoridation was withdrawn the Government concentrated their efforts on encouraging parents to give children fluoride supplements from a very young age.

Similarly, in Finland a scheme serving the city of Kupio (population 76,000) was in operation from 1959 to 1992. Again, it is sometimes claimed that fluoridation was 'banned' in Finland but this is not the case. In fact the scheme was stopped because the plant equipment was in need of repair whereupon the minority opposed to fluoridation stepped up their activities. Subsequently the Finnish Government, who by this time had dental disease in the population largely under control, decided that on balance it was probably not worth re-starting the scheme.

In Sweden, enabling legislation was introduced in the 1960s and many towns and districts sought and were granted permission to fluoridate. However, following another tough political battle, the legislation was withdrawn before they had time to implement the planned schemes [1].

Clearly, fluoridation of water supplies is not as extensive in Europe as it its in the US and elsewhere. However, it is important to note that the use of *fluoride* – whether in water, salt, toothpaste, milk or tablets and drops – is the foundation of prevention of tooth decay throughout Europe.

The United States continues to extend fluoridation

The United States is one of the most extensively fluoridated countries in the world with the first schemes starting in 1945. Some 171 million people – almost 68% of the population on public water systems - receive artificially fluoridated water. Major cities which are fluoridated include New York, Chicago, Philadelphia, Houston, Detroit, Dallas, San Francisco, Washington DC, Boston, Seattle, Memphis and Atlanta.

The 2000 US Surgeon General's report stated that:

> *'community water fluoridation continues to be the most cost-effective, practical and safe means for reducing and controlling the occurrence of tooth decay in a community.'*

As such, the US continues to extend fluoridation and in recent years fluoridation schemes have

[i] Personal communication from Professor Thomas Marthaler, 2003.

been introduced for several millions more US citizens in major cities including San Antonio, Los Angeles, Las Vegas, Sacramento and Mesa. A scheme that will benefit approximately 7 million more Southern Californians has recently been announced by the largest water supply agency in California.

Forty-six of the 50 largest US cities are fluoridated (see Table 30 below).

Table 30 Fluoridation Status of the Largest 50 U. S. Cities [i]

Rank 1999	City	State	Population*	Fluoridation Status	Year
1	New York	NY	8,008,278	Fluoridated	1965
2	Los Angeles	CA	3,694,820	Fluoridated	1999
3	Chicago	IL	2,896,016	Fluoridated	1956
4	Houston	TX	1,953,631	Fluoridated	1982
5	Philadelphia	PA	1,517,550	Fluoridated	1954
6	Phoenix	AZ	1,321,045	Fluoridated	1990
7	San Diego	CA	1,223,400	Approved**	2000
8	Dallas	TX	1,188,580	Fluoridated	1966
9	San Antonio	TX	1,144,646	Fluoridated	2002
10	Detroit	MI	951,270	Fluoridated	1967
11	San Jose	CA	894,943	Non Fluoridated***	
12	Indianapolis	IN	791,926	Fluoridated	1951
13	San Francisco	CA	776,733	Fluoridated	1952
14	Jacksonville	FL	735,617	Natural	N/A
15	Columbus	OH	711,470	Fluoridated	1973
16	Austin	TX	656,562	Fluoridated	1973
17	Baltimore	MD	651,154	Fluoridated	1952
18	Memphis	TN	650,100	Fluoridated	1970
19	Milwaukee	WI	596,974	Fluoridated	1953
20	Boston	MA	589,141	Fluoridated	1978
21	Washington	DC	572,059	Fluoridated	1952
22	Nashville-Davidson	TN	569,891	Fluoridated	1953
23	El Paso	TX	563,662	Natural	N/A
24	Seattle	WA	563,374	Fluoridated	1970
25	Denver	CO	554,636	Fluoridated	1954
26	Charlotte	NC	540,828	Fluoridated	1949
27	Fort Worth	TX	534,694	Fluoridated	1965
28	Portland	OR	529,121	Not Fluoridated****	---
29	Oklahoma City	OK	506,132	Fluoridated	1954
30	Tucson	AZ	486,699	Natural (partial)	N/A
31	New Orleans	LA	484,674	Fluoridated	1974
32	Las Vegas	NV	478,434	Fluoridated	2000
33	Cleveland	OH	478,403	Fluoridated	1956
34	Long Beach	CA	461,522	Fluoridated	1971
35	Albuquerque	NM	448,607	Fluoridated	1974

[i] *Reproduced by kind permission of M. W. Easley, National Center for Fluoridation Policy & Research, All Rights Reserved. Revised 6 August 2002*

Rank 1999	City	State	Population*	Fluoridation Status	Year
36	Kansas City	MO	441,545	Fluoridated	1983
37	Fresno	CA	427,652	Fluoridated (partial)	1954
38	Virginia Beach	VA	425,257	Fluoridated	1952
39	Atlanta	GA	416,474	Fluoridated	1969
40	Sacramento	CA	407,018	Fluoridated	2000
41	Oakland	CA	399,484	Fluoridated	1976
42	Mesa	AZ	396,375	Fluoridated	2000
43	Tulsa	OK	393,049	Fluoridated	1953
44	Omaha	NE	390,007	Fluoridated	1969
45	Minneapolis	MN	382,618	Fluoridated	1957
46	Honolulu	HI	371,657	Not Fluoridated****	---
47	Miami	FL	362,470	Fluoridated	1952
48	Colorado Springs	CO	360,890	Natural	N/A
49	St. Louis	MO	348,189	Fluoridated	1955
50	Wichita	KS	344,284	Not Fluoridated*****	---

* U.S. Census Bureau Population Estimates, April 2000

** San Diego (California) recently approved fluoridation. Fluoridation has not been implemented yet, however it will commence as soon as fluoridation equipment installation is completed at the jurisdictions' water plants.

*** San Jose (California) will be required to fluoridate under California's Mandatory Fluoridation Law (AB733) enacted in 1995.

**** Portland (Oregon) and Honolulu (Hawai'i) are not fluoridated, however legislation has been introduced in both states' legislatures that, if passed, will mandate fluoridation in all cities.

***** Wichita (Kansas), while not fluoridated, is experiencing extensive local legislative efforts that, if successful, would require Wichita to fluoridate.

Sources: U.S. Bureau of Census, April 1, 2000, U.S. Population, City Rankings; University of Texas Health Science Center, San Antonio, Fluoridation Facts; & Division of Oral Health, U.S. Centers for Disease Control & Prevention, Fluoridation Census, 1992.

Central and South America

A number of South American countries practice artificial water fluoridation – including Brazil, Argentina and Chile. In many other Central and South American countries (including Costa Rica, Guatemala, Nicaragua, Jamaica, Uruguay, Ecuador and Mexico) the use of fluoridated salt is widespread – indeed Mexico now requires all salt to be fluoridated and does not allow non-fluoridated salt into the country.

References

1. Frank RM, O'Hickey S, (1987): *Strategy for dental caries prevention in European countries according to their laws and regulations:* IRL Press.

Table 31 Optimal Water Fluoridation: Status Worldwide[i]

Country	Population	Adjusted population served	Natural population served	Total population served (%)
Argentina[a]	35,926,000	3,100,000	4,500,000	21.1
Australia[b]	19,338,000	11,722,000	143,433	61.0
Austria[c]	8,070,000	0	160,000	2.0
Brazil[b]	172,558,000	65,585,000	?	>41.0
Brunei[a]	310,000	175,000	0	56.0
Canada[c]	31,000,000	13,330,000	300,000	43.0
Chile[b]	15,401,000	5,423,877	788,550	40.0
China	1,292,378,000	0	200,000,000[ii]	15.0
Colombia	42,802,000	29,406,860	600,140	70.0
Cuba[d]	11,236,000	[iii]	0	
Cyprus[c]	689,471	0	approx 40,000	5.7
Czech Republic	10,260,000	0 [iv]	15,000	<0.1
Denmark	5,332,000	0	50,000	1.0
Egypt[d]	69,079,000	[v]	0	
Fiji	822,000	300,000	0	36.0
Finland	5,177,000	0 [vi]	200,000	4.3
France	59,452,000	0 [vii]	1,800,000	3.0
Gabon	1,261,000	0	1,261,000	100
Germany	82,183,824	0 [viii]	0	0
Guatemala[e]	11,686,000	1,800,000	?	15.0
Guyana	762,000	45,000	200,000	32.0
Haiti	8,269,000	0	11,461	<0.1
Hong Kong[c]	6,708,309	6,708,309	0	100.0
Iran	71,368,000	0	[ix]	
Ireland[f]	3,840,000	2,345,000	200,300	66.0
Israel[a]	6,370,000	4,267,900	509,000	75.0
Italy	57,502,000	0	[x]	
Japan[g]	127,334,000	0 [xi]	0	0
Korea[g]	46,125,000	5,367,000	0	11.4
Kiribati	84,000	0	50,400	approx 60.0
Libya[d]	5,407,000	400,000	1,000,000	26.0
Malaysia[a]	22,632,000	approx 15,842,000	0	approx 70.0

