



NFIS

National Fluoridation
Information Service

Review of Scientific Reviews Relating to Water Fluoridation Published between January 2000 and July 2010

National Fluoridation Information Service Review

Regional Public Health
Better Health For The Wellington Region



MASSEY UNIVERSITY
WELLINGTON



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National Fluoridation Information service

The National Fluoridation Information Service (NFIS) is a consortium funded by the Ministry of Health, led by Regional Public Health working in partnership with:

- Hutt Valley DHB Community Dental Services,
- Environmental Science and Research,
- Centre for Public Health Research at Massey University and
- National Poisons Centre

Our work includes:

- Following public debate and choices on water fluoridation
- Monitoring international research on the usefulness of water fluoridation
- Critically reviewing emerging research
- Working with District Health Boards and Councils to provide accurate and up-to-date information to their communities
- Providing clinical advice to the Ministry of Health
- Monitoring water fluoridation policy
- Providing access to New Zealand oral health data and research
- Sharing information via quarterly e-newsletters and e-briefings and the NFIS website

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PLAIN ENGLISH SUMMARY

Introduction

The Ministry of Health (the Ministry) recommends water fluoridation where technically feasible as a safe and effective means of improving oral health. Approximately 50% of the New Zealand population currently has access to fluoridated drinking-water.

Under current New Zealand law, district health boards (DHBs) are responsible for protecting the health of their populations, while local councils are charged with deciding whether to fluoridate the water supplies they operate. With water fluoridation being a controversial issue, it is important that DHBs and the Ministry have access to the best scientific evidence.

To this end, the Ministry has established a National Fluoridation Information Service (the Service). The function of the Service is to:

- i. monitor public discussion and decision-making processes on water fluoridation in New Zealand
- ii. provide a central authoritative, accurate and up-to-date source of information and critical commentary on research pertaining to fluoridation
- iii. coordinate support, communication and clinical and technical advice to, and on behalf of, DHBs and the Ministry
- iv. ensure consistent, accurate, and up-to-date information and messages are communicated by DHBs and the Ministry, and
- v. evaluate the effectiveness of the Service in advancing water fluoridation in New Zealand.

This literature review summarises the findings of international research on water fluoridation published in scientific reviews in peer-reviewed journals and the 'grey' literature (studies commissioned by government bodies or undertaken by learned societies) over the last ten years. It provides the base on which continuing six-monthly update reviews of the scientific literature can build.

The New Zealand context

Important facets of the New Zealand context in relation to water fluoridation are:

- i. naturally-occurring fluoride concentrations in New Zealand's water supplies are low – generally less than 0.2 mg/L
- ii. the maximum acceptable value for fluoride, given in the *Drinking-Water Standards for New Zealand* and based on the World Health Organization

Guideline, is 1.5 mg/L, which is designed to prevent possible undesirable health effects that may result from excessive fluoride intake

- iii. up-to-date information about the prevalence of tooth decay in New Zealand is available from the recently undertaken 2009 New Zealand Oral Health Survey (Ministry of Health, 2009a)
- iv. the prevalence of tooth enamel defects does not appear to be increasing in New Zealand (Ministry of Health, 2009b)
- v. toothpaste in New Zealand is fluoridated at approximately 1,000 mg/kg, which is typical of other developed countries, and considered safe for use by children (Ministry of Health, 2009b)

Method

Papers or reports (including some from the 'grey' literature) in the following fields were of interest for this review:

- epidemiology¹ in relation to water fluoridation
- oral and public health
- toxicology²/pharmacology
- ethical considerations in relation to water fluoridation
- communication and community engagement.

Two scientific bibliographic databases, Scopus and Web of Knowledge, were searched to provide an initial list of 3057 references. This draft list was reduced to 28 reviews based on the following set of rejection criteria:

- being in a language other than English
- not being primarily focused on water fluoridation – health effects or impacts
- being a report of a scientific study, not a scientific review³
- being an historical commentary, not a scientific review.

Regional Public Health oral health specialists and oral health advisors within the Ministry of Health were asked to assess the draft list, and make suggestions for deletions or inclusions. Reviewers were also able to suggest that a paper be dropped from review if, on closer examination, it met one of the rejection criteria. A total of 25 papers or reports were ultimately reviewed for this report.

¹ Epidemiology is the study of the distribution of health and illness, and the factors associated with them in a community.

² Toxicology is the study of the effects of chemicals on living organisms. It is concerned with dose-response relationships and in some cases the mechanisms by which the chemical acts.

³ An article that collates and summarises the studies reported in the scientific literature on a specific topic. Criteria for the inclusion of papers in the review may be defined.

Key findings

The key findings and the discussion of implications for fluoridation policy are based solely in the findings of the review and take no account of the findings of the recent 2009 New Zealand Oral Health Survey. (Page numbers reference the relevant “key point” and discussion in the main text.)

- a. Water fluoridation reduces the prevalence of tooth decay in children and adults (page 11).
- b. In some communities, stopping water fluoridation can result in an increase in tooth decay (page 15).
- c. The increased exposure to fluoride from sources other than water, such as fluoridated toothpastes, has reduced the difference in the rates of tooth decay between fluoridated and non-fluoridated communities (page 22).
- d. Dental fluorosis (flecking of tooth enamel) is an acknowledged adverse effect that can arise from water fluoridation. There is a clear dose-response relationship between the concentration of fluoride in water and the prevalence of flecks in tooth enamel (page 13).
- e. Flecking of enamel arising from water fluoridation is usually graded as mild or less. The flecking affects the appearance of teeth and is not a clinical concern (page 13).
- f. Total fluoride intake is the key factor influencing the risk of flecks in enamel. All sources of fluoride need to be taken into account when evaluating the optimum fluoride concentration in water (page 17).
- g. Reconstitution of infant formula with fluoridated water increases the likelihood of flecking in tooth enamel (page 13).
- h. Children less than six years of age, particularly those between 15 and 30 months, need to be protected from exposure to excessive levels of fluoride from all sources to minimise the likelihood of developing flecked enamel in permanent teeth (page 17).
- i. As a way to manage the flecking of enamel, improved control of exposure to other sources of fluoride is an alternative approach to reducing the fluoride concentration in drinking-water (page 20).
- j. Available evidence shows that water fluoridation does not increase the likelihood of bone fractures, or cancer (page 14).
- k. Insufficient evidence exists to reach conclusions about associations between water fluoridation and any other adverse health effects (page 14).
- l. The fluoride ion is the only chemical arising from the fluoridation process that needs to be taken into account when evaluating the health effects of fluoridated water (page 19).

- m. Trace impurities, such as heavy metals in fluoridating chemicals, do not present a health concern because of the degree of dilution they undergo when the chemicals are added to the water (page 19).
- n. In an adequately buffered water (one with sufficient alkalinity), the addition of fluorosilicic acid for fluoridation purposes will not make the water acidic enough to cause a health concern by dissolving metals from plumbing materials (page 19).
- o. In the view of the Nuffield Council on Bioethics, water fluoridation should not be prohibited outright on the basis of arguments about interference in personal life or coercion (page 21).
- p. In the view of the Nuffield Council on Bioethics, democratic processes should be used at a local level to decide whether a water supply should be fluoridated, and all of those involved need to be well informed (page 21).

Implications for the Ministry of Health's fluoridation policy

The beneficial effects of fluoridation are evident from the review, as is the importance of the retention of fluoridation as a public health intervention. While these findings support the fluoridation of water supplies, any review of the Ministry of Health's policy on water fluoridation should consider the flecking of tooth enamel, an acknowledged adverse effect that can arise from water fluoridation.

The flecking of enamel arising from water fluoridation, which is usually graded as mild or less, is of aesthetic rather than clinical significance, and occurs when concentrations of fluoride in water are close to or over 1 mg/L. However, *total* fluoride intake must be accounted for when considering enamel flecking, not just drinking-water intake. Other sources of fluoride include, use of fluoridated toothpastes and reconstitution of infant formula with fluoridated water. The contribution made by the different fluoride sources is likely to vary among individuals.

The Ministry of Health's fluoridation policy focuses on prevention of dental caries. At the fluoride concentrations presently recommended by the Ministry of Health's fluoridation policy, evidence shows that if fluorosis occurs, it is likely to be very mild or mild, and consequently of aesthetic rather than clinical concern. Given the controversial nature of fluoridation, it is important that any review of the policy considers whether its adverse effects are being experienced in New Zealand to an unacceptable degree. If the aesthetic consequences of fluoridation are occurring to unacceptable levels, consideration has to be given to whether these can be reduced while still finding a point of balance that ensures effective reduction in tooth decay.

While a fluoride concentration in water of approximately 0.7 mg/L has been used in some countries to achieve a balance between beneficial and adverse effects, the risk factors are likely to be different between jurisdictions. It would be prudent to review New Zealand's target fluoride concentration from time to time as new information becomes available. Given the completion of this review, now would seem an appropriate time to undertake the review of the target fluoridation concentration.

Research needs

Research needs were identified by many of the papers reviewed. These can be seen in full in Section 5 of the report. Although some may have been addressed since the reviews were published, or are inapplicable to the New Zealand context, they are identified as a guide to what work may still need to be considered to support review of the Ministry of Health's fluoridation policy. Seven research needs were considered to be of high priority:

- a. Improved estimations of the total fluoride intakes of individuals from different population sectors (e.g. different socioeconomic groups). This requires a determination of the contributions made from various fluoride sources.
- b. Determination of levels of prevalence and severity of enamel flecking, and the trends in these parameters.
- c. An understanding of the importance of infant formula reconstituted with fluoridated water and the use of fluoridated toothpastes from a young age in the development of flecked enamel.
- d. Identification of the most appropriate approaches for control of fluoride intake.
- e. Determination of the impacts of flecked enamel – factors that influence the importance people give to mild flecking.
- f. Determination of how reducing fluoride levels to values of ca. 0.7 mg/L affects the efficacy of fluoride in reducing tooth decay.
- g. Determination of the level of fluoride in drinking-water that provides the best balance between minimisation of tooth decay and control of enamel flecking.

1 INTRODUCTION

1.1 Background and purpose

Epidemiological studies in the first half of the 20th Century showed that naturally-occurring fluoride in water could have beneficial (caries reduction) and detrimental (fluorosis) effects on dental health (Parnell et al.2009). Work to find the fluoride concentration that offered an acceptable balance between these effects eventually led to the introduction of fluoride into water supplies as a public health measure in the USA and Canada in the mid 1940s (Parnell et al, 2009). Fluoride was first added to a water supply in New Zealand, the Hastings supply, in 1954 (Ministry of Health, 2011a). The fluoridation of water supplies in New Zealand expanded rapidly during the 1960s (Ministry of Health, 2011 a).

The Ministry of Health's *Annual Review of Drinking-water Quality 2008/2009* (Ministry of Health, 2009c) states that 51 water treatment plants in New Zealand added fluoride to their water during the 2008–2009 year. These treatment plants provided water to a little fewer than 2.25 million people – approximately 52% of the New Zealand population.

Under current legislation, local authorities hold the mandate to decide whether water supplies in their jurisdictions are fluoridated. Debate concerning the pros and cons of water fluoridation continues, with the fluoridation status of water supplies changing as the positions of councils and their communities on the issue shift.

To advance water fluoridation in New Zealand by ensuring that debates on fluoridation are based on the best available scientific evidence, the Ministry has established a National Fluoridation Information Service (the Service). The objective of the Service is to assist the Ministry of Health and District Health Boards (DHBs) through:

- i. monitoring public discussion and decision-making processes on water fluoridation in New Zealand
- ii. providing a central authoritative, accurate and up-to-date source of information and critical commentary on research pertaining to fluoridation
- iii. coordinating support, communication and clinical and technical advice to, and on behalf of, DHBs and the Ministry
- iv. ensuring consistent, accurate and up-to-date information and messages are communicated by DHBs and the Ministry, and
- v. evaluating the effectiveness of the Service in advancing water fluoridation in New Zealand.

This literature review contributes to ii) by providing a critical summary of key reviews in the scientific, medical, and 'grey'⁴ literature published between January 2000 and July 2010. This 'review of reviews' is intended to update the oral health community's understanding of the advantages and disadvantages of fluoridation determined by international research over the past 10 years, by contributing to a pool of authoritative information on the subject. This review will provide the base on which continuing six-monthly updates of reviews of the fluoridation literature can build.

1.2 The Ministry of Health's fluoridation policy

An important function of the review is to identify the implications of the review findings for the Ministry of Health's policy on water fluoridation, and to propose changes to this policy that appear necessary.

At present, the Ministry's policy focuses on the concentration of fluoride that is required in drinking-water to achieve the desired health outcomes. It is summarised in a statement approved by the Ministry's Executive Leadership Team (C. Thompson, personal communication, November 22, 2010) as:

The Ministry of Health recommends the adjustment of fluoride to between 0.7 ppm and 1.0 ppm in drinking-water as the most effective and efficient way of preventing dental caries in communities receiving a reticulated water supply, and strongly recommends the continuation and extension of water fluoridation programmes where technically feasible.

1.3 Water supply fluoridation in New Zealand

The *Drinking-water Standards for New Zealand 2005* (Ministry of Health, 2008) give the maximum acceptable value (MAV) for the concentration of fluoride in drinking-water as 1.5 mg/L. The purpose of the MAV is to prevent possible undesirable health effects that may result from excessive fluoride intake. This should not be confused with the recommended concentration range for fluoride contained within the Ministry of Health's fluoridation policy.

Although the recommended fluoride concentration range is below the MAV, it straddles 50% of the MAV which has implications for fluoride monitoring for compliance with the DWSNZ. To comply with the DWSNZ, all chemical determinands at concentrations exceeding 50% of their MAV within a water supply must be monitored on a regular basis. As fluoridating water treatment plants aim to add fluoride to achieve a concentration in

⁴ For the purposes for this work, studies commissioned by government bodies or undertaken by learned societies.

the range of 0.7–1.0 mg/L (cf. 50% of the MAV is 0.75 mg/L), these treatment plants are required to test the fluoride concentration in the water they produce at least weekly to comply with the DWSNZ. They are likely to determine the fluoride concentration in their water supply on a more frequent basis because of the relatively small difference between a therapeutic fluoride concentration and the fluoride MAV.

The *Annual Review of Drinking-water Quality 2008/2009* (Ministry of Health, 2010a) reported that of the 51 fluoridating treatment plants, two, supplying a total of ca. 11,400 people had reported one occasion each when the fluoride concentration had exceeded the MAV. The exact duration of these excursions beyond the MAV is unknown, but they cannot have been longer than seven days because of the weekly monitoring frequency. Exposures of this duration do not present a significant risk to health because the MAV is determined on the basis of a lifetime's exposure to fluoride.

1.4 The New Zealand context

Two important factors that can influence the extent to which individuals are exposed to fluoride in the absence of an intentionally-fluoridated water supply are the naturally-occurring levels of fluoride in the water and the use of fluoridated toothpaste. To contextualise the conclusions reached in this literature review, the levels of fluoride in these potential fluoride sources are discussed here.

With the exception of geothermal-influenced waters, which are not used as the source waters of community water supplies, naturally-occurring fluoride levels in New Zealand waters are low, certainly by the standards of many other countries. Davies et al., (National Fluoridation Information Service, 2001) reported a fluoride concentration range from nd (not detectable – 0.1 or 0.2 mg/L) to 1.8 mg/L, with a median concentration of nd in New Zealand drinking-water supplies. Only three drinking-water supplies showed a fluoride concentration greater than 0.75 mg/L (50% of the MAV).

In the light of this information, some of the findings relating to overseas jurisdictions in which fluoride may occur naturally at concentrations of many mg/L will not apply to New Zealand.

The Ministry of Health reports that the concentration of fluoride in most New Zealand toothpastes is ca. 1000 ppm (parts per million) (Ministry of Health, 2011b). This concentration is typical of the concentrations contained in toothpaste in developed countries, and findings associated with the use of fluoridated toothpaste in these countries may also be relevant to New Zealand. Toothpaste marketed for children less than six years of age is available with a fluoride content of 400 ppm.

One further factor that should be considered in association with overseas reports of increasing levels of dental fluorosis is the evidence of trends in fluorosis in New Zealand. The Ministry of Health's *Guidelines for the use of fluoride* (Ministry of Health, 2009b) states that "... the prevalence of diffuse opacities has not increased compared to earlier studies and is largely unchanged from estimates reported within New Zealand over the last 25 years." On this basis, trends of increasing fluorosis reported in overseas jurisdictions with fluoridated water supplies do not necessarily reflect the New Zealand context.

1.5 Structure of this report

Following the introduction, the report describes the method used to identify reviews for inclusion in this review. There is then a discussion of the findings of these reviews with key points summarised, which acts as the basis for a discussion about implications for the Ministry of Health's fluoridation policy, and proposals relating to fluoridation policy. The main body of the report closes with a presentation of research directions noted in the reviews. Some of these may assist in providing a basis for the policy, but because of the age of some and their links to other jurisdictions, not all will be applicable to New Zealand.

The Appendix discusses each of the 25 reviews, and includes bibliographic details, a presentation of the review's findings linked, where possible, to the New Zealand context, an evaluation of the quality of the review and level of evidence it provides, other comments the reviewer wished to make, and comment on the implications for the Ministry of Health's fluoridation policy.

2 METHOD

2.1 Selection of reviews

Two scientific bibliographic databases, “Scopus” and “Web of Knowledge”, were searched to generate an initial list of academic peer-reviewed reviews that might meet the requirements for inclusion in the literature review. Target publications were significant reviews published between January 2000 and July 2010 reviewing scientific studies concerning water fluoridation and the health effects of water fluoridation that might arise in conjunction with topical application of fluoride (for example, the use of fluoridated toothpaste, fluoride varnish). The subject areas of interest were epidemiology, oral and public health, toxicology/pharmacology, ethical issues in relation to water fluoridation and communication and community engagement.

The initial search keywords used were “review*” (* is a wild card) and “water fluoridation” which yielded 76 papers from Scopus and 48 papers from the Web of Knowledge. Concern that the “water fluoridation” search keyword may have been too specific, led to a second search of both databases using the keywords “review” and “fluorid*”. This resulted in 2177 hits in Scopus and 880 hits in Web of Knowledge.

The titles and abstracts of papers identified through the broader search were scanned manually and most were rejected as they covered subject areas outside those of interest to this review. After a more critical review of those papers from both sets of searches, a draft list of 28 reviews was prepared. In reaching this draft list, reviews were rejected for reasons which included:

- not being primarily focused on water fluoridation
- being a report of a scientific study, not a scientific review
- being an historical commentary not a scientific review.

Reviews that were not in English were also rejected.

The draft list was provided to Regional Public Health oral health specialists and oral health advisors within the Ministry of Health for their assessment of the need for their inclusion. After the removal of some papers from the list and inclusion of others, including those easily identified from the grey literature, a list of 26 reviews was assembled.

The last point at which a review was rejected from consideration was on the basis of a recommendation from the reviewer. A review by Tang et al (Tang et al., 2008) was rejected because it was found to be looking at associations between adverse intelligence

quotient (IQ) effects and fluorosis in areas of China where fluorosis is endemic. Only one of the 16 studies reviewed noted water as a possible risk factor.

The final list for consideration contained 25 reviews.

Although this literature review is primarily concerned with reviewing reviews, there are few, if any, reviews published during the period of interest in the areas of “Ethical issues in relation to water fluoridation” and “Communication and community engagement”. Some papers that are not reviews, published in this period, have been included to provide guidance on some of the thinking in these areas.

Review 14, *Fluoride in Drinking Water—A scientific review of EPA’s Standards*, (National Research Council of The National Academies, 2006) is a book of 530 pages. Review of the full document is outside the scope of the present review, and the review contained here is, by agreement with the Ministry of Health, based on the book’s executive summary only. The full book may be reviewed in a later report.

2.2 Evaluation of reviews

The review summaries in the Appendix follow the same format. However, the section dealing with evaluation of the reviews has been structured with the evaluation of systematic reviews⁵ of epidemiological studies in mind. As a result, it is not necessarily applicable to other types of reviews in other subject areas.

The evaluation section of each review summary makes use of the SIGN⁶ checklist for systematic reviews and meta-analyses⁵. The response options to each question given in the SIGN checklist are well covered, adequately addressed, poorly addressed, not addressed, not reported and n/a (not applicable). These are used in this report, and in addition, the response of “unknown” is sometimes given to the question regarding the direction in which the findings of a review may be biased, if the possibility for bias was evident, but the direction of bias was unclear.

Symbols are used when assigning a bias evaluation and are defined as follows.

- All or most of the criteria have been fulfilled. Where they have not been
- ++ fulfilled the conclusions of the study or review are thought very unlikely to alter.

⁵ See Section 2.2.1 for an explanation of systematic reviews and meta-analyses.

⁶ Scottish Intercollegiate Guidelines Network – which develops evidence based clinical practice guidelines for the National Health Service in Scotland.

- + Some of the criteria have been fulfilled. Those criteria that have not been fulfilled or not adequately described are thought unlikely to alter the conclusions.
- Few or no criteria fulfilled. The conclusions of the study are thought likely or very likely to alter.

For the purposes of evaluating the “level of evidence” for systematic reviews and meta-analysis, four assignments are possible.

1. High quality meta-analyses, systematic reviews of randomised controlled trials (RCTs), or RCTs with a very low risk of bias.
2. Well conducted meta-analyses, systematic reviews, or RCTs with a low risk of bias.
3. Meta-analyses, systematic reviews, or RCTs with a high risk of bias.
4. High quality systematic reviews of case control or cohort studies.

A different description may be given in summaries of other types of review, where the four categories above are inappropriate.

2.2.1 Systematic reviews, meta-analyses and meta-regressions

This section provides brief comment on systematic reviews and the data analysis techniques that are referred to in the review.

A systematic review considers all published studies on a specific theme (after the application of previously defined inclusion and exclusion criteria) to extract relevant information systematically from the publications. What is important is analysis of the methodological quality of the included publications and investigation of the reasons for any differences between the results in the different studies.

A systematic review is the first part of a meta-analysis. In addition, given the availability of the raw data, in a meta-analysis the results from several studies are quantitatively summarised using statistical methods. This allows calculation of pooled effect estimates (such as odds ratios) and examination of the differences among contributing studies (heterogeneity). The calculation of a pooled effect estimate (with confidence intervals) gives an overall conclusion. If a meta-analysis is performed correctly, it can provide very strong evidence of an effect.

Meta-regression can be performed as part of meta-analysis. It is used to examine the source of heterogeneity among studies. If studies are heterogeneous, the validity of combining the results from the studies to derive a single pooled estimate of effect has to be determined. Statistical tests are available to do this. The conclusions drawn from a

meta-analysis that combines data from statistically heterogeneous studies have to be treated very cautiously.

The meta-regression is helpful in determining what drives the heterogeneity among studies. For example, heterogeneity may be caused by methodological differences among the studies, such as differences in study population or study size, or differences in the methods of measurement. Meta-regression is akin to a sensitivity analysis. Some epidemiological reviews may have undertaken a meta-regression to understand the reasons for differences in study results.