Country	Population	Adjusted population served	Natural population served	Total population served (%)
Malta[c]	386,000	0	38,600	10.0
Mexico[a]	100,367,000	0 [xii]	3,000,000	3.0
Namibia	1,787,000	0	approx 200,000	approx 11.0
Nauru	13,000	0	[xiii]	
Netherlands	16,000,000	0 [xiv]	0	0
New Zealand	3,807,000	2,317,728	0	61.0
Nigeria	116,928,000	0	20,000	<0.1
Panama[a]	2,898,000	509,554[xv]	0	18.0
Papua New Guinea (1975)	4,919,000	102,000	70,000	3.0
Paraguay (1977)	5,635,000	350,000	[xvi]	>6.0
Peru[d]	26,092,000	500,000	80,000	2.0
Philippines	77,130,000	approx 5,000,000	850,000	approx 8.0
Poland	38,576,000	80,000	300,000	1.0
Puerto Rico[a]	3,500,000	approx 35,000[xvii]	0	<1.0
Senegal	9,661,000	0	1,000,000	10.0
Serbia	10,537,000	300,000	?	approx 3.0
Singapore[b]	4,107,000	4,107,000	0	100.0
South Africa[a]	43,791,000	0 [xviii]	?	?
Spain	39,920,000	4,000,000	0	10.0
Sri Lanka	19,103,000	0	2,799,390	15.0
Sweden	8,832,000	0	750,000	8.4
Taiwan[e]	22,500,000	0 [xix]	?	
Tanzania[c]	35,000,000	0	12,250,000 [xx]	35.0
Thailand[a]	60,161,000	91,000	approx 150,000	approx 4.0
UK[c]	59,541,000	5,400,000	330,000	10.0
USA[a]	281,421,906	171,000,000	10,001,000	64.0 [xxi]
Uruguay	3,360,000	0	15,000	<0.1
Venezuela	24,631,000	0	100,000	<0.1
Vietnam	79,700,000	4,400,000	0	6.0
Zaire	37,500,000	0	600,000	2.0
Zambia[c]	10,200,000	0	947,166 [xxii]	10.0
Zimbabwe[c]	13,000,000	0	2,600,000 [xxiii]	20.0
	TOTALS	**355,105,318**	**49,961,040** [xxiv]	

[i] Data published by FDI 1990 unless otherwise indicated as follows: a USPHS Division of Oral Health, CDC, 2002/3; b USPHS Division of Oral Health, CDC, 1998; c British Fluoridation Society survey, 2002; d FDI 1981; e FDI 1984; f O'Mullane, 1996; g Journal of Dental Health (Official publication of the Japanese Society for Dental Health) 51(4) 2001.

[ii] Includes above optimal.

[iii] Water fluoridation schemes in operation in 5 communities, number of people affected unknown.

[iv] Extensive fluoridation served 1.5 million people in the Prague area, 1975-1989.

[v] Pilot study begun in Alexandria number of people affected unknown.

[vi] Kuopia (population 76,000) fluoridated 1959-1992.

[vii] Fluoridated salt was introduced in 1986 and, for example for the period 1991-1996, made up 40-50% of sales.

[viii] Fluoridation in former GDR discontinued since reunification. Fluoridated salt was introduced in 1991 and as at 1997 made up 25% of sales.

[ix] Several cities, population coverage not known.

[x] 1 community, population coverage not known.

[xi] Planning to start fluoridation in Kumejima, Okinawa soon.

[xii] 100% of salt is fluoridated.

[xiii] Water supplies imported from Australia & New Zealand, not known if fluoridated.

[xiv] Fluoridation to around 30% of the Netherlands population was ceased in 1973 because of inadequate legislation and anti-fluoridation activity.

[xv] This estimate dates from 1974. However, recent communication with CDC confirmed that artificial fluoridation continues in the two largest cities.

[xvi] 3 communities numbers covered not known.

[xvii] Puerto Rico has passed a mandatory fluoridation law which has not been enforced yet.

[xviii] Mandatory fluoridation regulations signed in 2001; expected to start widespread fluoridation during 2003/2004.

[xix] Fluoridation project serving 600,000 operational from 1969 to 1981. Discontinued because of antifluoridation activity.

[xx] Remaining 65% of the population are at higher than optimal concentrations.

[xxi] This rises to 67.9% when expressed as a % of the population served by public water systems

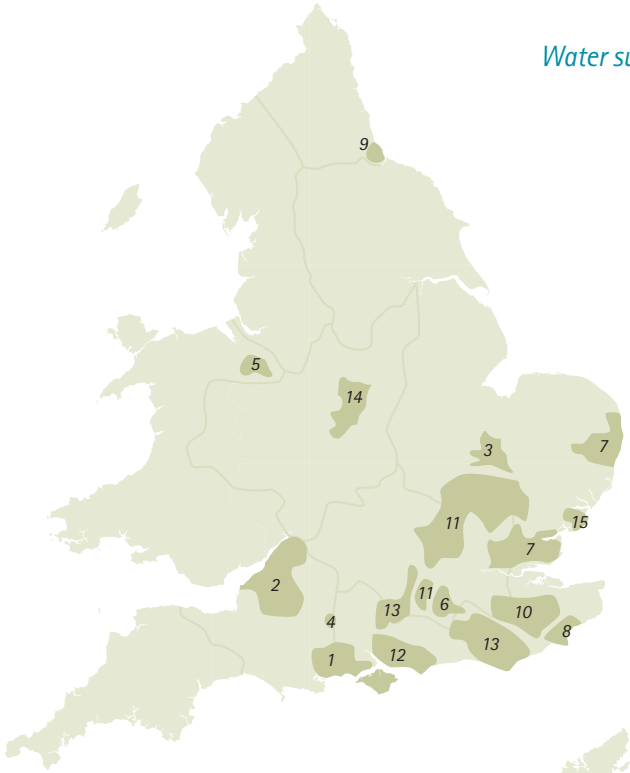
[xxii] Approximately 300,000 people receive water at 2.78 parts per million.

[xxiii] Approximately 650,000 people receive water with higher than optimal fluoride concentration

[xxiv] Excluding China where levels include above optimal.

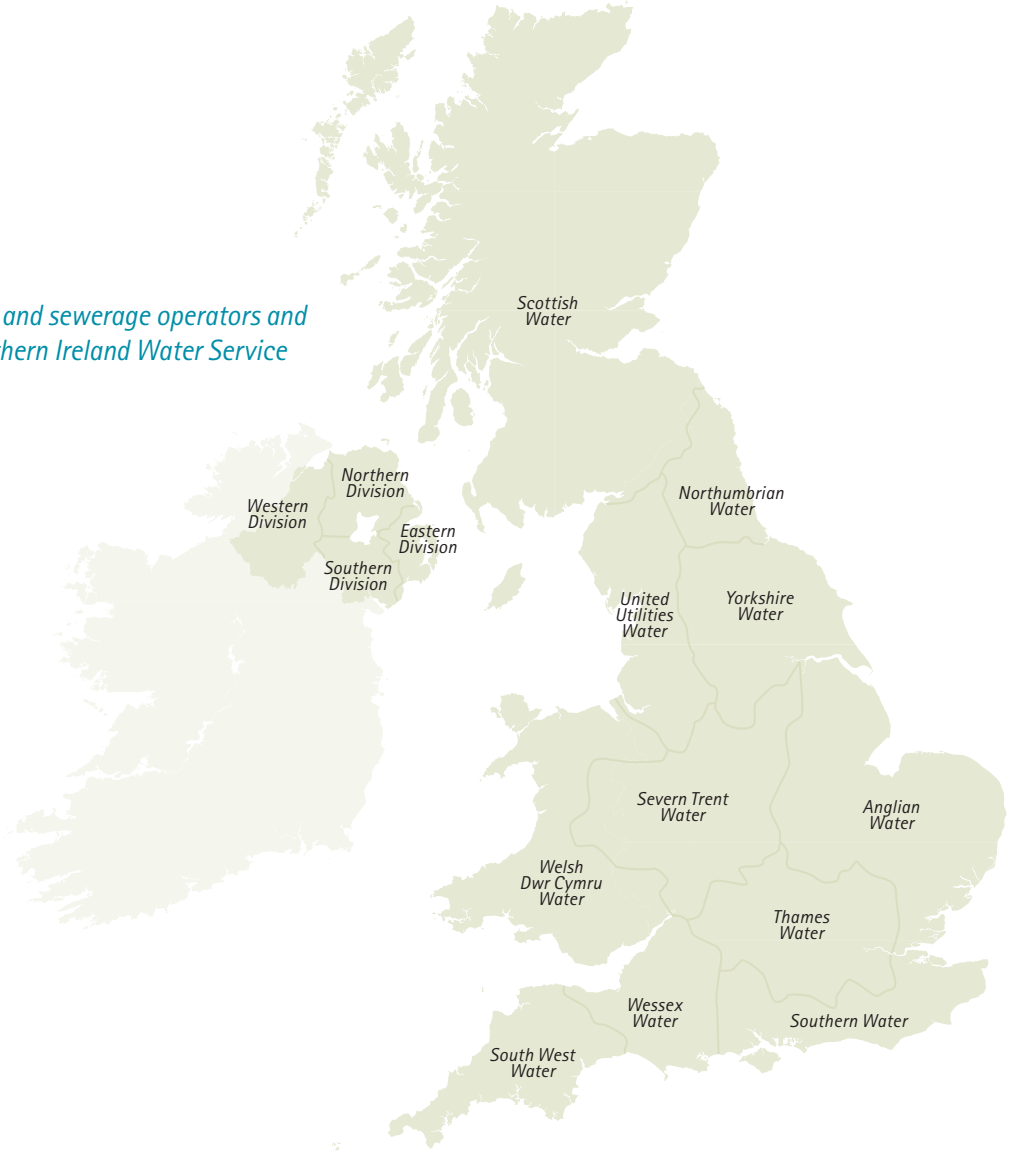
Approximate supply areas covered by water companies