3 LITERATURE REVIEW FINDINGS

3.1 Introduction

The terms of reference for this report identified the following subject areas that were to be covered:

- Epidemiology associated with water fluoridation
- Oral and public health
- Toxicology/pharmacology
- Ethical issues in relation to water fluoridation
- Communication and community engagement

The key findings of papers and reports reviewed are presented in this section under these headings, with an additional “General” section. Where appropriate, within each subject area, sub-headings have been established to bring together related findings. Consequently, the findings of a particular review may be discussed under more than one sub-heading.

The key findings and the discussion of implications for fluoridation policy are based solely in the findings of the review and take no account of the findings of the recent 2009 New Zealand Oral Health Survey (Ministry of Health, 2010b).

Several of the reviews could be considered to fall into more than one subject area. They have been included in the section to which they seem most closely aligned.

Square brackets contain the number assigned to the review for indexing in this document. Further detail concerning the findings of the review and the reviewer’s assessment are provided in the Appendix under this index number.

All the reviews discussed are listed in the Appendix. Each entry in the Appendix contains the bibliographic details of each review, a summary of important information provided and conclusions reached relevant to the New Zealand context, an evaluation of the quality of the review, additional comments by the reviewer, and comments on the implications of the review for the Ministry of Health’s fluoridation policy. Where the findings of a review are clearly of limited value to the New Zealand context this has been noted, and the reasons given. Where the relevance of the findings is unclear, they are included.

Knowing the validity of the findings of a review is critical for understanding the review’s implications. The review notes in the Appendix provide an assessment of the quality of

each review. Although a review may be well conducted, that is, the data have been handled appropriately, there are often situations where some of the studies available for review are of poor quality (for reasons such as confounding factors not being taken into account). In these cases, a good review will have discarded the poor studies, or, where all available studies are poor, clearly stated the implications for the review's findings. In Section 3, review findings or conclusions that should be disregarded or treated with caution, because the review was poor or the data on which the review was based are poor, are noted.

3.2 Background on the mechanism of action of fluoride in preventing dental caries

This section provides a brief discussion of what is understood about the action of fluoride in preventing dental caries to assist in the understanding of following sections.

It is now generally accepted that the main actions by which fluoride acts to protect dental enamel are through remineralisation and the inhibition of demineralisation (Kumar, 2008). Exposure of the enamel surface of the post-eruptive tooth (a tooth exposed through the gum) to fluoride is of greatest importance in creating a surface resistant to acids formed by bacteria. The beneficial effects of the post-eruptive interaction of fluoride with teeth have been well demonstrated by epidemiological studies. A constant low level of fluoride in the oral cavity assists the post-eruptive protective mechanism (Pizzo et al., 2007). The application of fluoride to the surface of the tooth to improve its resistance to caries, by using toothpaste or fluoride varnish, is termed *topical application*.

Although the post-eruptive effect of fluoride is well accepted, the pre-eruptive (prior to the tooth being exposed through the gum) effects of fluoride on the tooth, and the extent to which this influences resistance to caries is still under debate. The *systematic application* of fluoride which results from the ingestion of fluoride, through water fluoridation for example, is the means by which fluoride gains access to the pre-eruptive tooth.

Evaluating the relative contributions of the pre- and post- eruptive action of fluoride is extremely difficult, but irrespective of their relative importance, fluoridated water helps to ensure constant exposure to low concentrations of fluoride.

Excessive exposure of the tooth to fluoride during the pre-eruptive stage of enamel formation causes hypomineralisation (greater surface and subsurface porosity) of the enamel, known as enamel fluorosis (Browne et al., 2005).

3.3 Epidemiology associated with water fluoridation

Observations of the effects of fluoride on populations are what first led to water fluoridation being identified as a means of reducing dental caries. Epidemiological studies have investigated the human oral health effects, both beneficial and adverse, of water fluoridation strategies. This section describes the findings of epidemiological reviews (or those considered by the reviewer to be mainly epidemiological) in relation to dental caries, dental fluorosis, and a range of other adverse effects of water fluoridation that have been investigated, including bone disorders, cancers and Down syndrome. Evidence of the ability of water fluoridation to redress inequities in oral health across social strata is also considered.

Eleven of the reviews reviewed for this report were classified as being primarily epidemiological on the basis of their methodology or the nature of the studies they referenced.

3.3.1 Beneficial effects of water fluoridation

a) Reduction in dental caries

The “York Report” (University of York, 2000), as it came to be known, was commissioned by the Department of Health in the United Kingdom from York University. Its purpose was to “carry out an up to date expert scientific review of fluoride and health”, which it did through an assessment of the positive and negative health effects of population-wide fluoridation strategies to prevent caries. To do this, the authors undertook a systematic review and meta-analysis of 214 epidemiological studies published from 1966 to May 1999. Having been undertaken at the start of the period covered by the present review, and being so complete, the York Report’s findings have been reviewed and built on by several other reviews discussed in this section.

The York Report (2000), concluded, on the evidence found from 26 studies, that water fluoridation reduces the prevalence of dental caries in terms of both the proportion of children who are caries-free in areas receiving fluoridated water compared with those in areas receiving unfluoridated water, and the mean change in the dmft/DMFT⁷ score (the York Report also refers to this score as a measure of severity). However, the report found that the extent to which caries is reduced is unclear. The range of the mean difference in the proportion (%) of caries-free children was -5.0–64%, with a median of 14.6%. From consideration of studies conducted after 1974, the York Report also found that water fluoridation had a beneficial effect on dental caries (in terms of the proportion of caries-free children and the dmft/DMFT score) in fluoridated communities, which was

additional to any effect resulting from fluoride from other sources, such as fluoridated toothpaste. The authors were unable to quantify the additional effect because of the quality of the methodology used by the studies.

Harrison (2005), who had been an author of the York Report, undertook his own non-systematic review, most of which focused on possible deleterious effects of water fluoridation. However, he did report that other studies conducted in the UK, not considered by the York Report, also showed reductions in the levels of dental caries in children similar to those found by the York Report.

Seven years after the York Report was published, the Australian NHMRC's⁸ systematic review (2007) of 77 studies provided an update on the efficacy and safety of fluoride interventions. Studies published between 1996 and December 2006 were considered for the review. Work on the systematic provision and topical application, of fluoride were of interest, with the emphasis being on interventions that could be delivered as a widespread public health initiative. This review considered only that part of the document relevant to water fluoridation.

A review by Parnell et al. (2009) aimed to summarise the evidence from systematic reviews on the efficacy and safety of water fluoridation. Fifty-nine publications were identified by the literature search, only eight of which were relevant systematic reviews. Three of these were included in the review as five had been previously included in the NHMRC review. Three guidelines were also considered.

The York Report's findings on caries were supported by both the NHMRC review and the review of Parnell and colleagues. The NHMRC found only one relevant original study additional to the studies reviewed in the York Report, which met selection criteria, for examining the relationship between fluoride and caries. After adjusting for factors contributing to heterogeneity, the NHMRC meta-analysis estimated a mean difference in the proportion of caries-free children in fluoridated and non-fluoridated areas as 14.3% (95% CI 6.7–21.9).

Key point: Water fluoridation reduces the prevalence of dental caries in children.

A conclusion that water fluoridation has a beneficial effect on dental caries was also reached by Griffin et al. (2007). Their literature search identified 1248 records, 489 of these were examined, and 50 of these reviewed. Twenty studies provided the final body

⁷ An index for assessing the extent of caries. D-decayed, M-missing, F-filled, T-teeth (or sometimes S-surfaces). Lower case refers to primary teeth and upper case to secondary teeth.

of evidence for the review. The meta-analysis undertaken in this paper focused on evidence concerning the effectiveness of fluoridation (topical and in drinking-water) in preventing caries in adults. The authors considered the study important because adults today are more likely to retain their teeth into old age than did previous generations. Their analysis showed that coronal caries were lower in adults of all ages (older than 20 years) who received fluoridated water than in adults in a control population receiving unfluoridated water. The meta-analysis determined a summary prevented fraction⁹ of 27.2% (95% CI: 19.4–34.3%) on the basis of data from reports published since 1979.

Key point: Water fluoridation reduces the prevalence of dental caries in adults.

Pizzo et al. (2007) undertook a critical review of studies performed between January 2001 and June 2006 to examine the role of water fluoridation in the prevention of caries. The number of records retrieved by their literature search is not given, but 38 references are listed in the paper. This review is recorded here for completeness, but as its evaluation in the Appendix shows, it is a poor quality review with high likelihood of bias. The authors considered that a review of the relative effectiveness of water fluoridation and the use of topical fluoride was needed because of the increased use of topical fluoride and the increasing prevalence of fluorosis reported in some countries. They concluded that the anticaries effects of systematic fluoridation (which includes ingestion of fluoridated water) are minimal, and that topical application of fluoride is more effective. From this they argued that water fluoridation may be unnecessary for caries prevention, especially in industrialised countries where levels of dental caries are low, because in these situations, topical fluoride application may provide the optimum means of preventing caries.

b) Redressing inequalities in oral health due to socioeconomic status

One of the purported advantages of delivering fluoride through the water supply is its ability to reach all members of a community irrespective of their socioeconomic status. Social deprivation is a risk factor in poor oral health status (Burt, 2002). This is not simply because of an inability to afford dental services. Even where such services are state-funded, they are under utilised by those of lower socioeconomic status (Burt, 2002). The York Report (2000) questioned whether water fluoridation could reduce social inequities in oral health by reducing dental caries across social groups. The authors warned that their conclusions were to be treated with caution because of the small number of studies with which they had to work (n = 15), the variability in the results of

⁸ National Health and Medical Research Council.

⁹ The prevented fraction is the proportion of disease occurrence in a population averted due to a protective risk factor or public health intervention.

these studies and the low quality of the studies. Given these caveats, they stated that there was some evidence that water fluoridation reduces differences, due to social inequities, in the oral health status of five- and 12- year old children, when measured by the dmft/DMFT score. However, this finding was not apparent in five year old children when the measurement was made in terms of the proportion of caries-free children in communities. Given the limitations of the available information, little weight should be given to the York Report's guarded findings on the ability of fluoridation to redress oral health inequities.

Harrison (2005) noted that there was almost universal agreement that the prevalence of dental caries was influenced by social class (caries are more prevalent in more deprived social groups). He also maintained that there was evidence that water fluoridation addresses inequities in oral health results from socioeconomic status, but provided no statistical information to support it.

3.3.2 Adverse effects of water fluoridation

a) Dental fluorosis

Dental fluorosis is, according to the York Report (2000), the most widely and frequently studied adverse effect arising from water fluoridation. Although 88 studies were included in their review of adverse effects, they were all of low quality primarily because few attempted to control for confounding factors or potential observer bias. Despite the concern with the quality of the data, the report reported a significant dose-response relationship between the fluoride concentration in the water and the prevalence of fluorosis, obtained by meta-analysis. At the 1 mg/L fluoride concentration, the prevalence of fluorosis was estimated to be 48% (95% CI: 40–57%), and for fluorosis of aesthetic concern the prevalence was estimated to be 12.5% (95%CI: 7.0–21.5%). The robustness of this finding must be viewed with caution given the quality of the data on which it is based.

Whelton et al. (2004) undertook a poorly conducted non-systematic review of fluorosis in the European Union (see comments in Appendix). The paper lists 58 references, but their selection criteria are not discussed. The authors note that assessing trends in fluorosis is unreliable because of the complexity and inaccuracy of comparing studies using different methodologies carried out in different countries. As a result they could only conclude that the prevalence of very mild fluorosis in areas receiving fluoridated water *may* be increasing. The fluorosis was primarily of aesthetic, rather than health, concern and it was the appearance of the central incisors that was mainly affected. The prevalence of fluorosis was the same in fluoridated and non-fluoridated areas when fluoride

supplements were also used. Sources of fluoride, other than optimally fluoridated water, were found to be risk factors in the development of fluorosis.

Soto-Roja et al (2004) published a review of the prevalence of dental fluorosis in Mexico. This review is noted here for the sake of completeness, but is of limited value. This is in part because the Mexican context is markedly different from that in New Zealand in that water supplies are unfluoridated, naturally-occurring fluoride levels often exceed 1.5 mg/L, fluoridated salt is available, fluoride metabolism may be different in Mexico's high-altitude communities, and fluoride may be concentrated in some drinking-waters through boiling to destroy pathogens. Further, although the review was of high quality, the studies available to the authors were of moderate-to-low quality with the result that no conclusions about the prevalence of fluorosis or trends in its prevalence could be reached.

The NHMRC (2007) review used data from 10 additional studies published since the York Report and that met selection criteria similar to those of the York Report, for its meta-analysis. The quality of the studies ranged from poor-to-good (poor (2), fair (5) and good (3)). The analysis showed a clear risk of enamel fluorosis associated with water fluoridation, as the York Report had found. The pooled odds ratio of developing 'any fluorosis' with optimal fluoridation compared with suboptimal fluoridation was 4.61 (95% CI, 3.48–6.11). The review also found that most fluorosis cases associated with optimal water fluoridation were graded as mild or less, and were of no aesthetic concern.

Key points: There is a clear dose-response relationship between fluoride concentration in water and the prevalence of dental fluorosis.
Dental fluorosis arising from water fluoridation is primarily of aesthetic, rather than health, concern.

Hujoel et al (2009) examined the influence of infant formula on dental fluorosis. The review included 19 studies undertaken in eight countries and together included approximately 17,429 participants. The review concluded that the degree to which infant formula is associated with fluorosis depends on the level of fluoride in the water supply in the area in which the formula is being used, with the likelihood of the association increasing as the fluoride concentration increases. A 1 mg/L increase in fluoride concentration in the water supply increased the odds ratio for fluorosis associated with infant formula by 67% (OR 1.67, 95% CI, 1.18–2.36). However, there was only weak evidence that fluoride in the infant formula is responsible for the fluorosis. Fluoridation of a water supply will have a significant effect on the incidence of fluorosis compared with the incidence prior to the fluoridation of the water.

Key point: Reconstitution of infant formula with fluoridated water is associated with an increase in the likelihood of the development of dental fluorosis.

b) Other adverse effects

Possible associations between fluoride and several disorders have been investigated, including (Harrison, 2005) bone fractures, skeletal fluorosis, cancer (especially bone and thyroid), reproductive effects and birth defects, renal and gastrointestinal effects, effects on intelligence, goitre and Down syndrome.

The reviews by the York Report (2000), Harrison (2005) and Parnell (2009) examined the literature for information on the adverse effects of water fluoridation, other than dental fluorosis, and found:

- the available evidence indicated no effect of water fluoridation on the likelihood of hip fractures
- insufficient evidence to assess the effects of fluoridation on other bone disorders
- no influence of water fluoridation on the incidences of cancer in general or on specific types of cancer
- that evidence for other effects (noted in the first paragraph of this section) is weak, but Harrison (2005) noted that a Medical Research Council (UK) working group recommended that association between fluoridation and these effects be kept under review.

The NHMRC review (2007) concurred that water fluoridated to a level aimed at reducing caries has little effect on the likelihood of bone fractures, and that evidence concerning cancer mortality and incidence was mixed. It found insufficient evidence to reach any conclusions concerning links between water fluoridation and other adverse effects.

Key points: Available evidence shows that water fluoridation does not increase the likelihood of bone fractures, or cancer.
Insufficient evidence exists to reach conclusions about associations between water fluoridation and any other adverse health effects.
(NB. This does not include high naturally-occurring fluoride concentrations.)

The York Report (2000) reviewed studies investigating associations between fluoridated drinking-water and Down syndrome. Six studies were reviewed, but only two controlled for the important confounder of maternal age. The studies found a non-significant association between fluoridated drinking-water and Down syndrome at the 5% significance level. The Down syndrome data were published in a separate report by three

of the report's authors, and drew the same conclusion as the York Report (Whiting et al., 2001).

An Australian review by Demos et al., (2001) which makes no mention of the York Report (2000), focused on the association between water fluoridation, osteoporosis and bone fractures. The review found 33 epidemiological studies from different geographical regions and demographic populations that addressed the effect of water fluoridation and the endpoints of fracture incidence, bone mineral density and bone strength. They concluded that fluoride concentrations up to 1 mg/L had no adverse effect on any of these endpoints. Indeed, there was some evidence to suggest that fluoride concentrations around 1 mg/L could have beneficial effects on fracture incidence, bone mineral density and bone strength.

3.4 Oral and public health

The distinctions between the different classes used to sub-categorise Section 3 can become blurred, particularly between epidemiological reviews and oral health reviews. Seven of the reviews have been treated as "Oral and public health" papers, but six reviews are a combination of epidemiological and oral health work, and could have been passed into either classification.

The reviews that have been treated as oral health reviews deal with the subjects that include: the different ways in which fluoride can be used (systematic and topical); the factors that influence these uses and their effectiveness; the effects, beneficial and adverse, that result from the use of fluoride; strategies that can be used to encourage the use of fluoride; aesthetic perceptions of fluorosis and how this may affect the quality of life; and disparities in oral health status that arise from socioeconomic status.

3.4.1 Beneficial effects of water fluoridation

In 2001, a Task Force on Community Preventive Services (United States) systematically reviewed evidence of certain population-based interventions to prevent and control dental caries (Centre for Disease Control, 2001). Without considering adverse effects, it reached the following conclusions.

- Starting or continuing water fluoridation effectively prevents dental caries.
- Stopping water fluoridation is associated with an increase in dental caries in some communities.

On the basis of these findings, the task force strongly recommended the continued fluoridation of water supplies.

Key point: In some communities, stopping water fluoridation has increased the prevalence of dental caries.

In 2003, in a paper he termed an “update”, Levy (2003) discussed studies looking at different aspects of fluorosis including definition, appearance, prevalence, pre- and post-eruptive use of fluoride and aesthetic perceptions. Levy concluded that water fluoridation and the use of fluoridated dentifrices are the most efficient and cost-effective means of preventing caries, and that water fluoridation remains the most equitable and efficient means of supplying fluoride to a community. He also noted that decisions regarding the use of fluoride are more complex than they had once been because of the need to balance the benefits against the risks of fluorosis, the prevalence of which was increasing in the United States. As noted in Section 1.4, the evidence available from New Zealand shows no indication of a trend of increasing fluorosis.

The question of water fluoridation being a socially equitable means of caries prevention was addressed by Burt (2002). He stated that both socioeconomic status (SES) and water fluoridation are “determinants of caries status”, and that most of the evidence he reviewed showed that water fluoridation reduces “dental caries disparities between different SES strata”. Burt concluded that the reduction in social inequity is a primary reason why water fluoridation should remain a public health priority. (Note that this review is essentially an essay, and the rigour with which the references were identified is uncertain.)

Kumar (2008) prepared a symposium review, which addressed the question of whether fluoridation is still necessary. While this is a review aimed to answer a specific question, it is not a systematic review and makes no mention of the way in which evidence to support its conclusions was gathered. Caution is required in interpretation of its findings. Kumar concluded that, in many countries, water fluoridation is still the best mechanism for addressing caries, and the most cost-effective way of addressing caries in children, and that stopping fluoridation was reported to result in an increase in caries. He noted other less tangible benefits, beyond the numbers of caries averted, including the general impression of a delay in the progression of caries, giving more time for restorative care, and the disease being less complex to treat because of its confinement of the carious lesions to pits and fissures.

An Australian review by Satur et al. (2010) reviewed the evidence for the effectiveness of oral health promotion as a key part of the strategic planning for oral and general health. They noted that although there is good support for the incorporation of oral health into general health promotion in Australia, it is important that the outcomes are monitored in oral health terms. This review is of value at a population-based level because the current

reorientation of child and adolescent oral health services in New Zealand has a significant focus on oral health promotion.

The review also noted that there is:

- sound evidence for water fluoridation reducing caries prevalence, measured by the proportion of children who are caries-free, and by the mean dmft/DMFT score
- some evidence water fluoridation reduces inequalities in dental health across social classes.

These findings, the review concluded, support the continuation of the fluoridation of water supplies.

The Scientific Committee for Health and Environmental Risks (SCHER) of the European Union was requested to prepare a review (2010) into different aspects of the effects of fluoridation and the risks associated with the use of fluoridation compounds. The final report of this committee is not yet available, and the review provided here is based on a “pre-consultation opinion” adopted in May 2010.

The SCHER review concluded that water fluoridation, as well as topical fluoride treatments (eg, fluoridated toothpaste or varnish), appeared to prevent caries, primarily on the permanent dentition, but topical application is the more efficient way of achieving protection.

In children, a very narrow margin exists between achieving the maximal beneficial effects of fluoride in caries prevention and the adverse effects of dental fluorosis. The only advantage water fluoridation appeared to have over topical application was that through it caries prevention would reach disadvantaged children from lower socioeconomic groups. However, the SCHER concluded that there was insufficient evidence to confirm the efficacy of water fluoridation in achieving reductions in oral-health social disparities.

3.3.2 Adverse effects of water fluoridation

a) Dental fluorosis

In his 2003 review, Levy (2003) concluded that the most critical period for the development of dental fluorosis of the upper anterior incisors, is between the ages of 15–30 months. Total fluoride intake is the true determinant of risk of fluorosis, but this is difficult to quantify, and what might be considered the optimum total fluoride intake is uncertain. Levy noted that a level of intake of 0.05–0.07 mg/kg was often considered to be optimum, but that fluorosis had been reported at lower rates of intake. He concluded that water fluoridation and fluoridated toothpaste are the primary means by which

fluoride is delivered to a community. The importance of total fluoride intake means that before the age of six years, and especially before three years of age, other forms of fluoride need to be prescribed with care, taking account of the patient's exposure to fluoride from all sources.

Key points: Total fluoride intake is the key factor influencing the risk of fluorosis. All sources of fluoride need to be taken into account when evaluating the optimum fluoride concentration in water. Children less than six years of age, particularly those between 15–30 months, need to be protected from exposure to excessive levels of fluoride from all sources if the likelihood of the later development of dental fluorosis is to be minimised.

The consequences of dental fluorosis on aesthetic perceptions and oral health-related quality of life were reviewed in Chankanka et al (2010). The authors were interested in determining the true impacts of dental fluorosis on children and parents, because of the subjectivity that often accompanies the assessment of fluorosis. The review concluded that the existing evidence shows that mild and very mild fluorosis are not a concern, but that negative effects on oral health-related quality of life were consistently reported in relation to severe fluorosis. The review concluded that as, in the absence of high levels of naturally-occurring fluoride in water, fluorosis is only very mild and mild, fluoride (including topical application) needs to be used appropriately in preventing caries if moderate and severe dental fluorosis are to be avoided.

The SCHER report (2010) confirmed that there is a risk of dental fluorosis when children are systematically exposed to fluoride. The fluoride concentration threshold at which this happens was not determined.

b) Other adverse effects

The SCHER report also found that no cases of skeletal fluorosis were reported in the European Union (EU). The review considered that epidemiological studies showing a link between water fluoridation and osteosarcoma, were equivocal, and that they were not supported by animal studies. As a result, fluoride could not be classified with respect to its carcinogenicity.

The SCHER review's conclusions on other adverse effects were:

- fluoride from drinking-water does not hamper children's neurodevelopment or impair IQ at the levels occurring in the EU

- human studies do not suggest adverse thyroid effects at realistic human exposures to fluoride
- no new evidence from human studies indicates that fluoride in drinking-water influences male and female reproductive capacity.

The SCHER review found that for adults and children between the ages of 12–15 years living in fluoridated areas (fluoride concentration no greater than 0.8 mg/L), their daily intake of fluoride did not exceed what is considered to be the upper tolerable intake level (UL) (0.1 mg/kg BW/day for children; 0.12 mg/kg BW/day for adults) of fluoride. However, the committee determined that the UL could be exceeded for children under the following conditions.

- Those aged between 6–12 years consuming more than 1 L of water a day and brushing with adult strength toothpaste (0.15%) unsupervised.
- Those aged between 1–6 years consuming more than 0.5 L of water a day and brushing with adult strength toothpaste (0.15%) unsupervised.

For infants up to six months of age receiving infant formula, the safe fluoride level established by the UK's Department of Health (0.22 mg/kg BW/day) was only exceeded if formula was reconstituted with water containing fluoride levels higher than 0.8 mg/L.

3.5 Toxicology and pharmacology

Three reviews have been classed as primarily covering toxicological and pharmacological material. Toxicological/pharmacological reviews consider information about the toxicological endpoints resulting from exposure to fluoride, which are often identified through animal or human studies. They are concerned with dose-response relationships and in some cases the mechanisms by which fluoride acts. This information is unavailable from epidemiological studies.

3.5.1 Adverse effects of water fluoridation

Demos et al (2001) reviewed studies published after 1991 to assess the effect of fluoride on bone – bone strength, mass and fracture rate. The review covered cross-sectional studies, cohort studies, clinical trials, animal feeding studies and a nested case-control study. It found that a large body of evidence showed that water fluoride concentrations up to ca. 1 mg/L do not increase bone fracture rates or decrease bone mineral density compared with non-fluoridated water. Indeed, some evidence indicated that fluoride had a beneficial effect on these metrics. Evidence of increased fracture rates was found at fluoride concentrations greater than 4 mg/L by one cohort study.

Pollick (2004) published a review to address questions about the adverse effects fluoridation chemicals might have on human health and the environment. He considered three types of concern associated with fluoridation chemicals.

- The presence of impurities, such as lead and arsenic.
- The reduction in the pH of the water caused by treatment chemicals, which makes the water corrosive, possibly dissolving metals from plumbing materials.
- The toxicology of the fluoridation chemicals themselves.

The author concluded that:

- although there are impurities in fluoridation chemicals, the scale of dilution they undergo as a result of being used in fluoridation, means their concentrations are too low to be of health significance
- the fluoride ion itself is non-corrosive, but there may be a tendency for the pH to reduce when these chemicals are dissolved in water due to the dissociation of fluorosilicic acid. Adjustment of the buffering capacity of the water (the alkalinity) will ensure that this does not increase corrosiveness
- there is no credible evidence of toxicity resulting from fluoridation chemicals when diluted for use in the fluoridation process. They are expected to have dissociated to fluoride, hydrogen ions and hydrated silica by the time the water leaves the water treatment plant, or at worst, reaches the first consumers.

Key point: The fluoride ion is the only chemical species arising from the fluoridation process that needs to be considered from a toxicological viewpoint.

The SCHER review (2010) reached the same conclusions regarding hexafluorosilicates and heavy metal contaminants.

Key points: Trace impurities, such as heavy metals, in fluoridating chemicals do not present a health concern because of the degree of dilution they undergo when the chemicals are added to the water.
In an adequately buffered water, the addition of fluorosilicic acid for fluoridation purposes will not depress the pH enough to cause sufficient dissolution of metals from plumbing materials to be a health concern.

Browne et al. (2005) undertook a review of enamel fluorosis to understand its aetiology, metabolism and the measures by which it is assessed. They found that the prevalence in enamel fluorosis is increasing in some parts of the world. Fluorosis of secondary dentition can arise from excessive exposure to fluoride at a young age (15–30 months). The review concluded that the increased use of fluoridated products (such as fluoridated

toothpaste) by children under six years, is the most likely contributor to the increase in fluorosis prevalence. Fluoride from drinking-water can also contribute to enamel fluorosis if a water treatment plant is unintentionally maintaining a fluoride concentration exceeding 1 mg/L. The review noted that other studies had concluded that an acceptable trade off between the prevalence of enamel fluorosis and caries can be found at a fluoride concentration in water of approximately 0.7 mg/L.

Browne et al. (2005) considered that reducing exposure to fluoridated products was a preferred alternative to reducing the fluoride concentration in water for managing the prevalence of enamel fluorosis. They concluded that water fluoridation was a safe and effective method of reducing dental caries when used appropriately. They also concluded that the use of fluoridated toothpaste at a young age was a greater risk factor than the use of infant formula reconstituted with fluoridated water. The risks associated with both factors need to be assessed to ensure that water fluoridation and the appropriate use of fluoridated toothpastes continue.

Key point: As a way to manage dental fluorosis, improved control of exposure to other sources of fluoride is an alternative approach to reducing the fluoride concentration in drinking-water.

In 2006, the Committee on Fluoride in Drinking Water of the National Research Council (NRC) of the National Academies in the United States reviewed the US EPA's water standard for fluoride (National Research Council, 2006). This work is of limited value in the New Zealand context because the New Zealand MAV for fluoride (1.5 mg/L), the target level of fluoridation (0.7–1.0 mg/L) and natural fluoride levels in unfluoridated supplies in New Zealand are all well below the USEPA fluoride standard of 4 mg/L.

The findings of the NRC committee concerning water fluoride concentrations less than 4 mg/L were:

- less than 15% of children exposed to a fluoride concentration of 2 mg/L are expected to experience moderate enamel fluorosis (discolouration of the incisors)
- exposure to fluoride concentrations of 2–4 mg/L over a lifetime could lead to bone fluorosis
- at fluoride concentrations greater than 1.5 mg/L there was an increased rate of hip fractures
- some adverse endocrine effects associated with fluoride intakes can occur when fluoride concentrations in drinking-water are 4 mg/L or less, particularly in young children or people with high water intakes.

Evidence of associations between fluoride and cancers were reported to be “tentative and mixed”.

3.6 Ethical issues in relation to water fluoridation

Whole populations are directly affected by water fluoridation. Individuals in fluoridated communities who wish to “opt out” of receiving fluoride, face additional costs and inconvenience. This raises ethical and policy issues. Two of the papers reviewed were considered to fall within this subject category.

The Nuffield Council on Bioethics report *Public Health: ethical issues* (2007) was the only review on ethical issues found. The report identified and considered ethical, legal and social questions resulting from steps to improve public health. It did this through consideration of four case studies, one of which was the fluoridation of water supplies. The council’s report rejected the view that, on the basis of arguments about interference in personal life and coercion of ordinary adults, fluoridation of water should be prohibited outright. Instead, the acceptability of any policy involving the water supply should be considered in relation to:

- the balance of risks and benefits anticipated in a given community
- the potential of alternatives
- the role of consent where there are potential harms.

Key point: In the view of the Nuffield Council on Bioethics, water fluoridation should not be prohibited outright on the basis of arguments about interference in personal life or coercion. Its acceptability should be considered in relation to the balance of risks and benefits, the potential of alternatives, and, where there are harms, to the role of consent.

The council recommended that decisions concerning the introduction of fluoride into reticulated water systems be undertaken at the local or regional level, rather than the national level. In this way, the context in each area can be taken into account. Further, because of the complexity of the science associated with fluoridation, the public and policy makers need to have access to clear and accurate information to support the procedural justice approach (conventional democratic processes) used to reach a decision about the implementation of fluoridation. Uncertainties and the strength or weakness of the evidence should be explicitly recognised.

Key point: In the view of the Nuffield Council on Bioethics, democratic processes should be used at a local level to decide whether a water supply should be

fluoridated, and all of those involved need to have access to clear and accurate information.

A paper (rather than review) by Anand et al. (2002) discussed the ethical considerations associated with water fluoridation. The authors concluded that when deciding whether to fluoridate a drinking-water, three principles had to be followed. The process should ensure that the decision had to be:

- i. taken by a representative body
- ii. reached through informed consent
- iii. reached by consensus.

The authors argued that in deciding whether to fluoridate, either autonomy or the notion of equity has to be sacrificed.

3.7 Communication and community engagement

Communities making decisions about the fluoridation of their water supply are unable to make well-informed decisions in the absence of accurate and easily understood information on the risks and benefits of this public health intervention. Progress in understanding how information about fluoridation is best communicated is valuable in ensuring that communities are properly informed. Only one paper (not a review) was found that provides some insight into engagement with communities.

Schroth et al. (2009) reported a study of the oral health of indigenous children in North America. Early childhood caries is a complex disease with multiple causative factors. Consequently, a variety of strategies is needed to address it. Any strategy has to start with community engagement. The engagement must involve primary care providers and community health workers. Water fluoridation, while usually the most cost-effective and equitable way of preventing caries, can be rendered unrealistic or uneconomic because of the remoteness, small size and absence of infrastructure of indigenous communities. The authors recommend persevering with water fluoridation because of the success achieved in Alaskan communities, where a 30–50% reduction in the prevalence of caries was reported.

3.8 General

Newbrun (2010) recently published an overview of our understanding of the effects of fluoride. His discussion covered a wide subject area, and consequently his review has been placed in a separate section.

His key observations were:

- the differences in caries rates between fluoridated and non-fluoridated communities are smaller than previously found because of the increased use of other sources of fluoride (e.g. fluoridated toothpaste)
- communities receiving fluoridated water still have consistently lower rates of caries than those receiving non-fluoridated water
- excessive fluoride intake causes enamel fluorosis
- the prevalence of fluorosis in later erupting teeth can result from early use of fluoridated toothpastes and unintentional swallowing by children
- maximum caries prevention is achieved by systematic intake (e.g. through fluoridated water) coupled with daily topical application (e.g. toothpastes).

Key point: The increased exposure to fluoride from sources other than water, such as fluoridated toothpastes, has reduced the difference in the caries rates between fluoridated and non-fluoridated communities.

The paper focused primarily on how much we do not know about fluoridation. Importantly, when considering changes to fluoridation policy, the areas in which knowledge is limited are the:

- efficacy of lower levels of fluoride in water
- effect of discontinuing water fluoridation in the absence of other preventive measures
- prevalence of fluorosis and whether this constitutes an aesthetic problem.

Newbrun concluded that there is a need for other long-term, ongoing prospective investigations, including those into the effects of total fluoride exposure from all sources.

4 IMPLICATIONS FOR MINISTRY OF HEALTH WATER FLUORIDATION POLICY

4.1 Evidence base

This section summarises the findings from the literature review and identifies the reviews that contributed to the finding. The list in Table 1 provides the evidence base from which the implications for the Ministry of Health’s water fluoridation policy are identified.

Table 1. Major findings from the review

Beneficial effects	Review (as numbered in the appendix)
a) Dental caries	
<ul style="list-style-type: none"> Water fluoridation reduces the prevalence of caries in both children and adults in populations receiving water containing fluoride. Estimates of the mean difference in the proportion (%) of caries-free children place the figure between 14–15% [11, 13]. An estimate of the prevented fraction in adults was 27% [6]. 	6, 7, 9, 11, 13, 17, 21, 22
<ul style="list-style-type: none"> Water fluoridation has a beneficial effect (on caries) over and above the effect of fluoride from sources other than water. 	11
<ul style="list-style-type: none"> While water fluoridation reduces caries, topical application of fluoride is a more efficient way of achieving protection (i.e., post-eruptive action – although the relative contributions of pre- and post-eruption are argued). 	15, 21, 22
<ul style="list-style-type: none"> Differences in caries rates between fluoridated and non-fluoridated communities are smaller than has been found previously. The increased use of other sources of fluoride, such as fluoridated toothpaste, appears to be the reason. 	15, 18
<ul style="list-style-type: none"> Communities receiving fluoridated water have consistently lower rates of caries than those receiving non-fluoridated water. 	6, 15
<ul style="list-style-type: none"> Cessation of fluoridation can result in an increase in caries. 	9, 12
<ul style="list-style-type: none"> There is limited knowledge of the efficacy of fluoride in reducing caries if the fluoride concentration in water is reduced below levels presently considered as optimum. 	15
b) Redressing social inequalities	
<ul style="list-style-type: none"> The evidence for water fluoridation reducing differences, due to socioeconomic status, in oral health is inconclusive. 	3, 11, 17, 21, 22
Adverse effects	
a) Dental fluorosis	
<ul style="list-style-type: none"> Dental fluorosis is a demonstrated and acknowledged adverse effect that can 	9, 11, 13, 22, 24

arise from fluoridation.

- There is a dose-response relationship between fluoride concentration and the prevalence of fluorosis, but the fluoride concentration threshold at which fluorosis becomes evident has not been determined. The prevalence of fluorosis at a drinking-water fluoride concentration of 1 mg/L was estimated to be 48% [11]. 11, 22
- Fluorosis arising in areas with fluoride concentrations close to optimal (ca. 1 mg/L) is usually described as very mild or mild. 13, 24
- In some communities (reported in the European Union and United States) an increase in very mild and mild fluorosis has been reported in communities receiving fluoridated water. 24
- The most likely contributor to the increased prevalence of fluorosis, where reported, is increased use of fluoridated products (particularly adult-strength toothpaste) by children under six years of age. 2, 15
- Sources of fluoride other than fluoridated water, such as fluoridated toothpaste and fluoride tablets, are risk factors for the development of fluorosis. 24
- The association between fluorosis and use of infant formula increases with the level of fluoride in the water supply, but the evidence for this being due to fluoride in the formula is weak. 8
- The total fluoride intake, not just intake from water, of an individual is the true determinant of the risk of fluorosis, and it is important that contributions from all sources are determined. 7, 10
- The most critical period for exposure to fluoride with respect to the development of fluorosis of the upper anterior incisors (those of greatest cosmetic importance) is the period between the ages of 15 and 30 months. 2, 10
- Recent overseas studies have consistently shown that very mild fluorosis does not have an adverse effect on oral health-related quality of life, but severe fluorosis is consistently reported to do so. 4

b) Other adverse effects

- There is no evidence showing that water fluoridation increases the likelihood of hip fractures in the population receiving the water. 2, 7, 11
- Water fluoridation appears to have no effect on the likelihood of bone fracture, reduced BMD, or reduced bone strength, and some evidence suggests that fluoride concentrations around 1 mg/L may be beneficial. (NB. Reviews 7, 9 and 11 concluded that there was insufficient evidence to assess the effects of fluoridation on bone disorders other than hip-fractures). 5, 13
- There is either insufficient evidence to assess the effect of fluoridation on other adverse effects, or the available evidence indicates there is no influence. 7, 11, 13, 14, 22, 25

-
- c) Effects from fluoridation chemicals
- There is no evidence that, following the dissolution of fluoridation chemicals during the fluoridation process, any adverse effects will arise from the undissociated chemicals themselves, fluorosilicate species, impurities in the chemicals, or the dissolution of metals in water systems because of a substantial depression in the pH of the water. 19, 22

Ethical considerations - in the view of the Nuffield Council on Bioethics

- Water fluoridation should not be prohibited outright on the basis of arguments about interference in personal life or coercion. 16
 - The acceptability of water fluoridation should be considered in relation to the balance of risks and benefits, the potential of alternatives, and, where there are harms, to the role of consent. 16
 - Democratic processes should be used at a local level to decide whether a water supply should be fluoridated, and all involved need to have access to clear and accurate information. 16
-

4.2 Implications for fluoridation policy

With the exception of one review article (Pizzo et al., 2007), which concluded that there may be situations in which water fluoridation is unnecessary in the developed world, all reviews reviewed supported water fluoridation. Fluoridation protects against dental caries and there is some evidence supporting the contention that its benefits across socioeconomic strata provide an equitable strategy for improving oral health. Both these findings support a strategy of water fluoridation to improve oral health, and therefore the Ministry of Health's fluoridation policy.

Although fluoridation is very broadly supported, it is also clear that excessive intake of fluoride, particularly during early childhood, can lead to dental fluorosis. At the fluoride concentrations presently recommended by the Ministry of Health's fluoridation policy, evidence shows that if fluorosis occurs, it is likely to be very mild or mild, and consequently of aesthetic rather than of clinical concern.

To date, associations between fluoridation and other adverse effects that have been suggested are either not supported by the existing evidence, or are supported by insufficient good quality data to enable a reliable conclusion about their existence to be reached.

The statement of the Ministry of Health's present fluoridation policy (Section 1.2) focuses on caries prevention, and no comment is made on the minimisation of adverse effects. The prevention of adverse effects is implicit in the MAV of 1.5 mg/L, but fluorosis, albeit

mild or very mild, has been reported at fluoride concentrations considered optimum, that is, concentrations below the MAV at ca. 1 mg/L. It is apparent that other factors, including the use of fluoridated toothpastes, and the age at which they are used, are important in determining the likelihood, and extent, of fluorosis. These additional factors complicate the identification of the “optimum” level at which fluoride should be added to drinking-water, because account must be taken of the *total* fluoride intake when formulating fluoridation policy.

Given the controversial nature of water fluoridation, it seems important that a review of the policy should assess whether adverse effects (specifically enamel fluorosis) are being experienced in New Zealand to an unacceptable degree. If they are, then the policy should be modified to reduce adverse effects (preferably reducing them to an acceptable level) while ensuring a point of balance is found that also ensures effective caries reduction.

The Ministry of Health’s *Guidelines for the Use of Fluoride* state that on the basis of the available evidence, the prevalence of fluorosis in New Zealand is not increasing. To assist in determining whether steps to reduce fluorosis need to be considered in the fluoridation policy, work is needed (unless it has already been undertaken) to:

- a. undertake a structured review of all New Zealand studies of enamel defects to gain the clearest understanding possible of the status of fluorosis in New Zealand, including an examination of the interpretation of the presented indices with regards to fluorosis
- b. assess whether the existing prevalence of fluorosis is considered acceptable, even if the prevalence is not increasing.

Levy [10] described the decision, taken by the dental profession, that the trade-off of mild fluorosis for a substantial reduction in caries was acceptable, as “paternalistic”. He suggested that with aesthetics becoming more important, this decision might need to be revisited. Chankanka et al. (2010) reported a study that found that very mild and mild fluorosis did not adversely affect the oral health quality of life of the respondents. This may not necessarily be true of New Zealanders, because of our different ethnic makeup, and consequent cultural sensitivities. For this reason, studies to understand how New Zealanders view the cosmetic impact of very mild and mild fluorosis are needed to guide the development of fluoridation policy.

In the event that a revision of the fluoridation policy is required to reduce the levels of dental fluorosis, the information collected for this report indicates the importance of taking account of how sources of fluoride, other than drinking-water, are influencing the prevalence and severity of fluorosis.

The following are examples of the ways in which other jurisdictions have modified their fluoridation policies to take account of risk factors other than the fluoride concentration in water (Parnell et al., 2009).

- Ireland has lowered the level of fluoride in its fluoridated supplies from a range of 0.8–1.0 mg/L to a range between 0.6–0.8 mg/L with a target of 0.7 mg/L, with an accompanying recommendation that children under the age of two years not use toothpaste.
- Canada's approach is similar, targeting 0.7 mg/L as the concentration in fluoridated water, but also recommending the use of low-fluoride toothpaste for children and a reduction in the fluoride content of infant formula.
- Australia has retained the recommended level of fluoride in its water supplies (0.6–1.1 mg/L), but discouraged the use of toothpaste by children younger than 24 months, encouraged the use of low-fluoride toothpaste by children under seven years of age, and reduced the fluoride content of infant formula.

As shown by the actions of Ireland and Canada, 0.7 mg/L of fluoride may be considered an optimum fluoride concentration. While this concentration may provide some guidance for the optimum concentration for New Zealand, the relative importance of fluoride from water and from other sources in the New Zealand context needs to be ascertained. Furthermore, there is still uncertainty over how a reduction in the fluoride concentration to 0.7 mg/L will impact on caries (Newbrun, 2010).

The developmental stages during which the intake of an excessive amount of fluoride is likely to have the greatest impact on the severity of fluorosis in secondary dentition are before the age of six years, and particularly between 15–30 months. In reviewing fluoridation policy, the possible sources of fluoride to which children may be exposed need to be identified and the extent to which they contribute to total fluoride intake estimated. The literature shows that the use of adult-strength toothpaste (and subsequent unintentional swallowing of the toothpaste), and the consumption of infant formula reconstituted with fluoridated water, are major risk factors.

5 RESEARCH NEEDS

Research needs were identified by many of the reviews, and in some instances several reviews identified the same need. Table 2 summarises the research needs identified by papers and reports reviewed. It assigns a suggested priority (low, medium, high, key) with respect to work that would be valuable in developing a fluoridation policy, provides comment and the rationale supporting the identified need, and identifies the reviews in which the research need was identified or which made comment consistent with the need. The “key” classification identifies research needs that are judged most important for review of New Zealand’s fluoridation policy.

The table is a check list to assist in identifying the information important for further development of New Zealand’s fluoridation policy, but not all of the research needs listed are necessary for development of New Zealand’s fluoridation policy. Some may not be appropriate for the New Zealand context, while others may have been met already by research in New Zealand.