Water supply only companies



1 Bournemouth & West Hampshire Water plc
2 Bristol Water plc
3 Cambridge Water plc
4 Cholderton & District Water Company
5 Dee Valley Water plc
6 Sutton and East Surrey Water plc
7 Essex & Suffolk Water (part of Northumbrian Water Ltd)
8 Folkestone & Dover Water Services Ltd
9 Anglian Water Services Ltd
10 Mid Kent Water plc
11 Three Valleys Water plc
12 Portsmouth Water plc
13 South East Water plc
14 South Staffordshire Water plc
15 Tendring Hundred Water Services Ltd

Water and sewerage operators and Northern Ireland Water Service



Water company details

Water supply only companies

Anglian Water Services Ltd (part of awg plc)
Anglian House
Ambury Road
Huntingdon
Cambs PE23 3NZ
Phone: +44 (0)1480 323 000
Fax: +44 (0)1480 323 115
http://www.anglianwater.co.uk

Bournemouth & West Hampshire Water plc
George Jessel House
Francis Avenue
Bournemouth
Dorset BH11 8NB
Phone: +44 (0)1202 591 111
Fax: +44 (0)1202 597 022
http://www.bwhwater.co.uk

Bristol Water plc
PO Box 218
Bridgwater Road
Bristol BS99 7AU
Phone: +44 (0)117 966 5881
Fax: +44 (0)117 963 4576
http://www.bristolwater.co.uk

Cambridge Water plc
41 Rustat Road
Cambridge CB1 3QS
Phone: +44 (0)1223 403 000
Fax: +44 (0)1223 214 052
http://www.cambridge-water.co.uk

Cholderton & District Water Company
Estate Office
Cholderton
Salisbury
Wiltshire SP4 0DR
Phone: +44 (0)1980 629 203
Fax: +44 (0)1980 629 307

Dee Valley Water plc
Packsaddle
Wrexham Road
Rhostyllen
Wrexham LL14 4EH
Phone: +44 (0)1978 846 946
Fax: +44 (0)1978 846 888

Essex & Suffolk Water plc (part of Northumbrian Water Ltd)
Hall Street
Chelmsford
Essex CM2 0HH
Phone: +44 (0)1245 491234
Fax: +44 (0)1245 212345
http://www.eswater.co.uk

Folkestone & Dover Water Services Ltd
Cherry Garden Lane
Folkestone
Kent CT19 4QB
Phone: +44 (0)1303 298800
Fax: +44 (0)1303 276712

Mid Kent Water plc
Snodland
Kent ME6 5AH
Phone: +44 (0)1634 873 111
Fax: +44 (0)1634 242 764
http://www.midkentwater.co.uk

Portsmouth Water plc
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West Street, Havant
Hampshire PO9 1LG
Phone: +44 (0)2392 499 888
Fax: +44 (0)2392 453 632
Minicom: +44 (0)345 585873
http://www.portsmouthwater.co.uk

South East Water plc (part of the SAUR group)
3 Church Road
Haywards Heath
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Phone: +44 (0)1444 448 200
Fax: +44 (0)1444 413 200
http://www.southeastwater.co.uk

South Staffordshire Water plc
Green Lane
Walsall
West Midlands WS2 7PD
Phone: +44 (0)1922 638 282
Fax: +44 (0)1922 723 631
Minicom: +44 (0)1922 618 025
http://www.south-staffs-water.co.uk

Sutton and East Surrey Water plc
London Road
Redhill
Surrey RH1 1LY
Phone: +44 (0)1737 772 000
Fax: +44 (0)1737 766 807
http://www.waterplc.com

Tendring Hundred Water Services Ltd
Mill Hill
Manningtree
Essex CO11 2AZ
Phone: +44 (0)1206 399 200
Fax: +44 (0)1206 399 210
http://www.thws.co.uk

Three Valleys Water plc
PO Box 48
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Phone: +44 (0)1707 268 111
Fax: +44 (0)1707 277 333
http://www.3valleys.co.uk

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Phone: +44 (0)1480 323 000
Fax: +44 (0)1480 323 115
http://www.anglianwater.co.uk

Dwr Cymru Cyfyngedig/Welsh Water
Pentwyn Road,
Nelson
Treharris
Mid Glamorgan CF46 6LY
Phone: +44 (0)1443 452300
Fax: +44 (0)1443 452809
http://www.dwrcymru.co.uk

Northern Ireland Water Service
Northland House
3 Frederick Street
Belfast BT1 2NR
Phone: +44 (0)2890 244 711
Fax: + 44 (0)2890 354 888
http://www.doeni.gov.uk/water

Northumbrian Water Ltd
(part of Ondeo group)
Abbey Road
Pity Me
Durham DH1 5FJ
Phone: +44 (0)191 383 2222
Fax: +44 (0)191 384 1920
http://www.nwl.co.uk

Scottish Water
6 Castle Drive
Carnegie Campus
Dunfirmline
KY11 8GG
Phone: +44 (0) 1383 848200
Fax: +44 (0) 1328 622090
http://www.scottishwater.co.uk/

Severn Trent plc
2297 Coventry Road
Birmingham B26 3PU
Phone: +44 (0)121 722 4000
Fax: +44 (0)121 722 4800
http://www.severn-trent.com

South West Water Ltd
(subsidiary of Pennon Group plc)
Peninsula House
Rydon Lane
Exeter EX2 7HR
Phone: +44 (0)1392 446 688
Fax: +44 (0)1392 434 966
http://www.southwestwater.co.uk

Southern Water
Southern House
Yeoman Road
Worthing
West Sussex BN13 3NX
Phone: +44 (0)1903 264 444
Fax: +44 (0)1903 262 185
http://www.southernwater.co.uk

Thames Water Utilities Ltd
Gainsborough House
Manor Farm Road
Reading RG2 OJN
Phone: +44 (0)118 959 1159
Fax: +44 (0)1793 420711
http://www.thames-water.com

United Utilities Water plc
Dawson House
Liverpool Road
Great Sankey
Warrington WA5 3LW
Phone: +44 (0)1925 234 000
Fax: +44 (0)1925 233 360
http://www.unitedutilities.com

Wessex Water Services Ltd
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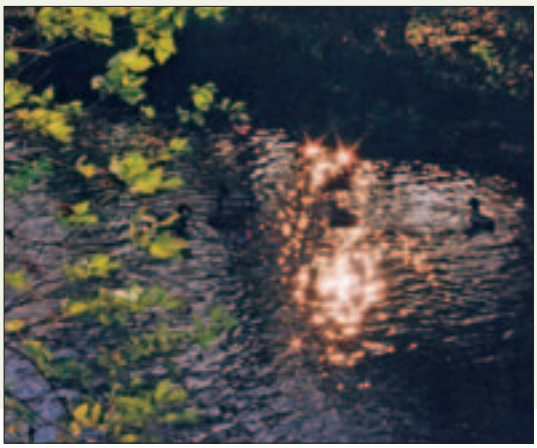
Environmental Aspects of Water Fluoridation

Key points

- Fluorides are very common in the environment.
- Reviews of the literature and environmental impact assessments have found no evidence of any adverse environmental effects resulting from water fluoridation.
- Water fluoridation could be described as *environmentally friendly* since it ensures maximum utilisation of natural resources, and reduces waste.



Sources of fluoride in the environment

The element fluorine, chemically combined in the form of fluorides, is abundant in the earth's crust. Drinking water and virtually all foodstuffs contain at least trace amounts of fluoride, and all organisms are exposed to fluoride originating either from natural processes or human activity. Fluoridation of drinking water supplies however is not a major source of fluoride in the environment. Fluorides are to be found everywhere in the environment their occurrence is as a result of:

- Natural processes – the erosion of fluoride-containing minerals and the rain cycle, and by emissions from volcanoes;
- Industrial processes - principally steel, glass, brick and ceramics manufacture, aluminium, copper, and nickel production, phosphate ore processing, phosphate fertilizer production and use, the use of fluoride-containing pesticides, and industrial and domestic coal burning; and finally,
- Fluoridation of drinking water supplies

Fluoride levels in surface waters, the air, and soil depend on the natural rock, geothermal and volcanic activity, and discharges and emissions resulting from human activity – the main sources of which are industrial - in particular phosphate ore production and use, and aluminium production [1]. The route of exposure and the ability of the species to absorb fluoride influence its uptake by organisms and plants. The environmental impact of fluorides has been well documented since at least 1937.

Recent reviews

More recent reviews of the environmental impact of water fluoridation include:

The World Health Organisation

The World Health Organisation has reviewed the literature [1-3] and identifies the principal sources of fluoride pollution as industries and mining. The World Health Organisation notes that in the absence of adequate emission control in such settings environmental pollution can be a problem. Such pollution has been a problem in the past in industrialised countries, and the World Health Organisation warns that unless proper environmental safeguards are adhered to, there is a danger of it occurring in developing countries with increasing industrialisation [3].

In areas not in the direct vicinity of emission sources, the mean concentrations of fluoride in

ambient air are generally less than 0.1 µg/m^3. Levels may be slightly higher in urban than in rural locations; but, even in the vicinity of emission sources, the levels of airborne fluoride usually do not exceed 2–3 µg/m^3. However, in some provinces of China where fluoride-rich coal is used as a source of fuel and for drying and curing food, reported indoor air concentrations of fluoride have reached 6 µg/m^3 [1].

Fluoride pollution is recognised by the World Health Organisation primarily as an *industrial* hazard; the World Health Organisation does not consider the fluoridation of water supplies to improve dental health to be a potential source of fluoride pollution.

Tacoma-Pierce County Health Department, Washington, USA August 2002 [4]

Under Washington's State Environmental Protection Act (SEPA) the Tacoma-Pierce County Health Department commissioned an independent investigation of the potential environmental consequences of a proposal by the Health Department to fluoridate all water systems serving 5,000 or more people.

The investigation looked at the proposal in terms of its impact under the following 16 headings standardised by the State: Earth; Air; Water including surface, ground, and water runoff; Plants; Animals; Environmental Health; Land and Shoreline Use; Housing; Aesthetics; Light and Glare; Recreation; Historic and Cultural Preservation; Transportation, Public services; and, Utilities. The study provided detailed confirmation that *'fluoridation of the public drinking water will not negatively impact the environment'* [4].

Environment Agency and the Scotland and Northern Ireland forum for Environmental Research [5]

An environmental risk assessment conducted for the Environment Agency and the Scotland and Northern Ireland forum for Environmental Research comprehensively reviewed the aquatic toxicity of fluoride and proposed environmental quality standard (EQs) for fluoride [5]. In personal communication, one of the report's authors (Wendy Young 18 August 1999) said

> *'on the basis that water systems are fluoridated at 1mg1^{-1}, the theoretical maximum in wastewater effluent (before dilution) could potentially be 1mg1^{-1} this is in line with EQS value for surface water.'*

(The fluoride content of seawater is fairly constant at levels between 1.2 – 1.4 mg/l which is higher than the theoretical maximum in wastewater effluent).

Osterman, McGill University Montreal, 1990 [6]

Focusing on the effects of fluoridation on aquatic environment, Osteman's investigation evaluated the impact of water fluoridation on the aquatic environment. He found that:

> *'fluoridated water loss during use, dilution of sewage by rain and groundwater infiltrate, fluoride removal during secondary sewage treatment, and diffusion dynamics at effluent outfall, combine to eliminate fluoridation related environmental effects.' [6].*

In the US, where well over 60% of water supplies are fluoridated, Osterman found the fluoride concentration in most rivers averaged 0.33ppm. A literature review by Osterman did not reveal any examples of municipal water fluoridation causing recommended environmental concentrations to be exceeded, although excesses occurred in several cases of severe industrial water pollution not related to water fluoridation.

Conclusion

As has been described in Section 6 of this report, the chemicals used for water fluoridation are manufactured as a co-product of the manufacture of phosphate fertilisers, and the raw material for that process is a natural resource (rocks excavated for their mineral content). Water fluoridation could therefore accurately be described as environmentally friendly since it ensures maximum utilisation of these natural resources, and reduces waste.

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Support for Water Fluoridation

Key points

- The World Health Organisation, the UK Health Departments, the Royal College of Physicians, the US Public Health Service and many other medical and scientific organisations endorse fluoridation as a safe and beneficial public health measure.
- Independent opinion surveys carried out recently show that the vast majority of people in the UK think fluoride should be added to water if it can reduce tooth decay. Many are wrongly under the impression they are already benefiting from fluoridated water when, in reality, they are not.

The Royal College of Physicians and the British Dental Association support water fluoridation

Public and professional support

In the UK, national opinion surveys conducted by NOP and Gallup consistently show that around 70% of the public believe that fluoride should be added to water supplies to prevent tooth decay. Furthermore, statutory local consultations conducted by over 60 health authorities have demonstrated a high level of public support [1].

An Alliance of over 100 top scientific medical and voluntary organisations – including the British Medical Association, the British Dental Association, MENCAP, the Patients Association, several NHS bodies and local authorities – endorses fluoridation and is campaigning for the rights of communities to choose fluoridation, and to have their wishes implemented.

Worldwide, every major health body that has considered the evidence have confirmed the effectiveness of water fluoridation and found no evidence of harm. Such bodies include expert working groups or committees of the World Health Organisation, the Royal College of Physicians, the US National Academy of Sciences, the Medical Research Council and several governments - including UK, US, Australia, New Zealand. (See Section 4 of this report for more detail.)

This combination of strong professional and public support for fluoridation is a powerful argument for ensuring that, where it is feasible and cost-effective, water supplies in the UK should have their natural fluoride content adjusted to the optimum level of one part per million.

Royal College of Physicians

Since the 1960s, the merits of fluoridation have been considered by many professional bodies concerned with the health and well-being of the UK population. Notably, the Royal College of Physicians undertook a thorough appraisal of all aspects of fluoridation. Its report Fluoride, Teeth and Health, published in 1976 [2], included the following unambiguous endorsement:

> *'The College recommends fluoridation of water supplies in the United Kingdom where the fluoride level is appreciably below 1 mg per litre.'*

The College has not had cause to change this view.

Other medical, dental and scientific bodies

Organisations which have either publicly recommended fluoridation, or have issued statements confirming its safety and effectiveness, include:

- UK Departments of Health
- US Public Health Service
- The Royal College of Physicians
- The Faculty of Public Health Medicine of the Royal College of Physicians
- The Royal College of Surgeons of England
- The Royal College of Surgeons of Edinburgh

- The Royal College of Paediatrics and Child Health
- The Royal College of Nursing
- The Royal College of General Practitioners
- The Royal College of Physicians and Surgeons of Glasgow
- The Royal Society for the Promotion of Health
- UK Public Health Association
- Help the Aged
- The Patients Association
- MENCAP
- The National Autistic Society
- National Children's Bureau
- The British Medical Association
- The British Dental Association
- The British Association for Community Child Health
- The British Society of Dentistry for Disability & Oral Health
- The British Society of Gerodontology
- Community Practitioners and Health Visitors Association
- General Dental Council
- Society of Community Medicine
- The British Association for the Study of Community Dentistry
- British Society for Allergy and Clinical Immunology
- American Dental Association
- FDI World Dental Federation

This is by no means an exhaustive list of the many organisations worldwide that support water fluoridation; however from this selection it can be seen that there is an overwhelming mass of professional opinion in favour of fluoridation. Indeed, very few other health promotion measures enjoy such a level of support.

The World Health Organisation

At the highest international levels of health policy-making, the World Health Organisation continues to support water fluoridation where it would be practicable to introduce it. The World Health Assembly passed the latest of three fluoride resolutions in 1978, and it remains in force today. It requests the Director-General to:

> *'continue to provide technical advice and assistance to Member States in the prevention and control of dental caries by the adjustment of the fluoride content of public water supplies to the optimal level.' [3]*

Subsequently the World Health Organisation has published technical guidance that recommends:

> *'Community water fluoridation is safe and cost-effective and should be introduced and maintained wherever it is socially acceptable and feasible.' [4]*

Support in Parliament

In 1985 Members of Parliament voted in favour of the Water (Fluoridation) Bill to give health authorities the legal power to improve dental health by water fluoridation.

Introducing the Bill the Minister for Health, Kenneth Clarke, stated that the evidence of effectiveness and safety had been followed for years in some areas and said:

> *'About 5 million people, including my own family, drink water where the fluoride content has been artificially increased to the optimum recommended level of 1 part per million.'*

The Bill received broad cross-party support.

The Opposition Spokesman on Health, Michael Meacher, said:

> *'The great advantage of fluoridation is that it benefits most the poorest and the ill-informed – those who are not reached by other initiatives ... How can one justify not giving the child who lives in Wolverhampton or Salford the same protection against tooth decay as the child who lives in Birmingham or Watford already enjoys?'*

The Liberals spokesman on health, Michael Meadowcroft, also strongly supported the Bill, drawing on the evidence of Birmingham during the previous 20 years:

> *'dental decay has been reduced dramatically ... the number of children attending for relief of toothache dropped ... children supplied with false teeth 12 times lower.'*

Following much debate, on 5th March 1985 the Bill received its Third Reading. Members of Parliament voted 2 to 1 in favour of the Bill which became law on 30th October 1985.