Table 2. Research needs identified by reviews

Apart from the low/medium/high/key ordering within each priority grouping there is no ordering

Research Need	Priority	Rationale/Comment	Reference as per appendix
1 Determination of the level of fluoride in drinking-water that provides the best balance between minimisation of caries and fluorosis control (in a given jurisdiction).	Key	Acceptance of fluoridation will be more readily achieved if its adverse effects can be minimised while maintaining its benefits. Determining the “optimum” fluoride level is fundamental to developing a satisfactory fluoridation policy.	9, 10
2 Determination of how reducing fluoride levels to values of ca. 0.7 mg/L affects the efficacy of fluoride in reducing caries	Key	Should a reduction of the fluoride concentration in water appear necessary to reduce the effects of fluorosis, it is important to know how the reduction will affect the ability of the fluoride to reduce caries.	15
3 Determination of levels of prevalence and severity of fluorosis, and the trends in these parameters (in a given jurisdiction).	Key	Fluorosis is the primary adverse effect associated with fluoridation, and the association is well documented. Policy decisions relating to the implementation of water fluoridation and the guidance required for the use of fluoridated dentifrices require an understanding of the existing status of fluorosis and how this may be changing with time.	15
4 Identification of the most appropriate approaches for control of fluoride intake	Key	Changes to water fluoridation policy need to be made in the context of an overall strategy that takes account of total fluoride application, and how social equity issues are best addressed. Different jurisdictions have taken different approaches to this, eg, see the notes on Ireland, Canada, and Australia (Section 5). This research need is not stated explicitly, but is implicit in Review 17.	17

Research Need	Priority	Rationale/Comment	Reference as per appendix
<p>5 Determination of the impacts of fluorosis on people – factors that influence the importance people place on mild dental fluorosis. Studies need to be appropriate for the jurisdiction.</p>	Key	<p>In determining the level to which water supplies should be fluoridated, there is a trade-off between the prevention of caries and the risk of enamel fluorosis. In determining the point of balance, an acceptable level of fluorosis has to be identified.</p> <p>Physical attractiveness is important to children and young adults, and dental appearance is an important factor in self image.</p> <p>A clinical classification of fluorosis as “very mild or mild” may seem to make it acceptable to the dental professional, but the person with the fluorosis may not consider it so. Work to understand how fluorosis is perceived is needed to help in justifying decisions made with regard to the level of water fluoridation.</p>	14, 24
<p>6 Determination of community views on fluoridation, and in particular, how local authorities inform their decision making in relation to fluoridation, and the role and importance of local, national, and international groups advocating for not fluoridating water supplies.</p>	Key	<p>If the Ministry wishes to increase the percentage of the population presently receiving fluoridated drinking-water, it needs to have a better understanding of why communities make the decisions they do concerning fluoridation. The provision of accurate and clear scientific information alone is unlikely to be sufficient for reaching the goal of 70% of the population receiving fluoridated water.</p>	1, 16 (implicit)
<p>7 An understanding of the importance of infant formula reconstituted with fluoridated water and the use of fluoridated toothpastes from a young age, as risk factors for the development of fluorosis.</p>	High	<p>Fluoridated water and the use of fluoridated toothpastes together is a key strategy to minimising caries. To ensure their continued use, the risks of excessive exposure to fluoride need to be monitored. This is especially true for the age groups most vulnerable to such exposure. Understanding the extent to which toothpaste usage and infant formula contribute to fluorosis is key to the development of fluoridation strategies and guidance for parents.</p>	2

Research Need	Priority	Rationale/Comment	Reference as per appendix
<p>8 Improved estimations of the total fluoride intakes of individuals from different population sectors (eg, different socioeconomic groups). This requires a determination of the contributions made from various fluoride sources.</p>	<p>High</p>	<p>Several reviews note the importance of the total fluoride intake in determining the positive or negative effects of fluoride on oral health. To make informed decisions about water fluoridation policies, the relative importance of various sources of ingested fluoride needs to be known. This would also influence the need for mandatory reporting of the fluoride content of infant formula.</p> <p>The comment is frequently made in the literature that assessment of individual fluoride intake is what is important, not an estimation at the community level. This reflects the fact that individuals in different situations within a community will be exposed to different amounts of fluoride from different sources. It should be possible to model a variety of scenarios for intake, for example, in key groups such as breastfed infants (fully, partially) in areas with fluoridated/unfluoridated water supplies.</p>	<p>2, 7, 9, 10 14, 15, 17</p>
<p>9 Studies in which confounding factors are controlled for to determine more definitively whether there are adverse effects, other than fluorosis, that arise from fluoridation.</p>	<p>High/ Medium</p>	<p>Concerns still exist about the health consequences of water fluoridation. Studies have been undertaken to assess whether these concerns are founded, but in most cases the poor quality of the studies has not allowed a clear conclusion to be reached. If water fluoridation is to be pursued, which requires individual rights of choice to be over-ridden, there needs to be a clear understanding of the health consequences of taking this decision so that a well informed assessment of the balance between harm and benefit can be made. The Nuffield Council on Bioethics review [16] indicates the need to know about potential harms.</p>	<p>11, 15, 16, 17</p>

Research Need	Priority	Rationale/Comment	Reference as per appendix
10 Determination of the effect of lowering the fluoride concentrations in some jurisdictions on the prevalence of fluorosis.	High/Medium	The York Report [11] found a dose-response relationship between fluoride concentrations in water and the development of fluorosis. Jurisdictions, such as Ireland and Canada, and latterly the USA, have lowered the fluoride concentration permitted in fluoridated water supplies to try to reduce the prevalence of fluorosis. These changes may have been too recent to ascertain the efficacy of these steps, but collection and analysis of this information, when available, will assist in informing decision makers.	11, 15
11 Better determination of the effectiveness of fluoridation in reducing dental caries among adults, and assessment of which methods of delivering fluoride provide greatest benefits to adults.	Medium	Improvement in oral health has resulted in adults retaining their teeth longer. While protection of the teeth of children is important, oral health strategies need to provide lifelong protection, therefore they need to ensure protection for adults' teeth. Very few studies have been undertaken since 1979 to assess the effectiveness of fluoride in preventing caries in the teeth of adults.	6, 17
12 Development of a standardised objective (photographic), method by which the severity of fluorosis can be assessed.	Medium	A standard approach to the assessment of fluorosis will allow valid comparisons to be made between studies in different jurisdictions, and within the same jurisdiction. Improved quality of information about trends in the prevalence and extent of fluorosis, which depend on a standardised method of assessment, will assist in making decisions about the optimum level of water fluoridation.	14, 24
13 Long-term studies to identify the benefits and potential adverse effects that may become apparent over time.	Medium	Fluorosis is evident in young populations within a relatively short time after the start of fluoridation, but other adverse effects may take longer to occur, or may occur largely in the adult population.	11, 15

Research Need	Priority	Rationale/Comment	Reference as per appendix
14 Identification of the most appropriate tool to measure social class with respect to dental health	Medium	One of the primary reasons for the delivery of fluoride through drinking-water is that it ensures that people within all social strata in a community are provided with protection against caries. The degree to which water fluoridation redresses oral health inequities results from socioeconomic status is still uncertain. The York Report [11] noted the need to identify the most appropriate measure of social class to assess whether the claimed benefits to social equity are being delivered.	11
15 Study of jurisdictions in which fluoridation of water has been halted, to determine how the rates of caries and fluorosis have been affected. (Care will be needed in controlling for changes in the topical application of fluoride.)	Medium	This information is needed in support of water fluoridation policy. There are some examples of communities having halted fluoridation with no increase in caries. Sufficient background information needs to be collected during these studies to take account of how changes in the use of fluoridated dentifrices, and other confounders, may be influencing the caries rate.	15
16 Evaluation of the effects on caries of fluoride mouth rinse, fluoride supplements and other modes of delivering fluoride.	Low	Assessing these effects will assist in determining how they should be incorporated into a total fluoridation strategy and policy.	10
17 Determination of an association between Down syndrome and water fluoridation.	Low	<p>Several studies have investigated the possibility of a link between Down syndrome and water fluoridation, but the quality of the studies is too poor to allow a conclusion to be reached. Studies designed to control for confounding factors need to be undertaken if a clearer understanding of any relationship is to be gained.</p> <p>Future studies need to take account of confounders, select study areas randomly, and blind the investigators to the fluoridation status of mothers when identifying cases.</p>	25

Research Need	Priority	Rationale/Comment	Reference as per appendix
18 Determination of fluoride concentrations in human bone as a function of exposure concentration, exposure duration, age, sex and health status.	Low	This research need was identified by the NRC review [14] to assist in the understanding of the effects of the higher levels of fluoride encountered in the USA. The low concentrations of fluoride in the waters used for water supply sources in New Zealand mean that this is of low priority for New Zealand.	14
19 Development of improved and available pharmacokinetic models	Low	This research need was identified by the NRC review [14]	14
20 Additional studies on supplies containing fluoride concentrations in excess of 1 mg/L fluoride – focusing on moderate and severe enamel fluorosis.	Low	This research need was identified by the NRC review [14] to assist in understanding the effects of the higher levels of fluoride encountered in the USA. There are very few supplies in New Zealand in which fluoride concentrations are greater than 1 mg/L for an extended period, making this low priority.	14
21 Studies to investigate the relationship between fluoridation exposure and dentine fluorosis.	Low	The NRC's [14] concern with fluorosis of dentine appears linked to the damage that may be associated with moderate and severe fluorosis. Very few people in New Zealand are likely to be exposed to fluoride concentrations leading to these disorders.	14
22 Determination of the adverse health effects of fluoride over a range of fluoride concentrations.	Low	The NRC [14] recommended studies of other adverse effects on the US populations exposed to various concentrations of fluoride, but until associations are apparent, it is premature to consider these in the New Zealand context.	14

APPENDIX REVIEW SUMMARIES

Review 1

Study identification:	Title	Ethical Issues in Public Health Policy
	Authors	K. Anand, N. Baridalyne, D. Moorthy, S.K. Kapoor, R. Sankar, C. S. Pandav
	Journal	The National Medical Journal of India
	Year	2002
	Volume	15, No. 2
	Pages	97–100
	Journal Impact Factor	0.626
	Review Type	Qualitative
	Area	Ethical considerations in relation to water fluoridation

Summary relevant to water fluoridation in New Zealand:

The authors state that three principles must be followed in arriving at any decision on ethical issues in public health, such as water fluoridation. The process should ensure that the decision would be: (a) taken by a *representative* body, (b) an *informed consent* and (c) by *consensus*. They further state that the issue of fluoridation (in India) was resolved with the help of scientific research when it was confirmed¹⁰ that there is no association between cancer and fluoridation of water. However the choice of individual freedom could not be resolved, either equity or autonomy has to be sacrificed. The availability of other preventative approaches has meant fluoridation of water has never taken off in a major way.

The article reiterates the findings in the Nuffield Council on Bioethics report, concluding that when ethical concerns occur in public health measures, such as water fluoridation, then decisions need to be made by representative bodies, informed consent and consensus. Although the decision is important, the process of arriving at that decision is of paramount importance.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	Not addressed
<i>A description of the methodology used is included.</i>	n/a

¹⁰ The findings of other reviews would suggest that “confirm” is too strong a word, as the existing evidence is inconclusive.

<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	n/a
<i>Study quality is assessed and taken into account.</i>	n/a
<i>There are enough similarities between the studies selected to make combining them reasonable.</i>	n/a
<i>How well was the study done to minimise bias?</i>	n/a
<i>If coded as +, or - what is the likely direction in which bias might affect the study results?</i>	n/a
Level of evidence provided by the review:	
Poor quality	
Comments:	
This was not a meta-analysis. References were few, and very little of the paper is related to water fluoridation.	
Implications for Ministry of Health's fluoridation policy:	
There is no implication for the Ministry of Health's policy.	

Review 2

Study identification:	Title	Fluoride metabolism and fluorosis
	Authors	D Browne, H Whelton, and D O'Mullane
	Journal	Journal of Dentistry
	Year	2005
	Volume	33
	Pages	177–186
	Journal Impact Factor	2.000
	Review Type	Narrative Review
	Area	Toxicology/Pharmacology

Summary relevant to water fluoridation in New Zealand:

Enamel fluorosis is the most well documented, least controversial effect of “excess” fluoride, with some evidence that comparatively modest “increases” in fluoride in drinking-water can be a causal factor. However, it is not easy to reliably diagnose fluorosis, distinguish it from other causes of lesions of similar appearance, or to accurately grade its severity, indeed several alternative classification systems exist.

Nonetheless, the studies presented indicate that the prevalence of enamel fluorosis is increasing in several parts of the world (at least until the mid-1990's). More data exist regarding fluorosis in secondary as opposed to primary teeth, though one Irish study has found a significant prevalence in the latter as well. Even secondary fluorosis can arise from excess fluoride exposure at a very young age. (The most vulnerable period lies somewhere between approximately 16–30 months, though particularly near the middle of this range, and with some gender difference). The second molars (primary or secondary) are particularly susceptible.

A major reason for such increased fluorosis prevalence is likely to be the increased use of other fluoride-containing products, including toothpastes, by children under six years of age.

A major risk is inappropriate use of fluoride toothpaste at a young age. A suitable trade-off between dental decay and fluorosis may occur at 0.7 mg/L fluoride in water. One study found little decline in caries observed across the fluoridation level range of 0.7–1.2 mg/L, while an increase in fluorosis was seen across this same range. Similarly, another group suggested that lowering the fluoride level in drinking-water to between 0.6–0.8 mg/L would be sufficient to considerably reduce dental decay while reducing the risks of fluorosis.

Other methods of reducing exposure to other fluoride products, particularly at the young ages of maximum vulnerability, were also discussed. These might have more impact than lowering drinking-water levels to between 0.6–0.8 mg/L.

Regarding other potential adverse effects besides enamel fluorosis, the studies and investigations that were presented did not suggest any such effects at drinking-water fluoride levels of 1 mg/L.

The authors conclude that when used appropriately, fluoride is a safe and effective agent for reducing dental caries. Use of toothpaste from a young age would seem of greater risk than use of infant formula diluted with water, however, further research is required to establish the relative contribution of these two factors. The risks associated with excessive ingestion of fluoride need to be monitored to ensure that water fluoridation and the use of fluoridated toothpastes continues.

Evaluation:

Criterion	In this study this criterion is:
<p><i>The study addresses an appropriate and clearly focused question.</i></p> <p>Having defined what is fluorosis, and the (various) methods historically used to identify and distinguish it, and assess its severity (eg, via various indices), the review goes on to discuss the following questions.</p> <p>1) What is (has been) the prevalence of enamel fluorosis?</p> <p>2) The mechanisms, with implications for the question what are the most vulnerable age periods for fluorosis?</p> <p>3) What are the (other) risk factors for enamel fluorosis?</p> <p>4) What is appropriate risk management?</p>	Well covered
<p><i>A description of the methodology used is included.</i></p> <p>No. A potentially significant limitation is that no literature search strategy is outlined and it is unclear what search methods were used. Therefore it is unclear how comprehensive and representative the chosen strategy was.</p>	Not addressed
<p><i>The literature search is sufficiently rigorous to identify all the relevant studies.</i></p> <p>As the search strategy is not outlined, it is not possible to assess how thorough it was.</p>	Poorly addressed
<p><i>Study quality is assessed and taken into account.</i></p> <p>No.</p>	Not addressed
<p><i>There are enough similarities between the studies selected to make combining them reasonable'</i></p> <p>In this report, the findings of the various studies cited are not formally combined in any statistical sense.</p>	n/a
<p><i>How well was the study done to minimise bias?</i></p> <p>The design of individual studies cited were not described or assessed in detail</p>	n/a

If coded as +, or - what is the likely direction in which bias might affect the study results?

n/a

Level of evidence provided by the review:

Moderately high quality, but the likelihood of bias is uncertain.

Comments:

A potentially significant limitation is that no literature search strategy is outlined and it is unclear what methods were used. Therefore it is unclear how comprehensive and representative the chosen search strategy was. However, a relatively large number of studies and reviews are cited, and the analyses provided of these are clear and logical.

Implications for Ministry of Health's fluoridation policy:

In assessing risks of enamel fluorosis, other sources of fluoride, as well as other individual risk factors, have to be considered alongside the concentration of fluoride in drinking-water. Young children are most vulnerable to fluorosis, and a major risk factor is likely increased use of other fluoride-containing products, including inappropriate use of fluoride toothpastes, by children under six years of age.

This review indicates that if water fluoridation is to be continued or more widely introduced, consideration should be given to a slightly lower target level than 1 mg/L, and, or alternatively, there should be renewed focus (by appropriate professional bodies) on reducing any excessive exposure to other fluoride products, particularly fluoride toothpastes at an excessively young age. A fluoride concentration range of 0.6–0.8 mg/L is discussed in the review, although it is noted more research to establish the effectiveness of this range is needed.

Steps should also be taken to ensure that accidental exceedances of the upper concentration limit of 1 mg/L do not occur, especially for any length of time.

Apart from enamel fluorosis, there appears to be no established risk of adverse effects at a drinking-water fluoride concentration of 1 mg/L that indicates a need to change the existing fluoride concentration range recommended in the Ministry of Health's fluoridation policy.

Review 3

Study identification:	Title	Fluoridation and social equity
	Authors	B. Burt
	Journal	Journal of Public Health Dentistry
	Year	2002
	Volume	62(4)
	Pages	195–200
	Journal Impact Factor	0.961
	Review Type	Essay
	Area	Oral and Public Health

Summary relevant to water fluoridation in New Zealand:

This paper reviews published literature on the relationship between socioeconomic status (SES) and health status, oral health status and then the presence of water fluoridation to craft a logical argument for why water fluoridation ought to be a public health priority.

Dental caries is a disease directly related to low SES. Regular maintenance of a low fluoride concentration in the oral cavity is required to ensure the protective action of fluoride. Those of lower SES are less likely to visit a dentist and brush their teeth less frequently compared with those of higher SES. A fluoridated water supply provides the only practical method of ensuring this sector of the population receives an adequate intake of fluoride.

The author concludes that SES and water fluoridation are “determinants of caries status” and that most of the evidence considered in the review shows that water fluoridation reduces “dental caries disparities between different SES strata”. Water supply fluoridation still offers the most efficient means by which fluoride can be delivered to the whole population, and should remain a public health priority.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	Poorly addressed
The paper did not address a focused question, but instead presented a case for why water fluoridation should be “retained as the cornerstone of caries control in public health”.	
<i>A description of the methodology used is included.</i>	Not addressed
The paper is not a systematic review but a commentary in the Journal of Public Health Dentistry. Inclusion and/or exclusion	

criteria are not reported.	
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	
No search strategy was reported and inclusion of papers is potentially subjective and/or less than comprehensive. There was no indication that the author searched (electronically or manually) for all published and unpublished literature relating to oral health disparities and water fluoridation.	Poorly addressed
<i>Study quality is assessed and taken into account.</i>	
An assessment of study quality was inconsistently incorporated into the analysis. The author cites studies to support well-established knowledge about health disparities including social deprivation as a risk factor for poor health status, but does not assess the quality of studies that demonstrate a link between socioeconomic status (SES) and oral health outcomes. He cites what are presumably two cross-sectional studies of SES and caries prevalence, but does not discuss the limitations of this particular study design.	
Studies from Britain, Australia and New Zealand are simply cited to show that “the evidence, on balance, suggest that [fluoridation] will reduce [oral health disparities], though not remove them completely” (p. 197). However, the author does assess the methodological quality of studies that found no interaction between social class and water fluoridation. The author noted confounding from restorative dental treatment and exposure to other sources of fluoride as well as difficulties in detecting relationships given low levels of caries and questionable treatment statistics. These include two dated New Zealand studies ¹¹ by Evans et al (1984) and Colquhoun (1985).	Poorly addressed
<i>There are enough similarities between the studies selected to make combining them reasonable.</i>	
Paper cites studies from around the world although notes that some studies are dated.	Adequately addressed
<i>How well was the study done to minimise bias?</i>	n/a
<i>If coded as +, or - what is the likely direction in which bias might affect the study results?</i>	n/a
Level of evidence provided by the review:	
Low, likely to contain bias	

¹¹ Evans RW, Beck DJ, Brown RH, Silva PA, 1984, Relationship between fluoridation and socioeconomic status on dental caries experience in 5-year-old New Zealand children. *Community Dent. Oral. Epidemiol.*, 12, 5-9.
Colquhoun J. 1985, Influence of social class and fluoridation on child dental health. *Community Dent. Oral. Epidemiol.*, 13,37-41.

Comments:

This paper is unlikely to have generated either a comprehensive or unbiased summary of the evidence base.

Implications for Ministry of Health's fluoridation policy:

The paper illustrates how a health inequalities lens may be applied to generate a case for the continued use of water fluoridation in the United States.

The paper supports the current Ministry of Health fluoridation policy, but the paper is not a well designed review, and could not, alone, be used as the basis for policy development. As New Zealand already employs an inequalities lens to public health policy, it is unclear what this paper adds to Ministry of Health water fluoridation policy development.

Review 4

Study identification:	Title	A literature review of aesthetic perceptions of dental fluorosis and relationship with psychosocial aspects/oral health-related quality of life
	Authors	O. Chankanka, S. Levy, J. Warren, and J. Chalmers
	Journal	Community Dentistry and Oral Epidemiology
	Year	2010
	Volume	38
	Pages	97–109.
	Journal Impact Factor	2.418
	Review Type	Literature review
	Area	Oral and Public health

Summary relevant to water fluoridation in New Zealand:

This paper reviews literature relating to the impact of dental fluorosis on aesthetic perceptions and oral health-related quality of life. It notes that a decline in the average caries rate has occurred with an increasing prevalence of fluorosis (although there is no evidence of increased fluorosis in New Zealand), and this has led to a conservative approach to the use of fluoride dentifrice (especially for infants/preschool children). The effects of dental fluorosis are subjective and the authors were interested in determining the “true impact of dental fluorosis on children and parents”. The paper therefore set out to “review the published literature assessing relationships between perceptions of dental appearance/oral-health related quality of life and dental fluorosis”.

The authors conclude that the current evidence base demonstrates that mild/very mild fluorosis has no negative effects on the respondents’ assessment of oral health related quality of life but severe fluorosis is “evaluated less favourably” and has “negative effects on the respondents’ [oral health related quality of life]”.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	Adequately addressed
What is the relationship between perceptions of dental appearance/oral-health related quality of life and dental fluorosis?	Adequately addressed
<i>A description of the methodology used is included.</i>	Adequately addressed
The inclusion/exclusion criteria were explicit. Papers deemed to have “relevant results to address an association between	

aesthetic perceptions and fluorosis conditions” were included. Abstracts were screened for relevance and of the 136 published papers 101 were excluded. These included papers relating to treatment, prevalence/risk of fluorosis, oral health practices of dental students, and those not deemed to be original studies, e.g. review/case report/letter/news/editorial. One paper about the association between aesthetics concerns and water fluoride levels was excluded. It is unclear whether at least two reviewers screened the abstracts in order to avoid selective inclusion of studies. There was a narrative discussion of study findings.

The literature search is sufficiently rigorous to identify all the relevant studies.

The authors claim they identified all published studies and acknowledge the failure to include unpublished studies may have introduced bias into the review. PubMed database from 1985 to March 2009 searched for English language papers using MeSH ‘dental fluorosis’ and ‘perception’/‘dental esthetics’/‘attitude’/‘judgment’/‘quality of life’ as keywords. This search identified 136 published articles.

Adequately addressed

The authors did not report whether they had contacted known experts in the field or utilised hand searching given incomplete indexing and lack of keywords in titles and abstracts. The authors did not report using non-electronic search strategies including (a) contacting known experts in the field to identify additional published papers or unpublished papers or (b) hand searching given incomplete indexing and lack of keywords in titles and abstracts. It is unclear whether the grey literature was searched.

Study quality is assessed and taken into account.

The authors claim they assessed the quality of included studies. While the paper’s appendices contain detailed information about included articles including comments on data collection and reliability, it is unclear whether the reviewers assessed the quality of the included studies beyond data collection.

Poorly addressed

It is unclear whether the included studies were assessed by at least two independent reviewers to minimise bias.

All included studies were observational studies and limitations associated with this research design were not taken into account in interpreting the significance of the studies.

There are enough similarities between the studies selected to make combining them reasonable.

The review noted “substantial heterogeneity of design, methods, indexes, outcomes and analyses” and this had “precluded [the authors] from conducting a true systematic review” (p. 105).

Adequately addressed

How well was the study done to minimise bias?

+

If coded as +, or - what is the likely direction in which bias might affect the study results?

Unknown

Level of evidence provided by the review:

Although not a systematic review, this literature review has incorporated some systematic review components.

Comments:

This is a general literature review, which has incorporated some systematic review components. It has a limited search strategy which is unlikely to have generated a comprehensive and unbiased summary of the evidence base.