The All Party Parliamentary Primary Care and Public Health Group Inquiry into Water Fluoridation

In March 2003 the All Party Parliamentary Primary Care and Public Health Group published a report of its Inquiry into Water Fluoridation. The All-Party Group chose to investigate issues surrounding the fluoridation of public water supplies in the UK following the Medical Research Council report but before the Government had formally responded to it. The All Party Group

report was submitted to Ministers with the intention of influencing future fluoridation policy.

The All-Party Group report endorsed the effectiveness and safety of water fluoridation, and rejected the `civil liberties' argument against it. The Group recommended that:

- Dental health policy should recognise targeted water fluoridation as a legitimate and effective means of tackling dental health inequalities; and that
- Legislation should be amended to allow the responsible health body, after public consultation has demonstrated strong local support, to require water companies to fluoridate as directed.

Support for fluoridation among backbench MPs in Parliament is as strong as ever. During the 2003 parliamentary session 149 MPs from all parties signed an Early Day Motion supporting fluoridation. Furthermore, following a massive 5 to 1 Lords vote in support of fluoridation, in November 2003, in a free vote, MPs voted 2 to 1 to support a Government amendment to the Water Bill to correct flawed legislation that had dogged health authorities' attempts to implement fluoridation for almost 20 years.

Support from local councils

Until 1974 local councils were responsible for both public health and water supplies, and it was local councils who were responsible for implementing practically all of the fluoridation schemes in operation in the UK today. With the support of local councils, in 1955 and 1956 three demonstration projects (controlled studies) were established in Watford (England), Kilmarnock (Scotland), and Anglesey (Wales). After publication of the first evaluation report in 1962 [5], many councils serving large urban populations – including Birmingham and Newcastle City Councils started fluoridating their water supplies.

During the late 1980s and early 1990s many local councils actively supported health authorities proposals for water fluoridation. In the North West, North East and West Midlands of England the majority of local councils consulted by health authorities supported fluoridation proposals. The councils of several major cities and towns - including Manchester, Salford, Oldham, Rochdale, Stockport, Durham, Gateshead, Kirklees, Leeds, Newcastle, Birmingham, Coventry, Sandwell, and Worcester are long-standing supporters of water fluoridation. Several are members of the National Alliance for Equity in Dental Health.

Support from the public

Before the early 1980s little systematic public opinion research had been conducted in the UK on the subject of fluoridation. It was therefore difficult to know whether the public generally supported it or not. All that changed, however, in 1980 when the West Midlands Regional Health Authority commissioned a leading independent research company - NOP - to undertake a nationwide survey. NOP asked a demographically representative sample of people in over 170 parliamentary constituencies whether they thought fluoride should be added to water if it can reduce tooth decay. The results were as follows:

Yes - 66%
No - 16%
Don't know - 18%

Support across all parts of the country and all social groups

For the first time, health authorities had incontrovertible evidence that two thirds of the population wanted fluoride added to their water supplies to prevent tooth decay. Not only that - the NOP survey showed clearly that there was a large majority in favour of fluoridation in all regions of England and in Scotland and Wales.

Some opponents of fluoridation attacked the wording of the question, claiming that it was biased because it asked people to say whether they would support fluoridation *if it reduced tooth decay*. The reduction of tooth decay should not have been mentioned, they claimed. However, those who framed the survey argued strongly that it would have been justifiable to have gone further and use the word *because*, and not simply *if* - on the grounds that it is an established scientific fact that fluoridation does reduce tooth decay.

Moreover, they stressed that the issue of tooth decay had to be incorporated within the question because that is what fluoridation is for. How could someone say whether or not he or she supported a health policy without being told the purpose of it? Common sense dictated that if respondents to the survey objected to the idea (either on ideological grounds or because they mistakenly believed it would cause harm to other organs of the body), they would say that they opposed it, whether or not it reduced tooth decay.

Support remains high

Since the first nationwide public opinion survey on fluoridation in 1980, more surveys have been carried out. In 1985 and 1987 the National Association of Health Authorities commissioned Gallup to find out how public opinion was changing in the light of increased publicity on the issue. Both surveys revealed a steadily rising level of support for fluoridation:

- **1985 survey by Gallup for NAHA**
  Do you think fluoride should be added to water if it can reduce tooth decay?
  Yes - 71%
  No - 17%
  Don't know - 11 %

- **1987 survey by Gallup for NAHA**
  Do you think fluoride should be added to water if it can reduce tooth decay?
  Yes - 76%
  No - 15%
  Don't know - 9%

- **1992 NOP nationwide survey - highest ever level of support**
  In May 1992 the British Fluoridation Society commissioned NOP to conduct a nationwide survey was conducted. NOP used the same basic set of questions as the three previous surveys in face-to-face interviews with a randomly selected sample of people across England, Scotland and Wales. This time the results were:
  Yes - 79%
  No - 15%
  Don't know - 6%

  These figures show the highest ever level of public support for fluoridation.

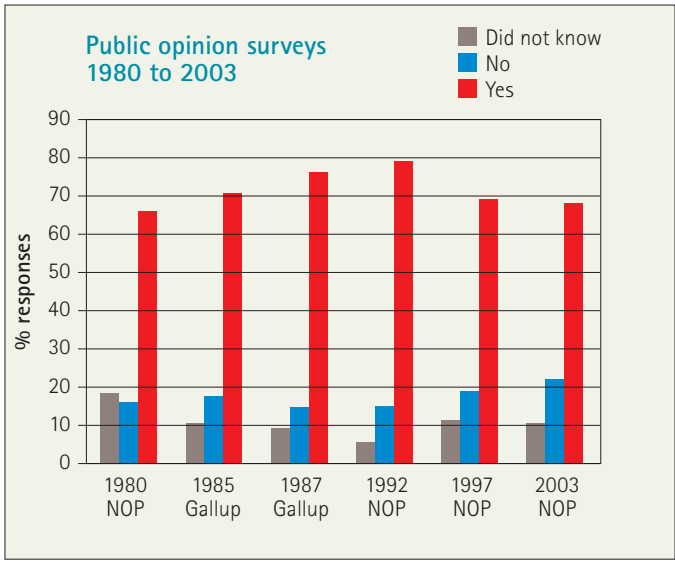
  In 1997 NOP carried out a further opinion poll for the British Fluoridation Society which showed a slight fall from the very high level of support in 1992. This is not surprising given the continued vigorous national campaigning of organisations opposed to fluoridation. However, it is clear that the majority (around two thirds) of the public continue to support fluoridation.

- **1997 survey by NOP for the British Fluoridation Society**
  Do you think fluoride should be added to water if it can reduce tooth decay?
  Yes – 69%
  No - 18%
  Don't know – 13%

- **2003 survey by NOP for the British Fluoridation Society**
  Do you think fluoride should be added to water if it can reduce tooth decay?
  Yes – 67%
  No - 22%
  Don't know – 11%

What is clear from all of these surveys of public opinion over almost 20 years is that consistently at least two thirds of the British public support water fluoridation.

Figure 1



Few, if any, public health issues have been subjected to such extensive opinion research at national level. All the evidence is that the majority of people support water fluoridation as a means of preventing tooth decay on a community-wide basis.

More people think their water is fluoridated than is actually the case

In 1988 the number of people in the UK estimated to be drinking fluoridated water was around 6 million [6] - one in every nine people in the country. What opinion research reveals, however, is that many more people think their water is fluoridated even though it is not.

In the 1992 NOP survey, and again in the 2003 survey over 40% of those interviewed thought they were already receiving fluoridated water, compared with 11% or thereabouts who were actually receiving it. This suggests a gap between public expectations on the one hand and what health authorities have been able to achieve on the other.

Most people do not realise that fluoride is present naturally in water

Unlike many of the other substances that are added to water to make it fit to drink, fluoride is present naturally in all water supplies. In fact, in some places it occurs in sufficient concentrations - one part of fluoride per million parts of water - to prevent tooth decay. Hartlepool in the North East of England, for example, has benefited for generations from adequate natural levels of fluoride in water. This is reflected in its children's dental health which is amongst the best in the country.

The existence of natural fluoride in water was how scientists first discovered the link between fluoride and dental health. However, surveys suggest that most people do not realise that fluoride is a natural constituent of water and that fluoridation is simply the process of topping up something which is already there rather than adding something which is ordinarily absent. In the 1992 and 2003 NOP surveys, only around 30% said (correctly) that there was natural fluoride in water, while around 35% of the sample of adults questioned thought there was no fluoride present naturally in water the remaining 35% said they did not know.

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10

The Ethics of Water Fluoridation

Key points

- Fluoridating water supplies replicates the benefits already enjoyed by communities receiving water naturally containing one part per million of fluoride. The greatest benefit is to children – who are least able to help themselves.
- Drinking fluoride-free water is not a basic human right but a question of individual preference. Personal preferences need to be balanced against the common good arising from the lower levels of tooth decay which fluoridation brings.
- Fluoridation can provide a high degree of protection against tooth decay. It can liberate people from the pain and misery of toothache and from the anxiety of having teeth extracted or filled.

Barnardo's Preschool, Rochdale Road, Oldham

A question of balance

Clearly, there is scope for different points of view on the ethics of any major issue of public policy, including fluoridation. Anyone taking up an extreme 'individualist' position which holds that the individual has the right to determine the precise composition of a publicly provided water supply, is unlikely to accept fluoridation as anything less than an intrusion. Does that mean that the individual can prevent the chlorination of water simply because of a personal aversion to chlorine? Surely in a society where people come together for mutual support and mutual benefit, it is a question of balancing individual preferences against the common good.

The professional philosopher's view

John Harris is Professor of Bioethics at the University of Manchester, and is recognised internationally as an expert in medical ethics. Professor Harris argues that fluoridation is perfectly ethical because:

- It is a safe process which confers benefits on human beings (protection from tooth decay, one of the commonest diseases).
- It does not in any way conflict with basic human rights (there is no such thing as the right to drink fluoride-free water - only a personal preference to do so).
- It is replicating a situation which occurs naturally in some places (where fluoride already exists in water at the optimum level of one part per million parts of water).
- It does not have any harmful consequences (its safety having been demonstrated by almost sixty years of experience and by the wealth of endorsements from leading dental, medical and scientific organisations).

John Harris goes further. He asserts that as dental decay may itself be responsible for a small number of deaths each year from anaesthesia used in treatment, fluoridation could be described as 'life-saving' if it prevents the need for treatment. Indeed, it could even be unethical not to fluoridate water where it is practicable to do so.

The view of a human rights' campaigner

Lord Avebury, former Chairman of the Parliamentary Human Rights Committee, enjoys an international reputation for his work in this field. No one could say that he was slow to champion the cause of individual freedom. His view on fluoridation is therefore particularly relevant, since he could scarcely be expected

to support a measure which infringed basic human liberties. Lord Avebury dismisses as invalid the so-called libertarian arguments of those who oppose fluoridation. Writing in the *British Dental Journal* [3] he said:

> *'Fluoride is a natural constituent of water supplies, as indeed it is of many foods. The adjustment of the quantity to an optimum level cannot be compared with the addition to water of a substance not found there ordinarily'.*

He also rejected claims that fluoridation could be construed as 'mass medication', pointing out that fluoridation is not a means of curing a disease. He said:

> *'A substance which has the effect of maintaining medical or dental health is more in the nature of a food or nutriment than a medicine.'*

Like John Harris, Lord Avebury sees the ethics of fluoridation in positive terms:

> *'No consumer has the right to dictate the chemical composition of water, a recipe for anarchy. What is at stake is not the erosion of liberty but, ... the erosion of millions of teeth and the resultant suffering and misery of thousands of children which fluoridation would go far to prevent.'*

How a practising dentist sees it

Lord Colwyn is a legislator and a dentist. He looks at fluoridation from two perspectives: what it can do to prevent tooth decay on the one hand and how it fits in with the rights of the individual on the other. Knowing that fluoridation is both safe and effective, he is clear in his view about the rights and wrongs of the matter:

> *'It is all very well saying that they (children) should clean their teeth and that we should take their sweets away from them. But it is not until you have had to hold down a screaming four-year old child, anaesthetise it and pullout baby teeth that you realise the immorality of not initiating a proven, comprehensive plan that will prevent untold cases of future suffering.'*

Helping those least able to help themselves

It is important to remember that whilst fluoridation benefits everyone with natural teeth, the greatest benefit of all goes to those least able to help themselves - children. Moreover, research shows that fluoridation succeeds in levelling out the differences in dental health which normally separate children from better off and poorer backgrounds. In fact, as Table 1 shows, in the 2001/2002 national dental survey of 5-year-olds, the dental health of children in fluoridated Rowley Regis and Tipton, one of the poorest PCT districts in England, was at least as good as that of 5-year-olds in one of the most well off but non-fluoridated PCT districts, Guildford and Waverley [4].

Table 1 The dental health of 5-year-old children (2001/2002) in fluoridated but socially deprived Rowley Regis and Tipton PCT, compared with that of 5-year-olds in affluent but non-fluoridated Guildford and Waverley PCT.

	Fluoridated Rowley Regis and Tipton	Non-fluoridated Guildford and Waverley
Average number of decayed, missing or filled teeth per child	0.90	1.15
Percentage of children with any decayed teeth	32.7%	35.4%
Average number of decayed teeth per child among children with any decay experience	2.75	3.25

It is also interesting to note how the familiar North South divide in health status has disappeared as far as the dental health of children in fluoridated parts of the North East and West Midlands is concerned. National surveys of children's dental health consistently confirm that five-year olds in fluoridated areas enjoy the same standard of dental health as those from the more well off, but non-fluoridated parts of the South of England [4-7]. Fluoridation is a great equaliser.

Verdict of the Irish High Court

In December 1960 the Irish Parliament (Oireachtas) passed the Health (Fluoridation of Water Supplies) Act which gave the Minister for Health the power to require health authorities to arrange for fluoridation of water supplies for everyone connected to the public water supply system. Local authorities - the bodies responsible for water supplies - were obliged by this legislation to co-operate with health authorities in implementing the policy.

Following the passage of the Act, a resident of Dublin applied to the Irish High Court to have it overturned on the grounds that it was unconstitutional. In a hearing lasting 65 days, the counsel for the plaintiff argued that the Act had overridden the inalienable rights of the individual citizen, which the State had a duty to respect and, as far as practicable,

to defend by its laws. These rights, it was argued, included that of 'bodily integrity'.

Personal rights not unlimited

In his final judgement, delivered in 1963, Mr Justice Kenny stated:

> *'None of the personal rights of the citizen are unlimited: their exercise may be limited by Parliament (Oireachtas) when the common good requires this.'*

He added:

> *'When dealing with controversial social, economic and medical matters Parliament has to reconcile the exercise of personal rights with the claims of the common good and its decision on the reconciliation should prevail unless it was oppressive to all or some of the citizens or unless there is no reasonable proportion between the benefit which the legislation will confer on the citizens or a substantial body of them and the interference with the personal rights of the citizen.' [8].*

On the question of bodily integrity, Mr Justice Kenny accepted that it would be oppressive to impose on a country's citizens any process which might be dangerous. But he also accepted arguments that fluoridation was safe and that it constituted no danger to individuals' bodily integrity. He concluded:

> *'In my judgement, the fluoridation of the public water supplies in this country is not a violation of any of the plaintiff's constitutional rights and this action must be dismissed.'*

Verdict of the Supreme Court

The judgement of Mr Justice Kenny was upheld by the Irish Supreme Court in July, 1964 [9]. Chief Justice O'Dalaigh commented:

> *'The effect on the teeth (of fluoridation) is demonstrably beneficial. The purpose and the effect of fluoridation is to improve children's teeth and so, indirectly, their health. These benefits are to a great extent carried forward into adult life.'*

Replicating nature's benefits

Rejecting the plaintiff's contention about the possible violation of bodily integrity, the Supreme Court stated:

> *'Fluoride ions occur naturally in water and in many foods. The Act has for its object where water is deficient in fluoride ions to bring it to the optimal level by fluoridation. Fluoride ions thus added differ in no respect from fluoride ions naturally occurring in water. In modern life the provision of public water supplies in cities is necessarily a community obligation, and if water occurring naturally is deficient in some of its wholesome elements, it is the right if not the obligation of the community to make good the deficiency where this can be done without harm or danger to the public. The desirability of adding to food or water elements in which they are deficient or removing elements which may be harmful has been widely recognised and frequently exercised. Water is chlorinated, salt iodised, vitamins added to margarine, flour fortified whenever these measures are shown to be beneficial.'*

Duty to protect citizens against disease

The Supreme Court went on to develop the argument that the State has a duty to protect its citizens from disease. It said:

> *'Dental caries is no new thing. It has adversely affected generation after generation and will continue to do so if measures are not taken. This constitutes the type of danger from which the State has not merely the right but the duty to protect its citizens. To deal with the problem, parliament has chosen a method, namely the fluoridation of the public water supply. The plaintiff has failed to refute the evidence that this is not only the most effective method but is indeed the only effective method.'*

The judgement continued:

> *'The Court is left in no doubt that the fluoridation of water to the extent proposed in the Dublin Health Authority area where the plaintiff resides cannot be said to involve physical changes which affect in any way either the wholeness or the soundness of the person concerned. The ingestion of the fluoridated water cannot, therefore, be said to constitute an infringement of or a failure to respect the bodily integrity of the plaintiff or her children.'*

Not mass medication

The Court also firmly rejected the anti-fluoridation argument of 'mass medication'. It said:

> *'The Court does not accept that the fluoridation of water is, or can be described as, the mass medication or mass administration of "drugs" through water. This matter was examined in detail by the Commission set up by the Government of New Zealand to inquire into the desirability of fluoridation and the conclusion was reached that "fluoride is not a drug but a*

nutrient and fluoridation is a process of food fortification." It is, in the opinion of the Court, a misuse of words to refer to this process as mass medication or mass administration of drugs.'