Implications for Ministry of Health's fluoridation policy:

This review suggests that as very mild to mild fluorosis does not negatively impact on oral health-related quality of life, fluorosis is unlikely to be a significant barrier to the acceptability of water fluoridation. However, in the New Zealand context, Māori may have different attitudes towards fluorosis and lack of first-hand knowledge about the impact of fluorosis on oral health related quality of life in the community may lead some to overstate its significance as a reason not to fluoridate.

Review 5

Study identification:	Title	Water fluoridation, osteoporosis, fractures – recent developments
	Authors	LL Demos, H Kazda, F M Cicuttini, MI Sinclair, CK Fairley.
	Journal	Australian Dental Journal
	Year	2001
	Volume	46 (2)
	Pages	80–87
	Journal Impact Factor	1.22
	Review Type	Systematic Review
	Area	Epidemiology

Summary relevant to water fluoridation in New Zealand:

The review sought studies published since 1991 that were concerned with the effect of water fluoridation on bone, and the endpoints of fracture incidence, bone mineral density (BMD) and bone strength. It found a large body of epidemiological evidence (from clinical trials, cohort and cross-sectional studies), from different geographical areas and demographic populations. From these studies the authors concluded that fluoride concentrations up to 1 mg/L in water do not have an adverse effect on bone strength, BMD, or the incidence of fracturing. Indeed, some evidence suggests that optimal fluoride concentrations (1 mg/L) could be beneficial.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
It summarises the findings of various types of studies which examine whether exposure to fluoride at levels of ca. 1 mg/L in drinking-water is associated with decreased BMD or strength, or an increased incidence of bone fractures.	Well covered
<i>A description of the methodology used is included.</i>	
Utilising the key words “fluoride and bone”, “fluoride and osteoporosis”, “fluoride and fractures”; a Medline search was carried out for publications over an eight year period from 1991–1998. (Only English language studies were considered).	Well covered.

The literature search is sufficiently rigorous to identify all the relevant studies.

The search was probably adequate, but probably not as rigorous as would be possible, if a search of databases other than Medline had been made.

Adequately addressed

Study quality is assessed and taken into account.

Study quality was taken into account to some degree. That is, studies were excluded for four specific reasons; ie, some specific exclusion criteria were applied, some of which would have helped to minimise particular sources of bias including confounding factors, including exclusion of:

- subjects with bone disease other than osteoporosis
- endpoints other than fracture incidence, BMD, or bone strength
- involvement of treatments other than fluoride, where it was not possible to separate the effects of the two
- studies not presenting their original data.

Adequately addressed

There are enough similarities between the studies selected to make combining them reasonable.

The findings of the various studies cited are not combined in this report.

n/a

How well was the study done to minimise bias?

+

If coded as +, or - what is the likely direction in which bias might affect the study results?

Insufficient information to assess the direction bias

Level of evidence provided by the review:

4 - High quality systematic review

Comments:

This paper presents information from a wide variety of different studies, some of which would be significantly susceptible to bias. The ecological studies were recognised to be particularly prone to bias, which cannot be well controlled. Cross-sectional studies cannot provide a reliable estimate of historical cumulative exposure, and case-control studies are also limited in this regard. Cohort studies are more reliable in that respect, but, particularly in regard to bone fractures, there are several potential confounders and only some adjustments for confounding bias were made in some of these studies.

No comments were made on the quality of the 12 clinical trials, but this type of study is generally substantially more efficient at minimising biases, and their findings were given appropriate emphasis in the overall review. They also provided the clearest data on dose response (or concentration response) relationships.

A potential strength is that only the more relevant and appropriately designed studies of their type were included, e.g. 353/368 (ca. 96%) of studies were excluded. (However this was partly because

many addressed a somewhat different study question though other reasons were the presence of potential bias including confounding factors).

Implications for Ministry of Health’s fluoridation policy:

This review provides reassuring evidence that daily doses of fluoride acquired from drinking-water fluoridated at levels of ca. 1 mg/L have not been demonstrated to cause any significant impairment of bone. Therefore, it appears that, at the 1 mg/L level, adverse effects on bone are not likely to be a risk which needs to be included in a risk benefit analysis.

With respect to adverse effects on bone this review supports the Ministry of Health’s fluoridation policy, and offers no reason why it might need to be modified.

However the cited clinical trials, constituting the best evidence, had a maximal duration of four years only and such studies may not have the power to identify any small, high-risk subgroups. Ongoing follow up of the literature in this area is desirable.

Review 6

Study identification:	Title	Effectiveness of Fluoride in Preventing Caries in Adults
	Authors	S.O. Griffin, E. Regnier, P. M. Griffin and V. Huntley
	Journal	Journal of Dental Research
	Year	2007
	Volume	86(5)
	Pages	410–415
	Journal Impact Factor	3.458
	Review Type	Meta-analysis
	Area	Epidemiology

Summary relevant to water fluoridation in New Zealand:

Adults today are likely to retain their natural teeth longer than those of previous generations. As a result dental caries in adults is becoming an increasingly important health issue. This review concluded that the incidence of coronal caries was less in adults of all ages (≥ 20 years) when their water supply was fluoridated.

A meta-analysis was undertaken using a random effects model. Twenty studies representing 13,551 participants were included in the final body of evidence. Of these studies, nine (7853 participants) considered community water fluoridation (with variable fluoride concentrations). The differences between levels of coronal caries in fluoridated and control populations were significant ($p < 0.001$). In the seven studies that included only lifelong residents of control or fluoridated-water communities (5409 participants), the summary relative risk ratio was 0.65 (95% confidence interval [CI]: 0.49–0.87); this is equivalent to a prevented fraction of 34.6% (95%CI: 12.6%–51.0%), but the dataset was heterogeneous. When only the results of the five fluoridation studies published after 1979 (2530 participants) were pooled, heterogeneity was eliminated and the summary-prevented fraction was 27.2% (95%CI: 19.4%–34.3%).

The effect size¹² for the modes of fluoride delivery among adults was found to be similar to those for children.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
1. Is fluoride effective in preventing coronal cavities in all adults and in older adults (≥ 40 yrs) and in preventing root caries in the older group?	Well covered

¹² Measured by the absolute difference in annual caries increment or relative risk ratio.

2. How effective are the different fluoride delivery modes in preventing caries?

A description of the methodology used is included.

Study inclusion and exclusion criteria were clearly explained. Two reviewers independently reviewed the abstract and title of each record for relevant articles: articles deemed relevant by at least one reviewer were examined.

Well covered

For the meta-analysis a well-documented data abstraction procedure was used, the outcome measure was clearly defined (difference in annual coronial/root caries increment between exposed and not-exposed) and statistical methodology described or included in the appendix.

The literature search is sufficiently rigorous to identify all the relevant studies.

Three electronic databases were searched to locate primary studies and systematic reviews relating to the topical effectiveness of fluoride (i.e. fluoridated water or fluoride-containing toothpaste, gel, varnish or rinse) in preventing or arresting caries among adults.

1. Medline: 1966 to 2004: 1044 records
2. Embase: 1988 to 2004: 56 records
3. Cochrane Control Register of Controlled trials: 148 records.

Two reviewers independently reviewed the abstract and title of each record for relevant articles. Articles deemed relevant by at least one reviewer were examined. 489 articles were examined and screened with a form developed for the review. Also the references from each retrieved article were searched. The authors contacted FDA, ADA and manufacturers for unpublished studies, but none were received. Fifty studies in total were reviewed. Twenty studies representing 13,551 participants were included in the final body of evidence.

Well covered

Exclusion criteria were:

- Mean age of study population < 20
 - Duration of study < 1 yr
 - No non-fluoride control group
 - Insufficient data to calculate effect measure or variance
 - Not all members of treatment group
-

Study quality is assessed and taken into account.

The type of study was determined by using a specific algorithm. Considered study design in inclusion criteria include direction, randomization, drop-out rate, examiner/participant blinding.

Well covered

There are enough similarities between the studies selected to make combining them reasonable.

Heterogeneity was tested for and when found to be present either a summary measure of effect was not reported, or studies were excluded from an early period resulting in a more homogeneous study population. When retested heterogeneity was not present and a summary difference or relative risk was calculated.

Well covered

How well was the study done to minimise bias?

++

If coded as +, or - what is the likely direction in which bias might affect the study results?

n/a

Level of evidence provided by the review:

1 - High quality meta-analyses

Comments:

This paper was reviewed by Parnell et al (2009) [17].

Implications for Ministry of Health's fluoridation policy:

This review's finding, that water fluoridation reduces coronal caries in adults, supports the assertion in the New Zealand Ministry of Health's present water fluoridation policy that the fluoridation of water supplies prevents dental caries. However, it provides no information that could be used to assess whether the fluoride concentration range presently recommended requires modification.

Review 7

Study identification:	Title	Fluoride in water: A UK perspective
	Authors	P.T.C. Harrison
	Journal	Journal of Fluorine Chemistry
	Year	2005
	Volume	126
	Pages	1448–1456
	Journal Impact Factor	1.737
	Review Type	Non-systematic review
	Area	Epidemiology

Summary relevant to water fluoridation in New Zealand:

This review provides an overview of fluoride exposure and absorption before reviewing papers that report on the possible health effects of fluoride. Possible effects that have been studied include:

- dental caries
- fluorosis
- bone health
- cancer
- immunological effects
- effects on reproduction
- birth defects
- renal and gastrointestinal effects
- effects on intelligence,
- goitre

The paper also reviews the potential indirect health effects of water fluoridation:

- toxicity from other substances added to water as part of the fluoridation process
- dietary exposure to toxic metals (e.g. through leaching of metals from pipework and cooking pans) caused by increased fluoride concentrations
- changes in the uptake/bioavailability or toxicity of metals in the gut.

The review concludes that:

- a) fluoride in water makes a significant contribution (ca. 80% for an adult) to the intake of the element.
- b) there is evidence that water fluoridation reduces caries in children, but can result in dental fluorosis possibly due to other sources of fluoride such as fluoridated toothpastes, and it is important to understand an individual's total exposure to fluoride.

- c) there is almost universal agreement that dental caries is related to social class, and much of the research to date concludes that water fluoridation reduces dental caries inequities between high and low social groups.
- d) Other non-dental health effects:
- available evidence indicates no effect on the likelihood of hip fractures
 - there is insufficient evidence to assess the effects of fluoridation on other bone disorders
 - available evidence indicates no influence of water fluoridation on the incidences of cancer in general or of specific types
 - evidence for other effects (noted above) is weak, but the author notes that a Medical Research Council working group recommended that they be kept under review.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	Adequately addressed
The introduction advises that the article focuses on the potential health disadvantages of fluoride.	
<i>A description of the methodology used is included.</i>	Poorly addressed
There was no indication of how published studies were searched for, selected or assessed.	
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	Poorly addressed
See comments above	
<i>Study quality is assessed and taken into account.</i>	
The assessment of study quality is not formerly documented but comments regarding study quality are made throughout this article. For example: "The validity and evidence value of the studies was generally assessed as low"; "Many of the epidemiological studies on fluoride and bone health have assessed risk only in relation to current or recent exposure to fluoridated water"; "However, these studies have used dietary concentrations very much higher than those in the fluoridated drinking-water of humans"	Adequately covered
<i>There are enough similarities between the studies selected to make combining them reasonable</i>	n/a
<i>How well was the study done to minimise bias?</i>	+
<i>If coded as +, or - what is the likely direction in which bias might</i>	Likely elevated risk of adverse health outcomes, due to

affect the study results?

publication bias

Level of evidence provided by the review:

3 - Review with a high risk of bias

Comments:

The author was the chair of the Medical Research Council (UK) Working Group on Water Fluoridation. This group was established to take the conclusions and recommendations of the York Review and consider what further research might be required to improve the evidence base in the area of fluoride and health. A report from the MRC group (2002) is extensively referenced within this paper.

Implications for Ministry of Health's fluoridation policy:

As the review is prone to bias, it has no implications for the Ministry of Health's fluoridation policy. However, it supports the assertion in the present water fluoridation policy that the fluoridation of water supplies prevents dental caries.

Review 8

Study identification:	Title	Infant formula and enamel fluorosis: A systematic review
	Authors	P. Hujoel, L. Zina, S. Moimaz and J. Cunha-Cruz
	Journal	The Journal of the American Dental Association
	Year	2009
	Volume	140
	Pages	841–854
	Journal Impact Factor	1.726
	Review Type	Meta-analysis (random effects)
	Area	Epidemiology

Summary relevant to water fluoridation in New Zealand:

With the increasing prevalence of enamel fluorosis, researchers are placing more emphasis on preventing infants' and children's overexposure to fluoride. As a result, studies are being undertaken to assess the potential for overexposure to fluoride through food and liquid, including infant formula.

This paper reviewed 19 such studies. Of these, 12 assessed the infant formula-fluorosis associated with different fluoride concentrations in the water supply. A meta-regression of these studies showed that as the fluoride in the water supply increased, the reported fluorosis risk associated with infant formula consumption increased significantly. A 1 mg/L increase in fluoride concentration in the water supply increased the odds ratio for fluorosis associated with infant formula by 67% (OR 1.67, 95 percent CI 1.18 -2.36).

Reports from countries in which the fluoride levels in the water are low typically indicate low levels of fluoride in infant formula, and some researchers in these countries have recommended the use of fluoride supplements for infants. Advice about infant formula use is more complex for people living in countries in which higher natural or adjusted fluoride levels in the water supply can increase fluoride concentrations in both the infant formula itself and in the water used to reconstitute it.

The study concluded that ingestion of infant formula may be associated with some level of dental fluorosis in permanent teeth depending on the level of fluoride in the water. There was only weak evidence that fluoride in the infant formula is responsible for the fluorosis.

Evaluation:

Criterion	In this study this criterion is:
<p><i>The study addresses an appropriate and clearly focused question.</i></p> <p>The objective of this report was to search the literature for evidence of the association between infant formula consumption from birth to the age of 24 months, as well as the risk of developing dental fluorosis by comparing children who are fed with formula with children who are fed with breast milk or cow's milk. A secondary aim was to evaluate any available evidence implicating the fluoride in the infant formula as the cause of fluorosis.</p>	Well covered
<p><i>A description of the methodology used is included.</i></p> <p>The paper provided a thorough description of article selection, infant feeding practices, enamel fluorosis outcome, and how the results were synthesised. The latter included a clear description of all assumptions.</p>	Well covered
<p><i>The literature search is sufficiently rigorous to identify all the relevant studies.</i></p> <p>This was particularly well done with a figure showing where the 1,059 potentially relevant studies came from (8 databases and reference list), duplication, if only an abstract was read or the full text, reasons for study drop out, and concluding with 19 studies being included in the analysis. A list of excluded reports is included in the supplementary data. The agreement between two reviewers regarding the appropriateness of abstracted publications for full evaluation was very good (kappa statistic =0.81)</p>	Well covered
<p><i>Study quality is assessed and taken into account.</i></p> <p>The authors clearly described how they classified studies, abstracted the number and type of confounders adjusted for. Two independent reviewers performed a detailed quality assessment of studies using a modification of the Newcastle-Ottawa scale. A summary table provided a detailed assessment of the study quality. Commonly identified weaknesses were: the potential for recall bias; lack of blinding; high non-response; no adjustment for socioeconomic status; and the use of fluoridated products such as toothpaste.</p>	Well covered
<p><i>There are enough similarities between the studies selected to make combining them reasonable'</i></p> <p>Heterogeneity was tested for and reported ($I^2 = 0.66$, $p < 0.0001$) by the authors. As a result it was advised that the summary OR of 1.8 (95 % CI 1.4- 2.3) be interpreted with caution</p>	Well covered

How well was the study done to minimise bias?

+

If coded as +, or - what is the likely direction in which bias might affect the study results?

Elevated risk of fluorosis due to infant formula feeding, as a result of publication bias.

Level of evidence provided by the review:

1 - High quality meta-analysis

Comments:

A full exploration of publication bias was performed. The authors concluded that publication bias was likely to be present and to have inflated the estimated summary measure of the fluorosis risk.

Implications for Ministry of Health's fluoridation policy:

The review concludes that as the fluoride concentration in a water supply is increased, the reported enamel fluorosis risk associated with infant formula consumption increases significantly. On this basis, for New Zealand waters, a large portion of which have low levels of naturally-occurring fluoride, the addition of fluoride at a concentration near the upper range recommended by the Ministry of Health's policy, will result in a substantially increased likelihood of the development of fluorosis in permanent teeth, compared with that of a non-fluoridated water supply.

The evidence for fluoride in the infant formula being responsible for the fluorosis is weak, more over very few of the studies included information about the fluoride content of the infant formula used, and this may differ from that used in New Zealand. For these reasons, caution is required in making modifications to the Ministry's fluoridation policy in the absence of other findings.

Depending on the results of studies undertaken to clarify the risk factors in the New Zealand context, consideration may need to be given to providing advice to mothers on the fluoride levels in infant formula, bottled water and their community water supply.

Review 9

Study identification:	Title	Is Water Fluoridation Still Necessary?
	Authors	J.V Kumar
	Journal	Advances in Dental Research
	Year	2008
	Volume	20(1)
	Pages	8-12
	Journal Impact Factor	3.458
	Review Type	Symposium Paper/ Expert opinion
	Area	Epidemiology/Oral and Public Health

Summary relevant to water fluoridation in New Zealand:

This review addresses the question: Is community targeted water fluoridation still an important tool for reducing dental caries within the population? This is a relevant question due to the international trend of dental caries reduction in both fluoridated and non-fluoridated communities and the magnitude of this variation becoming smaller between fluoridated and non-fluoridated communities.

Community water fluoridation continues to be an efficient method of delivery and ensures frequent low levels of fluoride are available in the saliva. It has high reach and low cost. Other sources of fluoride, such as toothpaste and chair-side application, complement water fluoridation.

While the benefit of water fluoridation is traditionally measured as incidences of dental caries averted, there are a number of intangible benefits which should also be considered. There is the general impression that the progression of dental caries is delayed which allows more time to undertake restorative care compared with 50 years ago. The disease is also less complex to treat in children, with the majority of carious lesions being confined to pits and fissures.

The diffusion or halo effect (those in non-fluoridated areas receiving fluoride through beverages and food processed in fluoridated areas) is also given as an explanation for the decrease in the differential of caries reduction between fluoridated and non-fluoridated communities. Water fluoridation continues to be the most cost effective way of averting tooth decay in children and continues to reduce disparities in deprived communities.

The mechanism of action of fluoride on dental enamel is post-eruptive. The extent to which water fluoridation contributes to the post-eruptive mechanism continues to be debated, but there is some evidence for fluoride in water providing post-eruptive as well as pre-eruptive protection. Enamel fluorosis continues to be the only acknowledged risk associated with water fluoridation.

The review concludes that fluoridation is still the best tool for addressing caries in many countries. No alternative strategy for preventing caries across all social strata in a population has been identified. Measuring the effectiveness of interventions to prevent caries is difficult because of the complex set of risk factors that influence the disease. A key research aim, for each country, is to

identify the optimum level to which drinking-water should be fluoridated to provide the balance between adequate control of caries and enamel fluorosis.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	Well covered
Is water fluoridation still relevant?	
<i>A description of the methodology used is included.</i>	Not addressed
This was a paper of relevant reviews. The inclusion/exclusion criteria were not mentioned.	
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	Not addressed
The methodology was not detailed in the paper	
<i>Study quality is assessed and taken into account.</i>	
The author acknowledges that the reviewed papers and reports are based on observational study designs. Although these are considered to be "lower quality" study designs the sheer volume and weight of the evidence from diverse populations provides convincing evidence about the effectiveness of water fluoridation	Well covered
<i>There are enough similarities between the studies selected to make combining them reasonable.</i>	n/a
<i>How well was the study done to minimise bias?</i>	Uncertain
<i>If coded as +, or - what is the likely direction in which bias might affect the study results?</i>	Uncertain

Level of evidence provided by the review:

This review cannot be assessed by the level of evidence scale used for systematic reviews. However, as the author has acknowledged the consistency of the existing evidence base it does provide a moderately high level of evidence.

Comments:

This paper has successfully assembled the key elements from several sentinel international reviews and reports, and summarises the key benefits and only risk of community-based water fluoridation programmes. It is a useful review paper.

Implications for Ministry of Health's fluoridation policy:

The review supports water fluoridation as a strategy for preventing dental caries, and consequently supports the Ministry of Health's fluoridation policy. It offers no quantitative guidance on the levels of fluoride in water that are optimum for maintaining oral health which could be used as the basis of modifying the Ministry's recommended fluoride concentration range. However, it acknowledges the need for further research to determine optimum fluoridation levels, which in may lead to the need to modify the fluoridation range contained in the Ministry's policy.

Review 10

Study identification:	Title	An update on fluorides and fluorosis
	Authors	S.M Levy
	Journal	Journal of Canadian Dental Association
	Year	2003
	Volume	69(5)
	Pages	286–291
	Journal Impact Factor	0.96
	Review Type	Expert opinion
	Area	Oral and Public Health/Epidemiology

Summary relevant to water fluoridation in New Zealand:

Water fluoridation remains the most equitable and efficient means of delivering fluoride to the population. However, in some countries a decrease in the prevalence of dental caries has been accompanied by an increase in dental fluorosis. Evidence to date from New Zealand shows no increase in fluorosis (see Section 1.3).

Fluoride intake between the ages of 15–30 months is believed to be the most critical for the development of dental fluorosis of the upper anterior incisors which have the largest impact on dental aesthetics, but intake at other ages can also be a concern. The dental profession decided that mild fluorosis was an acceptable trade-off for a substantial reduction in caries, but this decision now needs reconsideration given the growing focus by consumers on dental aesthetics.

The risk factors for fluorosis that have been identified are:

- fluoridated water
- infant formula reconstituted with fluoridated water
- fluoridated supplements
- fluoridated dentifrice.

The true determinant of risk is the total fluoride intake, but this is difficult to quantify. The optimum fluoride intake is uncertain. While a level of 0.05–0.07 mg/kg is often thought of as “optimal”, fluorosis has been reported at lower intakes.

In North America, at least, there is growing focus on risk assessment and the individualisation of fluoridation strategies.

The paper concludes that fluoridated water and toothpaste are the primary means by which fluoride can be delivered to the whole community. It recommends that fluoride supplementation be prescribed on a case-by-case basis where the whole of the patient’s exposure to fluoride is assessed, that is, fluoridated drinking-water or non-fluoridated, types of toothpaste and other consumer and dietary products to which the individual may be exposed.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
This criterion is inapplicable as the paper is an “update”. However, there is a question implied in the statement: “With aesthetics becoming more important than ever, decisions concerning this trade-off could warrant further reconsideration”. There is no conclusion at the end of this update indicating whether this area should be further explored.	n/a
<i>A description of the methodology used is included.</i>	
This was an expert opinion which also highlighted recent CDA recommendations as well as a longitudinal study in Iowa that may significantly add to the body of evidence.	n/a
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	
The methodology was not detailed in the paper.	n/a
<i>Study quality is assessed and taken into account.</i>	
The two papers reported on do seem appropriate. One is a longitudinal cohort study, the other a CDC recommendation document.	Well covered
<i>There are enough similarities between the studies selected to make combining them reasonable.</i>	
The conclusions drawn seem to be appropriate.	Well covered
<i>How well was the study done to minimise bias?</i>	+
<i>If coded as +, or - what is the likely direction in which bias might affect the study results?</i>	Uncertain

Level of evidence provided by the review:

This review cannot be assessed by the level of evidence scale used for systematic reviews.