The Forum on Fluoridation

Because of increased media coverage and apparent public interest and concern over the benefits and possible negative aspects of fluoridation, in May 2000 the Irish Minister for Health and Children established the Forum on Fluoridation to examine the issue. Recognising the complexity of the issue the Minister invited Professor Pat Fottrell, former President of the National University of Ireland, Galway, to act as the independent chair of the Forum. Forum members included representatives of the relevant Government Departments (in particular the Department of Health and Children which has the primary responsibility in this field), regional health authorities, university faculties engaged in relevant research areas, consumer bodies, environmental interests, and professional dental and medical bodies. In addition, its members included recognised authorities on ethics, law and sociology. The Forum report was published in 2002 [10].

Among other issues the Forum considered the legal and ethical dimensions of fluoridation in terms of the relationship between the State and the individual – in particular in light of the changing values in society since the early 1960s when mandatory fluoridation legislation had been enacted in Ireland.

Professor William Binchy, Regius Professor of Law, Trinity College, Dublin, gave evidence to the Forum on both the legal and ethical questions raised by fluoridation. His interesting presentations are included in full in Appendixes 16 and 17 of the Forum report (http://www.doh.ie/publications/fluoridation.html). Professor Binchy discussed in detail the contemporary legal position comparing it with the earlier judgements of Justice Kenny and Chief Justice O'Dalaigh. He said that the earlier judgements were no guarantee that the courts today would make an identical holding of fact or law. However, in his opinion the courts would be very reluctant to come to the conclusion that the 1960 Health (Fluoridation of Water Supplies) Act could be considered to infringe any constitutionally protected rights.

Professor Binchy also highlighted the radical changes which have taken place internationally in the 20th century in the predominant values relating to personal autonomy. Developing this theme, Professor Binchy suggested that there had been a movement *'from the social to the individual'* and that there was now increased emphasis on autonomy and *'disconnectedness'*. Nevertheless, he said, the State had assumed very wide-ranging new functions designed to achieve the goals of:

'enhancing social welfare, encouraging equality, protecting citizens from injury, improving their health, protecting potentially vulnerable groups such as employees and, within families, children - indeed generally to improve the quality of life for all.'

Public health is regarded as an important aspect of the State's responsibilities he asserted.

A sub-group of the Forum reviewed Professor Binchy's presentations and also consulted Dr Richard Hull, a respected ethicist. The sub-group addressed three areas of uncertainty:

- **Firstly whether water fluoridation posed any particular ethical problems:**
  Dr Hull addressed this question in terms of choice. He said that people *can* chose not to drink tap water, though he acknowledged that the choice was not an easy one. If the State were concerned about this, he said, consideration would have to be given to supplying an alternative source of water.
- **Secondly, whether water fluoridation breach bodily integrity or interfere with autonomy:**
  Dr Hull said that water fluoridation is a paternalistic intervention by the State to safeguard the health of its citizens. However, he said, such interventions are justifiable and the degree of infringement of bodily integrity by water fluoridation is relatively minor.
- **Thirdly, the issue of scientific uncertainty – it being impossible to state categorically that *anything* is completely safe:**
  Dr Hull suggested that the question relating to scientific uncertainty comes down to risk versus benefit. From an ethical perspective, he said, risk can be justified if the benefit significantly outweighs the risks.

Dr Hull further discussed the topic in terms of a potential conflict of values, between freedom and autonomy on the one hand, and welfare and paternalism on the other. Viewed from an

extreme libertarian perspective with the core values of freedom and autonomy, suggestions of equality and state intervention would be rejected he said. However other, less extreme, welfare liberal views might concede that freedom requires positive conditions such as a certain level of health, education and economic well being. Freedom in this sense is more positive and means more than just being free from interference. Furthermore, he said, along with positive conditions for freedom come positive rights to assistance. This reflects a position where allowing harm can be as bad or worse than doing it; such a position is consistent with limited paternalism, and allows for autonomy to be limited to a certain extent for the sake of freedom and justice.

In considering the safety argument Dr Hull, on the assumption that fluoridation is solely beneficial, balanced fluoridation against health education; however he conceded that this comparison is only valid if health education is effective:

> *'It is all very well to emphasise the value of autonomy, but the desire to effectively safeguard the health and safety of children (who are not yet autonomous) could be said to constitute a strong counter-emphasis.'*

Dr Hull concluded by saying that any evidence that fluoridation is unsafe will, of course, weaken the arguments in favour of it, although perhaps not fatally. Even given a modicum of risk, we might still ask whether it could ever be ethical to withhold an on balance beneficial treatment, to fail to prevent suffering when it is within our power? To do so *'would be to deliberately fail to protect and promote the health of people in our community,'* he said.

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The Cost and Cost-effectiveness of Water Fluoridation

Key points

- The World Health Organisation states that *'Community water fluoridation is safe and cost-effective and should be introduced and maintained wherever it is socially acceptable and feasible.'* [1]
- In the parts of the UK where tooth decay remains a significant public health problem, patients and the NHS economy would benefit hugely from water fluoridation.

Who pays for fluoridation?

Water fluoridation is a public health measure to improve dental health, and, as such, it is paid for entirely by the National Health Service. (Locally, the health authority is billed by the water company for the entire cost of fluoridating supplies.) The purpose of the National Health Service is to improve the health and well-being of the population; local health bodies – health authorities and boards, and primary care trusts – have a duty to improve the health of their local populations and to reduce health inequalities [2]. However, these local health bodies also have corresponding *financial* duties and they must not spend more cash than is allocated to them [3]. Clearly, with many competing demands on fixed NHS funds, health bodies will wish to be assured that they are spending public money wisely and obtaining `value for money'.

Cost-effectiveness

The *effectiveness* of water fluoridation in reducing tooth decay has long been established (see Section 2). However, effectiveness alone is not sufficient reason to implement such a measure: cost-effectiveness must also be considered. A healthcare measure is considered to be cost-effective if it provides the greatest benefit for a given expenditure, or if the value of the benefits exceeds the value of the costs [4].

Whilst surprisingly little is known about the cost-effectiveness of many common healthcare interventions [5], the cost-effectiveness of water fluoridation has been studied extensively over many years [6-16]. Indeed, a 1994 study by the University of York Health Economics Consortium of strategies for reducing tooth decay concluded:

> *'in terms of cost, effect and the certainty of that effect, the most cost-effective policy is fluoridation of water supplies.' [14].*

In 1998 the University of York Health Economics Consortium undertook a further, detailed, examination of the costs and benefits of water fluoridation and concluded:

> *'In areas where the average number of decayed, missing or filled teeth per child (dmft) is 2.0 or more (and especially if there are districts where it is greater than 2.6), and where the local water treatment works serve populations of at least 200,000 people, the benefits of water fluoridation are likely to be significantly greater than the costs.' [15]*

The 1998 study recognised that, overall, levels of tooth decay had improved dramatically since the 1960s when fluoridation was first introduced. However, it highlighted the significant variations in dental health across Britain that had become apparent as tooth decay in the general population had fallen. (See Section 2 for a more detailed discussion of these inequalities in dental health.) Recognising these variations, the study identified *'The range of possible benefits that would be associated with extending fluoridation into certain areas under certain assumptions.'*

The York study identified four key variables to be considered in evaluating the cost-effectiveness of water fluoridation:

- The size of the population;
- The level of tooth decay in the population;
- The age and condition of the water treatment works; and,
- The type of fluoride to be used.