The conclusions drawn are still relevant in 2011 and align well with contemporary thinking. This would indicate that this expert opinion provides a moderately strong level of evidence.

Comments:**Implications for Ministry of Health’s fluoridation policy:**

Dental fluorosis is the only known risk that is associated with drinking optimally fluoridated drinking-water in combination with other sources of fluoride either from toothpaste or dietary sources. Individuals, particularly parents of infants, need to be aware of their sources of fluoride intake and the concentrations of fluoride in these sources.

In any revision of the Ministry of Health’s fluoridation policy, it would be prudent to consider extending the policy beyond guidance on the levels of fluoride in water to actions that assist individuals in assessing what their fluoride intake is and understanding how they should control their exposure to fluoride.

There needs to be a strong message that “very mild/ mild” dental fluorosis is of no structural concern to the tooth but that there is the potential for a very minor cosmetic impact. “Moderate” and “severe” fluorosis, which cause severe structural and aesthetic problems, are caused by uncontrolled fluoride intake from waters with high naturally-occurring levels of fluoride. Such fluoride levels do not occur in New Zealand waters.

Review 11

Study identification:	Title	A Systematic Review of Public Water Fluoridation 2000 (The York Report)
	Authors	M McDonagh, P Whiting, M Bradley, J Cooper, A Sutton, I Chestnutt, K Misso, P Wilson, E Treasure, J Kleijnen
	Published by	NHS Centre for Reviews and Dissemination, University of York
	Year	2000
	Volume	
	Pages	
	Journal Impact Factor	
	Review Type	Meta-analysis and systematic review
	Area	Epidemiology

Summary relevant to water fluoridation in New Zealand:

This review was commissioned by the Chief Medical Officer of the UK Department of Health to 'carry out an up to date expert scientific review of fluoride and health'. The review agreed upon was one human epidemiological studies of water fluoridation.

The impact of fluoridation of drinking-water supplies depends on a number of major issues: the potential benefits (including improved dental health and reductions in dental health inequalities); the potential benefits over and above that offered by the use of alternative interventions and strategies (eg, fluoridated toothpaste); and the potential harms (including dental fluorosis, bone fractures and bone development problems, genetic mutations, birth defects, cancer and hypersensitivity).

The report identified five objectives. The conclusions reached for each are set out below.

Objective 1: *What are the effects of fluoridation of drinking-water supplies on the incidence of caries?*

Results suggest that fluoridation of drinking-water supplies does reduce caries prevalence, both as measured by the proportion of children who are caries free and by the mean change in the dmft/DMFT¹³ score. However, the degree to which caries is reduced could not be determined from the available data. The range of the mean difference in the proportion (%) of caries-free children is - 5.0 to 64%, with a median of 14.6% (interquartile range 5.05, 22.1%). The study quality was moderate. Main concerns about the 26 studies included the lack of adjustment for confounding factors and lack of a measure of variance for the estimates of decay.

¹³ An index for assessing the extent of caries. D-ecayed, M-issing, F-illed, T-eeth (or sometimes S-urfaces). Lower case refers to primary teeth and upper case to secondary teeth.

Objective 2: *If water fluoridation is shown to have beneficial effects, what is the effect over and above that offered by the use of alternative interventions and strategies?*

The objective assesses the impact of water fluoridation on caries prevention after the advent of other sources of fluoride, especially toothpaste. The results from nine studies (post-1974) were considered, but provision of a firm answer to the question was compromised by the quality of the studies. A beneficial effect of water fluoridation over and above that of fluoridated toothpaste (and other sources of fluoride) was found, but its extent could not be determined.

Objective 3: *Does water fluoridation result in a reduction of caries across social groups and between geographical locations, bringing equity?*

The small number of studies, differences between these studies, and their low quality rating, signal a need for caution in interpreting these results. There appears to be some evidence that water fluoridation reduces the inequalities in dental health across social classes in five and 12 year-old children, using the dmft/DMFT measure. This effect was not seen in the proportion of caries-free children among five year-olds. There were insufficient data for the effects in children of other ages to be investigated fully.

Objective 4: *Does water fluoridation have negative effects?*

Dental fluorosis was the most widely and frequently studied of all negative effects and is the only one considered in this summary (refer to the review by Harrison [7] which provides a summary of findings with regard to other adverse effects).

Although 88 studies of fluorosis were included, they were of low quality. Efforts to control for the effects of potential confounding factors, or reducing potential observer bias were uncommon. A significant dose-response relationship between the level of water fluoridation and fluorosis was identified through a regression analysis. At a water fluoride concentration of 1.0 mg/L the prevalence of any fluorosis was estimated to be 48% (95% confidence interval (CI) 40–57) and for fluorosis sufficient to be of aesthetic concern the prevalence was estimated to be 12.5% (95% CI 7.0–21.5).

Objective 5: *Are there differences in the effects of natural and artificial water fluoridation?*

Insufficient evidence did not allow a conclusion to be drawn concerning this objective.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
Overall, the aim was to assess the evidence on the positive and negative effects of population-wide drinking-water fluoridation strategies to prevent caries. To achieve this aim five objectives were identified as noted above	Well covered

A description of the methodology used is included.

The methodology is clearly and fully outlined and includes the search strategy, inclusion criteria (both general and objective specific), data extraction, assessment of study validity and data analysis.

Where the data were in a suitable format, measures of effect and their 95% CIs for the major outcomes identified were shown as forest plots. For example, in objective 1 the measure of effect used in the main analysis was the difference of the change in caries from the baseline to the final examination in the fluoridated area compared with the control area. Where the data were available a random effects meta-analysis was performed to produce a pooled estimate of the measure of effect. Heterogeneity was assessed and where possible meta-regression was used to investigate and explain the source of heterogeneity among studies. Publication bias was discussed.

Well covered

The literature search is sufficiently rigorous to identify all the relevant studies.

A preliminary search was undertaken to provide information on available reviews of fluoridation and to estimate the size of the research evidence on the effects of fluoridation of drinking-water. The search strategy is given in an appendix. The full search included 25 specialist databases, from their starting dates until June/October 1999. Other searching included a world wide web search, hand-searching of Index Medicus and Excerpta Medica, advisory panel and seeking of articles from individuals and organizations through the York website. Update searches were undertaken in February 2000 of Medline, Embase, Toxline and Current contents electronic databases. Two hundred and fourteen studies met full inclusion criteria for one or more of the objectives.

Well covered

Study quality is assessed and taken into account.

Study validity was formally assessed using a checklist modified to address issues of water fluoridation. The checklist was based on that contained in the NHS Centre for Reviews and Dissemination Report 4. Separate checklists were devised for studies using a case-control design and for all other study types combined. Checklists were available in the appendix.

Each study was assigned two scores:

Well covered

- (1) a "level of evidence" score (levels A, B and C) based on study design, adjustment for confounding and measurement bias; and
 - (2) a "validity" score (max of 9 for case-control studies, max of 8 for all others) based on the number of checks achieved on the checklist.
-

The “level of evidence” (A, B or C) was used to classify studies for inclusion criteria based on an overall quality and chance for bias. The validity assessment checklist was more specific to water fluoridation studies

Study validity was assessed independently by two reviewers, with disagreements resolved through consensus.

The study designs used included 45 ‘before and after’ studies, 102 cross-sectional studies, 47 ecological studies, 13 cohort (prospective or retrospective) studies and 7 case-control studies.

There are enough similarities between the studies selected to make combining them reasonable

Heterogeneity was assessed by visual examination of the forest plots and statistically using the Q-statistic. If heterogeneity was found, pooled estimates were still calculated, but the results were advised to be interpreted with caution. Where possible meta-regression was used to investigate and explain the source of heterogeneity among studies.

Adequately covered

How well was the study done to minimise bias?

++

If coded as +, or - what is the likely direction in which bias might affect the study results?

n/a

Level of evidence provided by the review:

1 - High quality meta-analysis/systematic review with a very low risk of bias

Comments:

The York Report is reviewed by other reviews contained in this report.

Implications for Ministry of Health’s fluoridation policy:

The limited conclusions that were reached by this review support the use of water fluoridation as a means of reducing caries, and perhaps support its use for redressing social inequities. However, evidence also shows that water fluoridation is linked to an increased prevalence of dental fluorosis. It provides no information on which to base any recommendations for changes to the range of fluoride concentrations recommended by the Ministry of Health’s fluoridation policy.

Review 12

Study identification:	Title	Promoting Oral Health: Interventions for Preventing Dental Caries, Oral and Pharyngeal Cancers, and Sports-Related Craniofacial Injuries. A Report on Recommendations of the Task Force on Community Preventive Services
	Authors	Centers for Disease Control
	Journal	Morbidity and mortality weekly report (MMWR)
	Year	2001
	Volume	50(RR-21)
	Pages	1–13
	Journal Impact Factor	
	Review Type	Systematic review
	Area	Oral and Public Health/Epidemiology

Summary relevant to water fluoridation in New Zealand:

This report, prepared by the Task Force on Community Preventive Services, contains systematic reviews of the evidence of selected population-based interventions to prevent and control dental caries and other diseases and injuries affecting the head and neck.

These reviews are to be used to link the evidence with recommendations in the “Community Guide”, a resource supported by the CDC and US Department of Health and Human Services.

In the United States, dental caries on smooth surfaces has decreased significantly over the decades and now 90% of dental caries in children’s permanent teeth is found in pits and fissures.

With respect to water fluoridation, the intervention was described as: “adding (or removing), monitoring, and adjusting fluoride in water supplies to reach optimal fluoride concentrations in community drinking-water. Situations where ongoing water fluoridation was stopped were also reviewed”.

The report’s key findings are:

- a) starting or continuing water fluoridation effectively prevents dental caries
- b) stopping water fluoridation is associated with an increase in dental caries in some communities.

The task force strongly recommends that community water fluoridation continues, to prevent and control dental caries.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
This report specifically looks at the effectiveness of multiple interventions. One of these was the question of whether water fluoridation is an effective intervention.	Well covered
<i>A description of the methodology used is included.</i>	
To be included, a study had to:	
a) involve a primary investigation of an intervention selected for evaluation	
b) be published in English on or before 31 December 2000	Well covered
c) be conducted in established market economies	
d) compare outcomes among groups or persons not exposed or less exposed to the intervention with those exposed to the intervention.	
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	
A systematic search of Medline yielded 4000 journal article citations that may have been relevant. 130 met the inclusion criteria, of which 94 were excluded because of limitations in their execution of design.	Well covered
36 studies were considered to qualify for the review.	
<i>Study quality is assessed and taken into account.</i>	
Studies that met the inclusion criteria also had to meet quality criteria. Each study was evaluated and assessed for suitability of the study design and threats on validity.	Well covered
<i>There are enough similarities between the studies selected to make combining them reasonable.</i>	n/a
<i>How well was the study done to minimise bias?</i>	++
<i>If coded as +, or - what is the likely direction in which bias might affect the study results?</i>	
Level of evidence provided by the review:	
1 - High quality systematic review with a very low risk of bias.	

Comments:

The report's sole interest is the effectiveness of fluoridation as an intervention to prevent caries. It takes no account of potential adverse effects, such as fluorosis, in its assessment.

Implications for Ministry of Health's fluoridation policy:

While this report is 10 years old, it offers a high degree of support for the Ministry of Health's policy of encouraging the fluoridation of water, although it provides no guidance as to the optimum concentration of fluoride necessary for the intervention.

Review 13

Study identification:	Title	A Systematic Review of the Efficiency and Safety of Fluoridation
	Authors	National Health and Medical Research Council (NHMRC) Australia
	Journal	
	Year	2007
	Volume	
	Pages	
	Journal Impact Factor	
	Review Type	Systematic review
	Area	Epidemiology/Oral and Public Health

Summary relevant to water fluoridation in New Zealand:

This review asked a number of research questions in relation to a range of interventions using fluoride. The review's aim was to further build upon the existing body of evidence that suggests that water fluoridation is beneficial in reducing dental caries.

The York Report's [11] systematic review in 2000 showed that the introduction of fluoridated drinking-water into an area significantly increased the proportion of children who were caries-free and decreased the severity of the dental decay when compared to non-fluoridated areas over the same time period. This review found only one other additional original study for inclusion and it did not change the conclusion of the York Report.

This review also:

- a) confirmed the known risk of dental fluorosis from drinking fluoridated water.
- b) concurred with three existing systematic reviews that optimally fluoridated drinking-water aimed at reducing dental caries has little effect on fracture risk – either protective or deleterious.
- c) looked at the existing systematic reviews with respect to water fluoridation increasing cancer risk, specifically osteosarcoma – the evidence about cancer mortality and incidence is mixed, with small variations on either side of the effect.

This review identified four additional studies that investigated this relationship. In particular a study by Bassin et al, (2006)¹⁴ suggested an increase in rate of osteosarcoma in young males with water fluoridation. However, further communication from Bassin's co-investigators warn that these findings could not be replicated in the broader study of which the original study was only part.

¹⁴ Bassin, E. B., Wypij, D., Davis, R. B., & Mittleman, M. A. 2006, "Age-specific fluoride exposure in drinking-water and osteosarcoma (United States)", *Cancer Causes and Control*, 17(4), 421-428.

- d) examined the literature to assess whether water fluoridation was associated with other adverse effects and concluded that there was insufficient evidence to reach a conclusion.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
1. Is intentional water fluoridation more efficacious than no water fluoridation in the prevention of dental caries?	Well covered
2. Does intentional water fluoridation result in dental fluorosis over and above no intentional water fluoridation?	
3. Does intentional water fluoridation result in fracture over and above no intentional water fluoridation?	
4. Does intentional water fluoridation increase the risk of cancer over and above no intentional water fluoridation?	
5. Is intentional water fluoridation associated with other adverse effects over and above no intentional water fluoridation?	
<i>A description of the methodology used is included.</i>	
The review provides an in-depth explanation of the methodology used to develop the research questions, undertake the literature search, synthesise the evidence, extract the data and identify and deal with methodological issues.	Well covered
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	
A literature search was undertaken using MEDLINE, EMBASE as well as the Cochrane Systematic Review and Clinical Trial databases. Due to the availability of recent systematic reviews, searches were limited to publications from 1996 onwards. Searches were also limited to English.	Well covered
5418 citations were identified and after applying exclusion criteria this number was reduced to 408. Following review of the full papers, 77 citations were included in this review.	
With respect to water fluoridation 21 of the 77 were relevant.	
<i>Study quality is assessed and taken into account.</i>	
Where possible, the effect of fluoride on dental caries was assessed using only comparative longitudinal studies in which fluoridation was either introduced or withdrawn in one	Well covered

treatment group.

There are enough similarities between the studies selected to make combining them reasonable.

Well covered

The study inclusion criteria are consistent with those used in the York Report which allows comparisons to be made.

How well was the study done to minimise bias?

++

If coded as +, or - what is the likely direction in which bias might affect the study results?

n/a

Level of evidence provided by the review:

1 - High quality meta-analysis/systematic review with a very low risk of bias

Comments:

Implications for Ministry of Health's fluoridation policy:

As the authors pointed out, this review builds on the existing body of evidence and further strengthens and/or clarifies issues and concerns raised in previous systematic reviews. The York Report is now 11 years old, and, as the NHMRC review shows, there is new research continuing to add to the body of evidence.

This review undertakes to strengthen support for the safety and efficacy of water fluoridation, and thereby supports the Ministry of Health's fluoridation policy. However, its conclusions are too broad to offer guidance on the optimum range for the fluoride concentration in water.

Review 14

Study identification:	Title	Fluoride in Drinking Water. A scientific review of EPA's Standards.
	Authors	Committee on Fluoride in Drinking Water; National Research Council of the National Academies
		National Academies Press: Washington DC.
	Year	2006
	Volume	
	Pages	1–12 (Executive Summary)
	Journal Impact Factor	-
	Review Type	Scientific Review (Summary)
	Area	Toxicology

Summary relevant to water fluoridation in New Zealand:

As noted in Section 2.1, only of the executive summary of this book has been reviewed at this point.

This review did not include an examination of the benefits and adverse effects that might arise at drinking-water fluoride levels of 0.7–1.0 mg/L, and is therefore of limited value in assessing the effects of current fluoridation practices in New Zealand. Nevertheless, key findings of the review are noted in this section.

At levels of 2 mg/L in drinking-water, fewer than 15% of children are predicted to experience moderate enamel fluorosis of aesthetic concern (ie, discoloration of the front teeth). However, the degree to which this might also create an adverse psychological effect also needs to be considered.

At levels of 4 mg/L in drinking-water, fluoride would put children at risk of developing severe enamel fluorosis (causing loss of the enamel protective function), and may also increase the risk of bone fractures.

Models predict drinking-water fluoride concentrations between 2–4 mg/L could, over a lifetime, result in fluoride concentrations in bone sufficient to be associated with bone fluorosis. However this is not highly predictive of individual risk, due to wide variations in bone deposition rates and susceptibility to skeletal fluorosis.

The “best available” study suggested an increased rate of hip fracture in populations exposed to fluoride in drinking-water concentrations above 1.5 mg/L; however this gives little information regarding the risk (if any) at 1.5 mg/L specifically.

Some case reports (and experimental studies) indicate that at greater than 4 mg/L, fluoride in drinking-water irritate the gut, can affect renal tissues and function, and can alter hepatic and immunological parameters. However, such effects are unlikely to be a risk for the average person exposed to 4 mg/L; though certain individuals, including those with renal impairment, are potentially more susceptible.

Regarding adverse reproductive and developmental effects, a relatively large number of animal studies published since 1993 suggest that such outcomes occur only at very high fluoride intakes that are unlikely to be encountered by U.S. populations at prevailing concentrations of fluoride in drinking-water (ie, those up to at least 4 mg/L).

Some adverse endocrine effects associated with fluoride intakes can occur when fluoride concentrations in drinking-water are 4 mg/L or less, particularly in young children or people with high water intakes. However, many of these effects are subclinical (although recent work suggests that these might be associated with an increased likelihood of developing adverse effects in the long term).

On the basis of data from all the various studies, the evidence for the potential of fluoride to initiate or promote cancers, particularly of the bone, is “tentative and mixed”.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
The executive summary does not focus on a specific question, but addresses a wide range of issues, concentrating most on risks of adverse human health effects as a function of fluoride levels in drinking-water; specifically levels of ≥ 4 mg/L, and levels of 2–4 mg/L.	n/a
<i>A description of the methodology used is included.</i>	
The executive summary contains no detailed description of methodology given rather it refers to “a large body of research... generated since the early 1990s”, and the “collective evidence from <i>in vitro</i> assays, animal research, human studies, and mechanistic information”.	Not addressed
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	Not addressed
<i>Study quality is assessed and taken into account.</i>	
There is no evidence in the executive summary that study quality was taken into account.	Not addressed
<i>There are enough similarities between the studies selected to make combining them reasonable.</i>	n/a
<i>How well was the study done to minimise bias?</i>	n/a
<i>If coded as +, or - what is the likely direction in which bias might affect the study results?</i>	n/a

Level of evidence provided by the review:

The level of evidence is relatively high, given the institution involved and the large body of research reviewed, including the full range of relevant types of study (human epidemiological, human case

reports, animal studies, and in vitro studies).

Comments:

The conclusions drawn from the evidence provided are reasonable. However this review focuses on water concentrations higher than the target range for water fluoridation in New Zealand; that is, it concentrates on levels ≥ 2 mg/L and particularly those ≥ 4 mg/L; higher than the target range for fluoridation of drinking-water.

The absence of some potential adverse effects at 4 mg/L or between 2–4 mg/L means these effects will also be absent at drinking-water fluoride concentrations of 0.7–1.0 mg/L. However the presence of other effects at 4 mg/L or 2–4 mg/L does not necessarily indicate they continue to be a potential concern in the 0.7–1.0 mg/L concentration range.

Implications for Ministry of Health’s fluoridation policy:

This review does not include an examination of any risks that might occur at drinking-water fluoride concentrations of 0.7–1.0 mg/L. However to the extent that adverse effects have not been found (or are not predicted to occur) at drinking-water levels of 2 mg/L or 2–4 mg/L, considerable reassurance can be taken regarding levels of 0.7–1.0 mg/L.

On the other hand, given the effects that have been found or are predicted as possible, at least in some individuals at 4 mg/L, or even between 2–4 mg/L, care needs to be taken that levels of fluoridation are easily maintainable between a chosen target range, which certainly should be less than 2 mg/L. This is particularly so for certain at risk groups, including young children, whose inexpert use of (especially high fluoride content) dentifrices can result in comparatively high fluoride intake from other sources.

Some uncertainties remain regarding the risks of some potential effects as a function of drinking-water fluoride levels, so that ongoing appraisal of new research is required.

Review 15

Study identification:	Title	What we know and do not know about fluoride
	Authors	E Newbrun
	Journal	Journal of Public Health Dentistry
	Year	2010
	Volume	70
	Pages	227–233
	Journal Impact Factor	0.961
	Review Type	Review of selected issues
	Area	General

Summary relevant to water fluoridation in New Zealand:

The specific impact of water fluoridation per se on dental benefit and risk is now more difficult to evaluate in systematic comparative epidemiological studies, because of the increased contribution to total intake of other sources of fluoride (e.g. as in dentifrices). This difficulty is partly because the degree of exposure at the individual level to these latter sources is more difficult to quantify than that derived from drinking-water (in which fluoride levels are more readily estimated, as are ingested amounts of fluoride).

The differences in caries rates between fluoridated and non-fluoridated areas are now smaller than previously, because of the widespread use of fluoride dentifrices (and likely also the consumption of foods and beverages manufactured in optimally fluoridated areas by residents in non-fluoridated areas, the so-called “diffusion effect”).

However, “optimally” fluoridated communities still consistently have lower caries rates.

While the randomised, controlled, double-blind clinical trial is the gold standard for clarifying the optimal level of fluoride in drinking-water in terms of controlling dental caries while also minimising risks of enamel fluorosis, these involve considerable time, cost and difficulty. Therefore there is a need for other long term, ongoing prospective investigations including those into the effects of total fluoride exposure from all sources.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
The article discusses a number of specific questions or issues (most relatively briefly) including:	Adequately addressed
1) What is the effect of discontinuing fluoride in drinking-	

water?

2) What is the prevalence of fluorosis (and is it just a cosmetic problem?)

3) What is the efficacy of low fluoride dentifrices in terms of caries protection and enamel fluorosis reduction?

4) What is the role of socioeconomic factors?

A description of the methodology used is included.

There is no information that allows a specific search strategy to be identified, nor can it be determined how comprehensive and representative the cited studies were with respect to the entire, relevant peer-reviewed literature.

Poorly addressed

The literature search is sufficiently rigorous to identify all the relevant studies.