The report's main findings, conclusions and recommendations were:

- Studies comparing the cost-effectiveness of water fluoridation compared with other strategies for reducing tooth decay always conclude that water fluoridation is the most cost-effective approach.
- One of the greatest strengths of water fluoridation is that it does not require any behavioural changes from its recipients.
- The scale of the effect of campaigns to change behaviour cannot be predicted, and such campaigns may fail to influence those who would benefit most from them. It is, however, possible to predict the costs and benefits with water fluoridation, and to be confident that those people likely to benefit the most from it will do so. Furthermore, the costs are borne by the NHS, and no private contribution is required.
- Calculating the capital and revenue costs of fluoridation for a population of a particular size is relatively straightforward, although these costs have to be discounted to determine the equivalent annual cost over each year of the installation's life (discounting allows the capital cost to be depreciated over the period). From this, an equivalent annual cost per person of fluoridation can be calculated, and indeed a ready-reckoner devised to determine this for populations of different sizes, and plants with different capital and revenue costs.
- Calculating the benefits of fluoridation is less straightforward. The approach used in this study draws upon work undertaken by Sanderson and Wilson [17] for Yorkshire data, based on the methodology of Birch [12], which identifies the expected reduction in tooth decay each year for children receiving fluoridated water from birth until they reach 14 years of age.
- Using population projections and knowledge of underlying oral status, it is possible to predict the numbers of decayed teeth, fillings and extractions that will be prevented each year of the life of the fluoridation installation (ie 14 years) for children born after fluoridation.
- A monetary value can then be assigned to these 'benefits', which are also discounted over the period to estimate the annual equivalent 'saving'.
- It should be noted that these calculations only consider the benefits to people born after the fluoridation of the water supply. However, those born prior to fluoridation will also benefit, although to a lesser extent. There is a paucity of research on the magnitude of the benefits of receiving fluoridated water for all of one's life, but all residents with natural teeth would benefit to some extent. For example, adults would have less decay on exposed root surfaces, and young children would have less decay in their permanent teeth. Due to the difficulties associated with quantifying such benefits, these have not been included in the calculations, but their omission means that the benefits of fluoridation are underestimated in the model.
- Considering the costs and benefits associated with water fluoridation shows which areas of Britain would benefit most. Such analysis also identifies which areas are not a priority for fluoridation, either due to good underlying oral status and/or the local water treatment works only serve a small population (eg less than 50,000). In such situations other approaches should be taken to target the families of children with particularly poor oral status. However, as the size of the population served by a particular water treatment works increases, the cost per person of fluoridation decreases, making fluoridation much more cost-effective.
- Where tooth decay risk is `medium' to `high' (average of 2.0 or more decayed teeth in children aged 5 years, and especially if there are districts where it is over 2.65), the benefits of water fluoridation are likely to be significantly greater than the costs. Such areas include most or all of Scotland, Wales, Merseyside and North West England, plus some parts of West Yorkshire.

Reducing the burden of cost to the NHS

The most common treatment of tooth decay in young children is tooth extraction which is usually carried out under general anaesthetic [18]. Following a Department of Health Review, and a General Dental Council ruling, from 1 January 2002 all general anaesthetics for dental treatment must be performed in a hospital setting with critical care facilities [19, 20]. Whilst necessary, this requirement makes the treatment of such a common disease particularly expensive, and places a strain on scarce NHS resources.

Tooth decay in young children is a particular problem in the North West of England, for example, and, each year, around 1500 general anaesthetics are administered to children for extraction of decayed teeth in the Manchester Dental Hospital alone. The cost per case is approximately £160 giving an annual cost of £240,000. However, based on recent studies [21-23], fluoridation of Manchester's water supply could reduce demand for tooth extraction under general anaesthetic by between 35% and 67%, bringing the number of cases in Manchester to between 500 and 1000 a year. At today's prices such a reduction in demand would represent cash savings of between £84,000 and £160,000 per annum - in Manchester alone! Similar savings could be expected in comparable non-fluoridated parts of the country – for example Liverpool, Leeds, Bradford, Inner London, Glasgow, Cardiff, and Belfast.

It is worth also considering the `opportunity' costs of the huge demand for general anaesthetic for tooth extraction - that is the costs of *not* using the NHS resources used in providing general anaesthetic for tooth extraction to treat conditions other than tooth decay. In the Manchester Dental Hospital three general anaesthetic sessions take place each week. Each session requires two paediatric anaesthetists, the operating dentist, the consultant paediatric dentist supervising the session, and around 10 support staff. If demand for general anaesthetic for tooth extraction were reduced, much of this human and technical resource could be used to reduce waiting lists and delays for other treatments.

Of course, none of the above takes account of the costs to the children and their parents (time lost from school and work etc), and to the children in terms of their health and well-being both while waiting several weeks for treatment, and resulting from the treatment itself. (In Manchester the waiting list for general anaesthetic for tooth extraction is generally around 500 children.) There is little doubt that in parts of the country where tooth decay remains a significant public health problem, patients and the NHS economy would benefit hugely from water fluoridation.

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Help and Resources

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Websites

The following websites provide more information about public health and health promotion, oral health, and water fluoridation:

UK professional organisations

- British Association for the Study of Community Dentistry: http://www.dundee.ac.uk/dhsru/bascd/bascd.htm. BASCD co-ordinates regular surveys of children's dental health in the UK and sponsors a scientific journal, *Community Dental Health,* covering dental public health issues.
- British Dental Association: http://www.bda-dentistry.org.uk. Professional association for dentists in the UK.
- British Medical Association: http://web.bma.org.uk/ap.nsf/Content/__Home_Public. The BMA represents doctors from all branches of medicine in the UK.
- UK Public Health Association: http://www.ukpha.org.uk. The UK PHA promotes the development of healthy public policy at all levels of government and across all sectors, and supports those working in public health (full contact details on page iv).

Independent oral health information providers

- British Dental Health Foundation: http://www.dentalhealth.org.uk. Charity that works to improve standards of oral health care, and to provide information for the public and professionals.
- British Fluoridation Society: http://www.bfsweb.org. The Society promotes better dental health by securing the optimum fluoride content of water supplies (full contact details on page iv).

Key reports

- The UK Medical Research Council (MRC) is a national organisation promoting research into all areas of medical and related science with the aims of improving the health and quality of life of the UK public. The Medical Research Council Report *Water Fluoridation and Health* can be found at: http://www.mrc.ac.uk/pdf-publications-water_fluoridation_report.pdf. A lay summary of the report is provided at: http://www.mrc.ac.uk/index/public-interest/public-news/public-fluoridation_report-2/public-fluoridation_report_lay_summary.htm.
- The University of York Centre for Reviews and Dissemination undertakes reviews of the effects of interventions used in health care. The report *Fluoridation of Drinking Water: A Systematic Review of its Safety and Efficacy* can be accessed at: http://www.york.ac.uk/inst/crd/fluorid.htm.

Evidence based oral health

- Centre for Evidence Based Dentistry: http://www.ihs.ox.ac.uk/cebd/. The Centre is an independent body promoting evidence-based dentistry world-wide.
- The Oral Health Specialist Library of the NHS National Electronic Library for Health: http://libraries.nelh.nhs.uk/oralhealth/. This site provides rapid access to recent, relevant, and reliable evidence.

Government funded bodies

- The Commission for Patient and Public Involvement in Health. http://www.cppih.org. The Commission is an independent, non-departmental public body, sponsored by the Department of Health, with a remit to ensure that the public is involved in decision making about health and provision of health services. It works at national, regional and local levels in England to ensure that the voice of both public and patients are heard in health matters.
- Health Development Agency: http://www.hda.nhs.uk. The HDA gathers evidence of what works in improving health and reducing health inequalities, and advises on putting evidence into practice in England.

Wales

- Chief Medical Officer, Wales: http://www.cmo.wales.gov.uk. This site covers a wide range of public health, health promotion and health professional issues. The Office of the Chief Medical Officer (OCMO) leads on policy and programmes for the protection and improvement of people's health and for the reduction of inequalities in health.
- HOWIS (Health of Wales Information Service): http://www.wales.nhs.uk. The official website of NHS Wales brings together information sources about the health and lifestyle of the population of Wales, and offers access

to reports and consultation documents issued by NHS Wales, Welsh Assembly Government and other statutory bodies.

Scotland

- NHS Health Scotland: http://www.healthscotland.com. Provides a national focus for improving health and reducing inequalities in Scotland.
- SHOW (Scotland's health on the web): http://www.show.scot.nhs.uk. Online information provided by NHS Scotland.

Northern Ireland

- The Health Promotion Agency for Northern Ireland (HPA): http://www.healthpromotionagency.org.uk. The Agency provides leadership, strategic direction and support to all those involved in promoting health in Northern Ireland.

The Republic of Ireland

- The Dental Health Foundation - Ireland: http://www.dentalhealth.ie. Facilitates and supports the promotion of oral health in Ireland, by providing effective resources or interventions and by influencing policy, through a multi-sectoral, partnership approach.
- The Forum on Water Fluoridation in Ireland: http://www.fluoridationforum.ie. Established by the Minister for Health and Children to independently review the fluoridation of public piped water supplies and the programme of research being undertaken on behalf of health boards in the area and to make recommendations to the Minister.

USA websites

- American Dental Association: http://www.ada.org. Professional association for American dentists.
- CDC National Centers for Chronic Disease Prevention and Health Promotion: http://www.cdc.gov/oralhealth/index.htm. The USA Centers for Disease Control and Prevention (CDC) is the lead federal agency for protecting the health and safety of United States people, providing credible information to enhance health decisions, and promoting health through strong partnerships. *Oral Health in America - A Report of The Surgeon General* can be accessed at: http://www.cdc.gov/OralHealth/factsheets/sgr2000-05.htm.
- National Center for Fluoridation Policy and Research: http://fluoride.oralhealth.org. NCFPR was created to help provide reliable, timely, and scientifically-based information about community water fluoridation for scientists, educators, public officials, organizational representatives, and the media.

International bodies

- World Health Organisation Oral Health Country/Area Profile Programme: http://www.whocollab.odont.lu.se/. The objective of CAPP to present global information on dental diseases and oral health services.

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