As the literature search method was not described in any detail, it is not readily possible to assess its rigour and comprehensiveness. However it is likely it was reasonably thorough and representative, as “negative” as well as “positive” studies were discussed.

Adequately addressed

Study quality is assessed and taken into account.

The quality of the studies is not addressed, but this is not unexpected given the nature of the review.

Not addressed

There are enough similarities between the studies selected to make combining them reasonable

n/a

How well was the study done to minimise bias?

n/a

If coded as +, or - what is the likely direction in which bias might affect the study results?

n/a

Level of evidence provided by the review:

This review cannot be placed into one of the epidemiological study categories. However, it is a thorough review, providing relatively high quality data to help inform the debate regarding the risk benefit balance of water fluoridation. The evidence is insufficient to answer all the questions addressed.

Comments:

This is a general commentary on the author’s perceptions of the major controversies and sticking points with respect to the risk benefit evaluation of fluoridated drinking-water, in the wider context of the variability of population exposure to other sources of fluoride.

The search strategy used cannot be determined, and nor is it possible to assess how comprehensive and representative the cited studies were with respect to the entire, relevant peer-reviewed literature. However, overall it is a fair-minded review, which is unable to unequivocally answer all the questions it poses.

Implications for Ministry of Health’s fluoridation policy:

The increased contribution of sources of fluoride other than fluoridated drinking-water to the total intake of fluoride is making identification of the specific impact of water fluoridation *per se* on oral health difficult to assess.

Largely for the same reasons, the differences in caries rates between fluoridated and non-fluoridated areas are now smaller than previously, although, “optimally” fluoridated communities still consistently reported to have lower caries rates. Thus, despite difficulties in conducting epidemiological evaluations, there is ongoing evidence that fluoridation can be justified from a dental risk-benefit point of view.

This review shows that a more precise “definition” of the optimum level of fluoride in drinking-water is needed. This definition should account for maximising caries prevention while minimising the risk of significant dental fluorosis and include other sources of fluoride exposure, is needed. This is necessary before any adjustments to the target fluoride range stated in the Ministry of Health’s fluoridation policy are made.

Significant medical impacts (beyond dental fluorosis), such as skeletal fluorosis, are very unlikely at the “optimum” fluoride level.

Review 16

Study identification:	Title	Public Health: Ethical Issues
	Authors	Nuffield Council on Bioethics
	Journal	
	Year	2007
	Volume	
	Pages	
	Journal Impact Factor	
	Review Type	Qualitative review
	Area	Ethical considerations in relation to water fluoridation

Summary relevant to water fluoridation in New Zealand:

The best available evidence suggests that fluoridation is beneficial, although the evidence on the extent of benefits and harms is weak overall, particularly in the context of the current historically low levels of caries in the population.

The report considers three principles that might justify fluoridation.

- Reducing risks of ill health
- Protecting the vulnerable
- Reducing inequalities.

Three principles that are referred to by those opposing fluoridation are also considered.

- Not coercing people to live health lives
- Respecting important personal values
- Requiring consent.

The report rejects the view that, on the basis of arguments about interference in personal life and coercion of ordinary adults, fluoridation of water should be prohibited outright. Instead, the acceptability of any policy involving the water supply should be considered in relation to:

- the balance of risks and benefits anticipated in a given community
- the potential of alternatives
- the role of consent where there are potential harms.

The council suggests adopting decision-making procedures at the local and regional, rather than the national, level that take into account the context in each area in which a decision is to be taken.

Additionally, a procedural justice approach involving the public (eg, conventional democratic procedures) should be undertaken because of the complexity of the science associated with fluoridation. The public and policy makers need to have access to clear and accurate information, and uncertainties and the strengths and weakness of the evidence should be explicitly recognised.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
Two clearly focused questions were identified.	
(a) What is the justification for overriding the preferences of those people who wish to receive water that has not been fluoridated?	Well addressed
(b) Is the intervention justifiable even if it is not possible (or feasible) to obtain individual consent?	
<i>A description of the methodology used is included.</i>	
No methodology reported.	Not addressed
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	
<i>Study quality is assessed and taken into account.</i>	
<i>There are enough similarities between the studies selected to make combining them reasonable</i>	
<i>How well was the study done to minimise bias?</i>	
<i>If coded as +, or – what is the likely direction in which bias might affect the study results?</i>	
Level of evidence provided by the review:	
High quality	

Comments:

The review was not a meta-analysis.

A ‘method of working’ in Appendix 1 outlined an expert working party, workshops and fact-finding meetings that were held along with consultation with the public on the report findings. Additionally, an ethical framework was developed to provide a coherent approach to the difficult issues raised by public health policies, called the ‘Stewardship Model’. Even though there was no methodology reported in how the literature was sourced, The Nuffield Council on Bioethics that conducted this report is a well respected independent body that identifies, examines and reports on ethical questions raised by advances in biological and medical research. The council has published major reports on a range of topics, and the level of evidence is considered to be of high quality.

Implications for Ministry of Health's fluoridation policy:

In New Zealand, local authorities have authority to decide whether their water supplies should be fluoridated. This concurs with the Nuffield Council on Bioethics recommendations. The council states that the factors that should be taken into account when reaching a decision concerning the fluoridation of water supplies include risk-benefit considerations and the appropriateness of alternative approaches to achieving improved oral health. This implies that there may be some situations in which water fluoridation may not be the optimum approach to protecting public health. This conclusion is, to some degree, at odds with the Ministry of Health's fluoridation policy which aims to ensure fluoridation of all reticulated water supplies. To follow the conclusions reached by the council, the Ministry would need to modify its policy to one which identified the factors that need to be considered in deciding on the fluoridation of a water supply. These might include the extent to which the community can be provided with other sources of fluoride (such as fluoridated toothpaste), and the difficulties in implementing other fluoride sources so that adverse effects are minimised.

The Nuffield Council on Bioethics report concludes that the evidence base supporting fluoridation is not strong, because many studies have not been of high quality, and it consequently recommends the need for further monitoring and research, especially on the risks of fluoridation.

If the Ministry of Health, in New Zealand, were to consider a more flexible water fluoridation policy that acknowledged that in some circumstances water fluoridation needed to be augmented, or replaced, by other methods of insuring an adequate intake of fluoride, there would be a need for research to understand:

- the levels of caries and fluorosis in communities, the trends in these levels and the reasons for the trends
- the extent to which different sources contribute to the total intake of fluoride in communities, and the ease with which these could be managed to ensure the best oral health outcomes.

These would be high priority to provide the evidence needed for policy modification.

Review 17

Study identification:	Title	Water fluoridation
	Authors	C. Parnell, H. Whelton, D. O'Mullane
	Journal	European Archives of Paediatric Dentistry
	Year	2009
	Volume	10(3)
	Pages	141–149
	Journal Impact Factor	-
	Review Type	Summary of evidence from systematic reviews
	Area	Epidemiology

Summary relevant to water fluoridation in New Zealand:

Water fluoridation has faced controversy related to (a) the risk/benefit balance of fluoridation, (b) difficulty in identifying long-term adverse effects and (c) the ethics of population intervention. This paper presents a summary of the evidence from a number of recent systematic reviews of the effectiveness and safety of water fluoridation. The paper also reports on a search of websites of fluoride guideline organisations and appraises these.

Three systematic reviews formed the basis of this paper (11), [13], [6]), all of which are reviewed separately for the current review for the Ministry of Health. Together these three reviews consider 244 original studies from the 1940s to 2005, and include a further five systematic reviews on the effectiveness and safety of water fluoridation. The reviews were of good quality, however, the primary studies themselves were of moderate-to-low quality, especially those exploring adverse effects.

Two guidelines were identified. Both came from countries with extensive water fluoridation, the USA¹⁵ and Australia¹⁶. Both guidelines were developed by expert working groups and fell short of the AGREE¹⁷ criteria in their rigour of development. Both recommended the continuation and extension of water fluoridation in their countries and included recommendations on the appropriate use of topical fluoride in the context of a fluoridated population.

The authors reached the following conclusions based primarily on the three major reviews considered.

Beneficial effects

- Water fluoridation reduces the prevalence of caries in both children and adults for all social

¹⁵ Centers for Disease Control and Prevention, Recommendation for using fluoride to prevent and control dental caries in the United States, MMWR Recomm. Rep. 2001, 50, 1-42.

¹⁶ Australian Research Centre for Population Oral Health. The use of fluorides in Australia: Guidelines, Aust. Dent. J., 2006, 51, 195-199.

¹⁷ Appraisal of Guidelines Research and Evaluation. www.agreecollaboration.org

classes.

- Water fluoridation may have a beneficial effect even in the presence of other sources of fluoride.

Adverse effects

- Fluorosis is the most commonly reported adverse effect, and there is a dose-response relationship between the concentration of fluoride in the water and the prevalence of fluorosis. A significant association was reported between water fluoride concentrations in the range 0.8–1.0 mg/L and the development of fluorosis of aesthetic concern. The likelihood of fluorosis development is linked to total fluoride intake, some of which may be from sources other than water
- Poor methodology in studies considering other adverse effects limited the certainty of conclusions that could be reached regarding these effects.
- No association could be found between water fluoridation and the likelihood of bone fractures, or the incidence of, or mortality from, bone, thyroid or all cancers.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
The aim of the paper was to present a summary of the evidence from a number of systematic reviews of the effectiveness and safety of water fluoridation.	Well covered
<i>A description of the methodology used is included.</i>	
Study inclusion and exclusion criteria were explained. The process of how the relevancy of articles was determined and if there was cross checking of this was not explained. Given that this is a summary of reviews, this information may not be as important as where primary studies are under consideration.	Adequately addressed
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	
Four electronic databases were searched to locate relevant English-language systematic reviews on the effectiveness and safety of water fluoridation published since the EAPD fluoride guideline in 2000 ¹⁸	Well covered
1. PubMed	
2. Embase	
3. The Cochrane Database of Systematic Reviews	
4. The Database of Abstracts of Reviews and Effects in	

¹⁸ Oulis C I, Raadal M, Martens L, Guidelines on the use of fluoride in children: an EAPD policy document, Eur. J. Paediatric Dent., 2000, 1, 7-12.

the Cochrane library

The search yielded 59 publications, eight were deemed relevant. Five of these were covered in the NHMRC review [13] and were no longer considered.

Websites of guideline organisations and the World Health Organization were also searched for relevant guidelines on the use of fluoride that included water fluoridation. Two guidelines were identified.

Study quality is assessed and taken into account.

The quality of the systematic reviews was assessed using the Scottish Intercollegiate Guideline Network (SIGN) methodology. An adaptation of the SIGN evidence hierarchy for public health interventions was used to grade the level of evidence (see Section 2.2 of this document).

Well covered

The quality of the guidelines was assessed using the AGREE instrument.

There are enough similarities between the studies selected to make combining them reasonable.

n/a

How well was the study done to minimise bias?

++

If coded as +, or - what is the likely direction in which bias might affect the study results?

n/a

Level of evidence provided by the review:

1 - High quality summary of the evidence from systematic reviews

Comments:

The review reported actions taken in Ireland and Canada in the light of declining caries levels and increasing prevalence of dental fluorosis (USA, Canada, Australia and Ireland).

In Ireland, the fluoride concentration range in water has been reduced from 0.8–1.0 mg/L to 0.6–0.8 mg/L with 0.7 mg/l as the target concentration. This is coupled with discouragement of the use of toothpaste with children under two years of age. Canada has taken similar steps, reducing the target fluoride concentration in water to 0.7 mg/L, and recommending the use of low-fluoride (400–550ppm) toothpaste for children, and limiting the fluoride content of infant formula. In Australia, the levels of fluoride in fluoridated water supplies have been maintained, but emphasis has instead been placed on controlling exposure of young children to fluoride through toothpaste and infant formula. In Australia, there was a substantial reduction in fluorosis with no apparent increase in dental caries. This would suggest that once an optimal target of level of water fluoride is reached, it is feasible to manage the risk of dental fluorosis through control of alternate sources of fluoride.

Implications for Ministry of Health's fluoridation policy:

This review's finding that water fluoridation is effective at reducing caries in children and adults and for all social classes supports the New Zealand Ministry of Health's present policy of water fluoridation. Furthermore the review suggests that the lower limit of the fluoride concentration range presently recommended (0.7–1 mg/L) is reasonable given appropriate advice on the use of other fluoride-containing products by young children. However, the review's findings, and the actions taken in other jurisdictions where water fluoridation has been used for sometime, indicate that consideration should be given to moving the presently recommended fluoride concentration range downward.

Review 18

Study identification:	Title	Community water fluoridation and caries prevention: a critical review
	Authors	G. Pizzo, M.R. Piscopo, I. Pizzo, G. Giuliana
	Journal	Clinical Oral Investigations
	Year	2007
	Volume	11
	Pages	189–193
	Journal Impact Factor	2.233
	Review Type	Systematic review
	Area	Epidemiology

Summary relevant to water fluoridation in New Zealand:

This review discusses the current view that the cariostatic effect of fluoride is almost exclusively post-eruptive and that the mechanism of action is topical. The authors infer that frequent exposure to low concentrations of fluoride in the oral cavity is the most important factor in preventing/controlling caries, and that the anticaries effects of systemic fluoride (introduced through such measures as water fluoridation) are minimal. Other issues reviewed include the impact of fluoride-containing products (toothpaste, mouth-rinse, gel) on declining caries prevalence in developed countries, and the increase in prevalence of fluorosis over the last two decades in the USA and in other western countries with community water fluoridation.

The authors conclude that community water fluoridation may be unnecessary for caries prevention, especially in industrialised countries where the caries level is low. In these situations, topical fluoride application may provide the optimum means of preventing caries.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	Adequately addressed
The aim of this paper was to critically review the current role of community water fluoridation in preventing dental caries.	
<i>A description of the methodology used is included.</i>	
Original articles and reviews published in English language from January 2001 to June 2006 were selected through the MEDLINE database. No other methodology was included.	Poorly addressed

<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	Poorly addressed
Other sources were taken from the references of the selected papers. However, searching only one database is insufficient.	
<i>Study quality is assessed and taken into account.</i>	Poorly covered
There was no assessment of study quality.	
<i>There are enough similarities between the studies selected to make combining them reasonable'</i>	Not applicable
<i>How well was the study done to minimise bias?</i>	+
<i>If coded as +, or - what is the likely direction in which bias might affect the study results?</i>	Possible elevated risk of adverse health outcomes due to inclusion of poor quality papers that report an adverse effect of fluoridation.
Level of evidence provided by the review:	
3 - Systematic review with a high risk of bias	
Comments:	
Implications for Ministry of Health's fluoridation policy:	
This review is generally unsupportive of the New Zealand Ministry of Health's present policy of water fluoridation, and points to a reconsideration of the presently recommended fluoride concentration range. However, the risk of bias limits the extent to which the findings should be taken into account when formulating policy.	

Review 19

Study identification:	Title	Water fluoridation and the environment: Current perspective in the United States.
	Authors	H F Pollick
	Journal	International Journal of Occupational and Environmental Health
	Year	2004
	Volume	10
	Pages	343–350
	Journal Impact Factor	2.640
	Review Type	General review of selected issues
	Area	Toxicology/pharmacology

Summary relevant to water fluoridation:

Concerns have been raised about the specific chemicals used to fluoridate water supplies. In New Zealand, as overseas, the chemicals used for fluoridation are sodium fluorosilicate, fluorosilicic acid and sodium fluoride. The expense of the latter makes it less popular than the other chemicals.

Three types of concerns have been raised.

- The presence of impurities, such as lead and arsenic, in the chemicals
- The reduction in the pH of the water caused by dissociation of the treatment chemicals, which makes the water corrosive and may increase the dissolution of metals from plumbing materials.
- The toxicology of the fluoridation chemicals themselves.

There do not appear to be any concerns regarding environmental effects as a consequence of standard water fluoridation practices and fluoridation levels.

The review finds that:

- although there are impurities in fluoridation chemicals, their concentrations after the degree of dilution resulting from use in fluoridation are too low to be of health significance
- The fluoride ion itself is non-corrosive. While the pH may tend to reduce due to the dissociation of fluorosilicic acid, adjustment of the buffering capacity of the water (the alkalinity) will ensure that this does not increase corrosiveness
- there is no credible evidence of toxicity resulting from fluoridation chemicals when diluted for use in the fluoridation process. The chemicals are expected to have dissociated to fluoride, hydrogen ions, and hydrated silica by the time the water leaves the water treatment plant, or at worst, reaches the first consumers.

Further, the review concludes that scientific evidence supports water fluoridation as a measure that is safe for the environment and good for people.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	Poorly addressed
The review focused more on broader topics than on any single, clear question.	
<i>A description of the methodology used is included.</i>	Adequately addressed
There is no description of the details of the literature search process. However this is not an epidemiological study or a review such as a meta-analysis of such studies (where search strategies and inclusion and exclusion criteria for example are critical to the interpretation).	
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	Adequately addressed
As the literature search is not outlined in detail, it is not possible to fully assess this. This criterion is likely reasonably well covered, but this has not clearly been demonstrated.	
<i>Study quality is assessed and taken into account.</i>	Poorly addressed
The relative quality of relevant studies of various sorts is at times alluded to, however, comparisons are not made in a formal, consistent and detailed manner.	
<i>There are enough similarities between the studies selected to make combining them reasonable.</i>	n/a
No such combining of "like" studies (such as in a meta-analysis) was involved in the production of this article.	
<i>How well was the study done to minimise bias?</i>	n/a
This was not an epidemiological study focusing on a specific research question.	
If coded as +, or - what is the likely direction in which bias might affect the study results?	n/a
Level of evidence provided by the review:	
Moderately high level of evidence based on the emphasis placed on the 2004 Fort Collins review which provides more detail on search and selection strategies than does this review.	

Comments:

The review focuses more on broader topics than on any single, clear question. For example:

What are the real or potential adverse effects of water fluoridation practices on rivers, plants, animals, humans?

What are the risks from the specific chemicals used in water fluoridation?

Is there credible evidence indicating a causal relationship between water fluoridation and increased health risks?

Implications for Ministry of Health's fluoridation policy:

The review notes that more research on the health effects of fluoride still needs to be done, but that the gains made from water fluoridation should not be undone whilst waiting for such research to be completed. It also concludes that fluoridation is a safe and effective measure for improving the oral health of the community. Consequently, it broadly supports the Ministry of Health's fluoridation policy, although it provides no quantitative indication of the fluoride concentrations in drinking-water that will inhibit caries, while minimising adverse effects.

Review 20

Study identification:	Title	A review of the prevalence of dental fluorosis in Mexico
	Authors	A E Soto-Rojas, J L Ureña-Cirett, E de los Angeles Martínez-Mier
	Journal	Pan American Journal of Public Health
	Year	2004
	Volume	15(1)
	Pages	9–18
	Journal Impact Factor	0.994 (2008)
	Review Type	Systematic review
	Area	Epidemiology

Summary relevant to water fluoridation in New Zealand:

This paper is concerned solely with reports of fluorosis in Mexico. While it was reviewed because it may have provided a useful comparison with the New Zealand situation, its findings are limited and the peculiarities of the Mexican situation mean that inferences for the New Zealand context cannot be drawn.

It reports that in Mexico:

1. most communities are exposed to naturally-occurring fluoride in the water. Many of the studies report fluoride in excess of 1.5 mg/L, with the tap water in one location containing up to 16 mg./L fluoride
2. a nationally implemented salt fluoridation program was introduced in 1995. This type of salt was not to be distributed in cities where the fluoride concentration in water for human consumption was above 0.7 mg/L
3. multiple types of drinking-water sources are used (rivers, lakes, reservoirs, wells) providing water of variable levels of safety, so that boiling water is a common practice. Boiling the water is reported to increase its fluoride concentration “dramatically”, suggesting extended boiling
4. there are many high altitude communities. High altitude is associated with high naturally-occurring fluoride concentrations in water and may also affect fluoride metabolism
5. water fluoridation is not practiced.

The authors conclude that as a result of inadequate information, the prevalence of fluorosis in Mexico, and whether it is falling or rising cannot be determined.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
The aim of this paper was to “evaluate published data regarding dental fluorosis in Mexico to assess if sufficient data have been obtained in order to determine if dental fluorosis is rising and if it constitutes a public health problem in Mexico”. No definition of “sufficient” or “problem” was given.	Adequately addressed
<i>A description of the methodology used is included.</i>	
Seven bibliographic databases using the terms “fluorosis and Mexico” were searched (January 1970 to December 2001). Criteria were set for paper inclusion and once included, information was recorded on a data extraction sheet in a systematic fashion.	Well covered
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	
Once articles were located their reference lists were also searched to capture additional reports. Manual searching of non-indexed material was also included.	Well covered
<i>Study quality is assessed and taken into account.</i>	
Eight inclusion criteria needed to be fulfilled for inclusion. For example, the residence of the study participants had to be documented, the content of fluoride in the water had to be stated, conclusions had to correspond to the aims of the study. Once papers were included differences among studies, such as which index of fluorosis was used and population selection criteria were assessed. The search yielded 24 papers and 14 of these met the inclusion criteria.	Well covered
<i>There are enough similarities between the studies selected to make combining them reasonable</i>	n/a
<i>How well was the study done to minimise bias?</i>	++
<i>If coded as +, or - what is the likely direction in which bias might affect the study results?</i>	n/a
Level of evidence provided by the review:	
2 - Well conducted systematic review with a low risk of bias	
Comments:	
Although high quality methodology was used in the preparation of this review, the contributing	

papers were of moderate-to-low quality.

Implications for Ministry of Health's fluoridation policy:

There are no implications for the Ministry of Health's water fluoridation policy for the reasons given in the summary.

Review 21

Study identification:	Title	Review of the evidence for oral health promotion and effectiveness
	Authors	J.G Satur, M.G Gussy, M.V. Morgan, H. Calache, C. Wright
	Journal	Health Education Journal
	Year	2010
	Volume	69(3)
	Pages	257–266
	Journal Impact Factor	2.194
	Review Type	Systematic review
	Area	Oral and public health – health promotion

Summary relevant to water fluoridation in New Zealand:

The key objective of this article is to report on a systematic review of the evidence of the effectiveness of oral health promotion as an integral part of strategic planning for both oral and general health.

The current reorientation of child and adolescent oral health services in New Zealand has a significant focus on oral health promotion so this review is of value at a population-based level. While the review focuses mainly on a number of interventions aiming at early childhood and aged-care settings, smoking cessation and capacity building with non-oral health providers, it finds that the evidence continues to support continuation of fluoridation of water supplies.

There is sound evidence to support the assertion that the fluoridation of drinking-water reduces caries prevalence, both as measured by the proportion of children caries-free and by mean dmft/DMFT scores.

There is some evidence that water fluoridation reduces inequalities in dental health across social classes and it remains the most socially equitable means of achieving community-wide exposure to the caries prevention effects of fluoride.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	Well covered
Should oral health promotion be incorporated into general health promotion	
<i>A description of the methodology used is included.</i>	Well covered

Inclusion and exclusion criteria were well explained\	
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	
The English literature on oral health education and oral health promotion post-1988 was systematically searched using library and web-based searches.	
Community, state and national oral health promotion activities published outside the peer-reviewed literature, as well as information from relevant systematic reviews were also included.	Well covered
The search found 243 references of which 98 met the inclusion criteria. There were 26 reports of which 21 were included.	
<i>Study quality is assessed and taken into account.</i>	
A framework developed by the Cochrane Public Health and Promotion Field was used to assess the quality of the retrieved studies. These were then ranked as weak (poorly designed study methods), moderate (well reported but weaker study designs or better studies lacking information) or good (well designed studies with good methods reporting including randomly controlled trials and systematic reviews).	Well covered
<i>There are enough similarities between the studies selected to make combining them reasonable'</i>	
This is covered in the inclusion criteria.	Well covered
<i>How well was the study done to minimise bias?</i>	++
<i>If coded as +, or - what is the likely direction in which bias might affect the study results?</i>	n/a
Level of evidence provided by the review:	
High quality of evidence	
Comments:	
Implications for Ministry of Health's fluoridation policy:	
This review further supports the role of water fluoridation as the most cost-effective and equitable way of improving oral health in a population. In so doing, it supports the Ministry of Health's fluoridation policy. It reaches no quantitative conclusion concerning the optimum levels of fluoride that should be maintained in a fluoridated water supply.	

Review 22

Study identification:	Title	Critical review of any new evidence on the hazard profile, health effects, and human exposure to fluoride and the fluoridating agents of drinking water
	Authors	Scientific Committee on Health and Environmental Risks (SCHER)
	Journal	
	Year	
	Volume	
	Pages	
	Journal Impact Factor	
	Review Type	Consensus document/expert opinion (SCHER adopted this <i>pre-consultation</i> opinion at its 7th plenary on 18 May 2010)
	Area	Oral and Public Health/Epidemiology

Summary relevant to water fluoridation in New Zealand:

This is a significant review of the key issues raised about benefits and risks from water fluoridation. This includes its effectiveness and relevance in decreasing dental caries, possible adverse effects and its impact on the environment. This is undertaken within the context of the European Union (EU). Fluoride, either naturally present or intentionally added to water, food and consumer products, is generally considered beneficial in the prevention of dental caries. SCHER has reviewed the newest information in the area of risk and benefit of using fluoridated drinking-water and intake of fluoride from all sources.

This is a pre-consultation opinion and is not the final report.

Conclusions

1. Hydrolysis of hexafluorosilicates used in drinking-water fluoridation to fluoride is rapid and the release of fluoride ion is essentially complete (i.e., total dissociation of the fluorosilicate). This opinion considers that the fluoride ion is the only relevant substance in the drinking-water.
2. The risk of dental fluorosis is confirmed when children are systemically exposed to fluoride – the threshold could not be detected.
3. There have been no reported cases of endemic skeletal fluorosis in the EU.
4. SCHER agrees that some epidemiological studies seem to indicate a possible link between fluoride in the drinking-water and osteosarcoma, but the studies are equivocal. There are no animal studies that support this link, therefore fluoride cannot be classified as to its carcinogenicity.
5. Fluoride from drinking-water does not hamper children's neurodevelopment or impair IQ at the levels occurring in the EU.

6. Human studies do not suggest adverse thyroid effects at realistic human exposures to fluoride.
7. There is no new evidence from human studies indicating that fluoride in drinking-water influences male and female reproductive capacity.
8. The upper tolerable intake level (UL) is not exceeded for adults and children between 12 and 15 years of age living in areas with fluoridated drinking-water (<0.8 mg/L)
9. The UL was exceeded in children between 6 and 12 years living in fluoridated areas (0.8 mg/L) when consuming 1L of drinking-water per day and using adult strength toothpaste (0.15%) *unsupervised*
10. The UL was exceeded in children between 1 and 6 years living in fluoridated areas (0.8 mg/L) when consuming 0.5L of drinking-water per day and using adult strength toothpaste (0.15%) *unsupervised*
11. Water fluoridation, as well as topical fluoride treatments (eg, fluoridated toothpaste or varnish), appear to prevent caries, primarily on the permanent dentition, but topical application is the more efficient way of achieving protection.
12. In children, a very narrow margin exists between achieving the maximal beneficial effects of fluoride in caries prevention and the adverse effects of dental fluorosis
13. Exposure of environmental organisms to levels of fluoride as used in fluoridation of drinking-waters, are not expected to lead to unacceptable risks in the environment.

Two other points to note are:

1. For infants up to 6 months receiving infant formula, the safe fluoride level established by the Department of Health in the UK (0.22 mg/kg BW/day) was only exceeded if formula was reconstituted with water having fluoride levels higher than 0.8 mg/L
2. Water fluoridation appears to have no obvious advantage over topical application of fluoride with respect to preventing caries. However, it was acknowledged that as a means of delivering fluoride, water fluoridation was advantageous in ensuring caries prevention was able to reach disadvantaged children from the lower socioeconomic groups.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	

The terms of reference for this review were:

- | | |
|--|--------------|
| <ol style="list-style-type: none"> 1. taking into account previous work done in the EU in 2005 about the safety of fluorine compounds in oral hygiene products as well as a 2005 opinion on the UL for fluoride to: <ol style="list-style-type: none"> a) critically review any new information that is available in the public domain on the hazard profile and epidemiological evidence of adverse/beneficial health effects of fluoride, in particular new evidence available after 2005 | Well covered |
|--|--------------|

-
- b) conduct an integrated exposure assessment covering all known possible sources
 - c) on the basis of the answers above, SCHER were asked to:
 - i) evaluate the evidence of the role of fluoride in tooth decay prevention and rank the various exposure situations as to their effectiveness in preventing tooth decay
 - ii) identify any reasons for concern arising from the exposure of humans to fluoride. If these exist to identify these particular exposure scenarios that may give concern for a particular population or subgroup.
 - d) identify any additional investigative work that needs to be done in order to fill data gaps in the hazard profile, the health effects and exposure assessment of fluoride.
2. To assess the health and environmental risks that may be associated with the most common drinking-water agents – taking into account their hazard profiles.
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<i>A description of the methodology used is included.</i>	Not addressed
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<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	Not addressed
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<i>Study quality is assessed and taken into account.</i>	Not addressed
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<i>There are enough similarities between the studies selected to make combining them reasonable.</i>	Not addressed
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<i>How well was the study done to minimise bias?</i>	+
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<i>If coded as +, or - what is the likely direction in which bias might affect the study results?</i>	Unknown
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Level of evidence provided by the review:

4 - High quality systematic review

Comments:

Implications for Ministry of Health’s fluoridation policy:

The conclusion reached by SCHER that, for children, there is a very narrow margin between achieving the maximal beneficial effects of fluoride in caries prevention and the adverse effects of dental fluorosis,

shows that there is a need to accelerate the review of New Zealand's UL for fluoride. This need is also shown in the Ministry of Health's *Guidelines for the use of fluoride*¹⁹ which do show a potential window for infants to exceed the current UL if drinking fluoridated water and consuming infant formula.

Several of the conclusions of the review concerning the UL not being exceeded relate to fluoridated water having a fluoride concentration of 0.8 mg/L. The Ministry of Health's fluoridation policy recommends a target fluoride concentration extending beyond this to 1.0 mg/L. Review of the UL may result in the need to adjust the limits of the recommended range.

¹⁹ Ministry of Health, 2009, *Guidelines for the Use of Fluorides*, Wellington, available at www.moh.govt.nz and www.nzgg.org.nz

Review 23

Study identification:	Title	Oral Health of Indigenous Children and the Influence of Early Childhood Caries on Childhood Health and Well-being
	Authors	R J. Schroth, R L. Harrison, M E K Moffatt
	Journal	Pediatric Clinics of North America
	Year	2009
	Volume	56, (6)
	Pages	1481–1499
	Journal Impact Factor	1.36
	Review Type	Qualitative
	Area	Communication and Community Engagement

Summary relevant to water fluoridation in New Zealand:

Dental caries in indigenous children is a child health issue that is multifactorial in origin and strongly influenced by the determinants of health. Unfortunately, a universally effective, caries-prevention programme with predictable long-term results has yet to be found. Early childhood caries (ECC) is a complex disease, and preventive programme must include a variety of strategies, there is no ‘magic bullet’. Any strategies should begin with community engagement and always include primary care providers and other community health workers. Although water fluoridation is the most cost-effective and equitable way of preventing caries, the remoteness, small size, and lack of infrastructure in many indigenous communities usually means that water fluoridation is neither realistic nor economic. However results of a recent unpublished study (2009) performed in Alaskan communities suggests that water fluoridation should be pursued. A reduction in caries by 30–50% with community fluoridation “even when other risk factors were accounted for” was reported.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	Not addressed
<i>A description of the methodology used is included.</i>	Not addressed
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	
<i>Study quality is assessed and taken into account.</i>	

There are enough similarities between the studies selected to make combining them reasonable.

How well was the study done to minimise bias?

If coded as +, or - what is the likely direction in which bias might affect the study results?

Level of evidence provided by the review:

Poor quality

Comments:

The review is not a meta-analysis. There was no clear focused question(s) and there was no methodology reported. The article has extensive references but because it is unclear how these were sourced the level of evidence is deemed to be of poor quality.

Implications for Ministry of Health's fluoridation policy:

There are no clear implications for the Ministry of Health's policy. The review indicates that there is very little evidence to support the development of health promotion strategies for the improvement of the oral health of indigenous children.

Review 24

Study identification:	Title	A review of fluorosis in the European Union: prevalence, risk factors and aesthetic issues
	Authors	H.P. Whelton, C.E. Ketley, F. McSweeney and D.M. O'Mullane
	Journal	Community Dentistry and Oral Epidemiology
	Year	2004
	Volume	32 (Suppl. 1)
	Pages	9–18
	Journal Impact Factor	2.418
	Review Type	Non-systematic review
	Area	Epidemiology

Summary relevant to water fluoridation in New Zealand:

This paper provides a definition of optimum level of fluoride in fluoridated water as:

“that concentration which provides the maximum protection against caries with the least clinically observable fluorosis”.

Approximately 20% only of this review focuses on risk factors for dental fluorosis and is potentially relevant to water fluoridation policy in New Zealand. The review noted the following risk factors that have been reported in previous studies for fluoridated and non-fluoridated supplies:

Fluoridated supplies

- Use of toothpastes by young children
- Age at which brushing started
- Frequency of brushing
- Fluoride concentration in the toothpaste
- Amount of toothpaste applied to the brush and later swallowed
- Inappropriate fluoride supplement use
- Infant formula use (in powdered form)
- Early weaning from breast feeding
- Higher socioeconomic status

Non-fluoridated supplies

- Use of toothpastes by young children
- Fluoride supplement use
- Higher socioeconomic status

The review notes the difficulty in ascertaining the extent of dental fluorosis and trends in its prevalence in Europe because of the complexity and inaccuracy in comparing studies using different fluorosis assessment methodologies from different countries.

In summarising the prevalence of fluorosis in Europe, the authors report that the prevalence of fluorosis is greater in fluoridated than non-fluoridated areas, and that the prevalence of very mild fluorosis is increasing. Where supplements, such as fluoride tablets, are used, the prevalence of fluorosis in non-fluoridated areas is similar to that in fluoridated areas. They note that, to date, fluorosis does not appear to be a health concern, but rather an aesthetic concern primarily associated with the appearance of the permanent central incisors.

- In concluding, the review reports that fluoride sources other than optimally fluoridated water are important in the development of dental fluorosis.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	
The aim of this paper was to “determine, by review, recent trends in the prevalence of fluorosis in Europe and the associated aesthetic concerns”.	Adequately addressed
<i>A description of the methodology used is included.</i>	
There was no indication of how studies were searched for, selected or assessed.	Poorly covered
<i>The literature search is sufficiently rigorous to identify all the relevant studies.</i>	
See comments above.	Poorly covered
<i>Study quality is assessed and taken into account.</i>	
No assessment of study quality was performed.	Poorly covered
<i>There are enough similarities between the studies selected to make combining them reasonable</i>	n/a
<i>How well was the study done to minimise bias?</i>	+
<i>If coded as +, or - what is the likely direction in which bias might affect the study results?</i>	Likely elevated risk of fluorosis due to publication bias

Level of evidence provided by the review:

3 - Poorly conducted systematic review with a high risk of bias

Comments:

The introduction gives an overview of the vehicles for and sources of fluoride in the European Union (EU) and outlines the recent controversies around community water fluoridation. Only a small portion of the paper (20%) reviews risk factor for fluorosis and is relevant for the purposes of this work. A further 20% of the paper, approximately, reviews measurement indices for dental fluorosis, 20% reviews the aesthetic concerns of fluorosis, and another 20% reviews the prevalence of fluorosis in the EU.

Caution is required in drawing inferences for water fluoridation in New Zealand from the conclusions of this review, because of differences in the extent of water fluoridation in Europe. While some countries carry out fluoridation (Ireland, Spain, Switzerland and the UK), others provide fluoridated salt as an alternative vehicle for fluoride because of a strong antifuoride lobby (Germany, Switzerland, France, Belgium and the Czech Republic).

Implications for Ministry of Health's fluoridation policy:

As the review was poorly conducted and has a risk likelihood of bias, it has no implications for the New Zealand Ministry of Health's present policy of water fluoridation.

Review 25

Study identification:	Title	Association of Down's syndrome and water fluoride level: a systematic review of the evidence
	Authors	P. Whiting, M. McDonagh and J.Kleijnen
	Journal	BMC Public Health
	Year	2001
	DOI	http://www.biomedcentral.com/1471-2458/1/6
	Journal Impact Factor	2.2
	Review Type	Narrative synthesis
	Area	Epidemiology

Summary relevant to water fluoridation in New Zealand:

This study is a publication from the York Report [11]. Water fluoridation has been suggested as a possible risk factor for Down syndrome and its association with water fluoride exposure has been investigated by a number of studies. The aim of this review was to examine the evidence for an association between water fluoride level and Down syndrome.

Six ecological studies were reviewed. Insufficient information precluded pooling of data or an investigation of statistical heterogeneity.

The authors report that the evidence of an association between water fluoride level and Down syndrome is inconclusive, and acknowledge that the quality of the included studies was low.

The authors seemed well aware of the importance of control for confounding factors such as maternal age, incidence of termination of pregnancies in which the child is diagnosed with Down syndrome, and other sources of fluoride.

Evaluation:

Criterion	In this study this criterion is:
<i>The study addresses an appropriate and clearly focused question.</i>	Well covered
The objective of this report was to investigate the association of water fluoride level with Down syndrome and discuss in detail the quality of the studies investigating this association.	
<i>A description of the methodology used is included.</i>	
Study inclusion and exclusion criteria were explained. Six studies were identified. Two reviewers independently assessed each paper for inclusion, disagreements were resolved through consensus. Extraction of data from individual included studies	Adequately addressed

was independently performed by two reviewers, and checked by a third reviewer. Disagreements were resolved through consensus.

Reliance on reference to the York Report meant the reader needed to refer to the original to find further details. This was acceptable

The literature search is sufficiently rigorous to identify all the relevant studies.

Twenty-five specialist databases were searched to locate studies that compared the incidence of Down syndrome in populations with different levels of fluoride in their water, either artificially added or naturally-occurring, for inclusion in the review. Also hand-searching, advisory panel and seeking of articles from individuals and organizations through the York website generated information.

Well covered

Study quality is assessed and taken into account.

Study validity was formally assessed using a published checklist modified for the review. The criteria used to assess study validity had been developed for the main review (York Report). Each study was assigned a score, based on the number of checks achieved on the checklist, out of a maximum score of eight. The criteria used to score the studies included, but were not limited to, control for confounding factors, fluoride measurement and study design. Study validity was assessed independently by two reviewers, with disagreements resolved through consensus.

Well covered

There are enough similarities between the studies selected to make combining them reasonable.

Insufficient information precluded pooling of data or an investigation of statistical heterogeneity.

Not applicable

How well was the study done to minimise bias?

+

If coded as +, or – what is the likely direction in which bias might affect the study results?

bias towards an association between fluoridation and Down syndrome

Level of evidence provided by the review:

3 - Narrative synthesis with a high risk of bias

Comments:

The high risk of bias is due to the poor study quality of the contributing papers, rather than as a result of the conduct of this particular review. The major weakness in the contributing papers was the failure to control sufficiently for confounding factors. All six studies used ecological study design: the population exposure to fluoride was measured, not the individual exposure. The other major weakness in four of the six papers is that the investigators did not control for maternal age.

Implications for Ministry of Health's fluoridation policy:

The review did not reach any conclusions that showed that the fluoridation of drinking-water is a risk factor with respect to Down Syndrome. Consequently, it has no implications for the Ministry of Health's fluoridation policy. It provides no information that could be used to assess whether the fluoride concentration range presently recommended requires modification.

REFERENCES

- Anand, K., Baridalyne N., Moorthy, D., Kapoor, S.K., Sankar, R., & Pandav, C. S. (2002). Ethical Issues in Public Health Policy. *The National Medical Journal of India*, 15(2), 97-100.
- Browne, D., Whelton, H., & O'Mullane, D. (2005). Fluoride metabolism and fluorosis. *Journal of Dentistry* (23), 177-186.
- Burt, B. (2002). Fluoridation and social equity. *Journal of Public Health Dentistry*, 62(4), 195-200.
- Centre for Disease Control. (2001). Promoting Oral Health: Interventions for Preventing Dental Caries, Oral and Pharyngeal Cancers, and Sports-related Craniofacial Injuries. (A report on Recommendations of the Task Force on Community Preventive Services. *Morbidity and mortality weekly report*, 50(RR-21), 1-13
- Demos, L.L., Kazda, H., Ciucuttini, F.M., Sinclair, M.I., Fairley, C.K. (2001). Water fluoridation, osteoporosis, fractures – recent developments. *Australian Dental Journal*. 46(2), 80-87
- Griffin, S.O., Regnier, E., Griffin, P.M., & Huntley, V. Effectiveness of Fluoride in Preventing Caries in Adults. *Journal of Dental Research*, 86(5), 410-415.
- Harrison, P.T.C. (2005) Fluoride in water: A UK perspective. *Journal of Fluorine Chemistry*, (126), 1448-1456.
- Hujoel, P., Zina, L., Moimoz, S., & Cuncha-Cruz, J. (2009). Infant formula and enamel fluorosis: A systematic review. *The Journal of the American Dental Association*, 140, 841-854.
- Kumar, J.V. (2008). Is Water Fluoridation Still Necessary? *Advances in Dental Research*, (20) 1, 8-12.
- Levy, S.M. (2003). An update on fluorides and fluorosis. *Journal of Canadian Dental Association*, 69(5), 266-291
- Ministry of Health. (2009a). *Our Oral Health: Key Findings of the 2009 New Zealand Oral Health Survey*. Retrieved from <http://www.moh.govt.nz/moh.nsf/indexmh/dataandstatistics-survey-oralhealth#Overview>

Ministry of Health. (2009b). *Guidelines for the Use of Fluorides*. Retrieved from <http://www.moh.govt.nz/moh.nsf/indexmh/guidelines-for-the-use-of-fluorides?Open>

Ministry of Health. (2009c). *Annual Review of Drinking Water Quality in New Zealand 2007/8*. Retrieved from <http://www.moh.govt.nz/moh.nsf/indexmh/annual-review-drinking-water-quality-nz-2007-08>

Ministry of Health. (2008). *Drinking-water Standards for New Zealand 2005. (Revised 2008)*. Retrieved from <http://www.moh.govt.nz/moh.nsf/pagesmh/8534>

Ministry of Health. (2010a). *Annual Review of Drinking-water Quality in New Zealand 2008/9*. Retrieved from <http://www.moh.govt.nz/moh.nsf/indexmh/annual-review-drinking-water-quality-nz-2008-09>

Ministry of Health (2010b). *Our Oral Health: Key findings of the 2009 New Zealand Oral Health Survey*. Retrieved from <http://www.moh.govt.nz/moh.nsf/indexmh/our-oral-health-key-findings-2009-nz-oral-health-survey>

Ministry of Health (2011a). *Fluoridation in New Zealand. Water Fluoridation. History*. Retrieved from <http://www.moh.govt.nz/moh.nsf/pagesmh/3597>

Ministry of Health (2011b). *Fluoridation in New Zealand. Sources of fluoride*. Retrieved from <http://www.moh.govt.nz/moh.nsf/pagesmh/3578>

National Health and Medical Research Council. (2007). *A systematic Review of the Efficacy and Safety of Fluoridation*. Canberra, Australia: Author

National Research Council of the National Academies. (2006). *Fluoride in Drinking Water. A scientific review of EPA's Standards*. Washington, DC: Author.

National Fluoridation Information Service (2001). *A report on the chemical quality of New Zealand's community drinking water supplies*. Retrieved from <http://www.huttvalleydhb.org.nz/RPH/Resource.aspx?ID=30207>

Newbrun, E. (2010). What we know and do not know about fluoride. *Journal of Public Health Dentistry*, 70, 227-233.

Nuffield Council on Bioethics. (2007). *Public Health: Ethical Issues*. London, UK: Author.

Parnell, C., Whelton, H., & O'Mullane, D. (2009). Water Fluoridation, *European Archives of Paediatric Dentistry*, 10(3), 141-148.

Pollick, H.F. (2004). Water fluoridation and the environment: Current perspective in the United States. *International Journal of Occupational and Environmental Health*, 10, 343-350.

Pizzo, G., Piscopo, M.R., Pizzo, I., & Giuliana, G. (2007). Community water fluoridation and caries prevention. *Clinical Oral Investigations*, 11, 189-193.

Satur, J.G., Gussy, M.G., Morgan, M.V., Calache, H., & Wright, C. (2010). Review of the evidence for oral health promotion and effectiveness. *Health Education Journal*, 69(3), 257-266.

Scientific Committee on Health and Environmental Risks (SCHER). (2010). *Critical review of any new evidence on the hazard profile, health effects, and human exposure to fluoride and the fluoridating agents of drinking water*. Retrieved from http://ec.europa.eu/health/scientific_committees/environmental_risks/docs/scher_o_13_9.pdf

Schroth, R.J., Harrison, R.L., & Moffatt, M.E.K. (2009) Oral Health of Indigenous Children and the Influence of Early Childhood Caries on Childhood Health and Well-being. *Pediatric Clinics of North America*, 56(6), 1481-1499.

Soto-Rojas, A.E., Ureña-Cirett, J.L., & de los Angeles Martinez-Mier, E. (2004). A review of the prevalence of dental fluorosis in Mexico. *Pan American Journal of Public Health*, 15(1), 9-18.

Tang, Q., Du, J., Ma, H., Jiang, S., & Zhou, X. (2008). Fluoride and children's intelligence: a meta-analysis, *Biological Trace Element Research*, (126) 115-120.

University of York. (2000). *A Systematic Review of Public Water Fluoridation 2000*. York, UK: NHS Centre for Reviews and Dissemination.

Whelton, H.P., Ketly, C.E., McSweeney, F., & O'Mullane, D.M. (2004). A review of fluorosis in the European Union: prevalence, risk factors and aesthetic issues. *Community Dentistry and Oral Epidemiology*, 32(Suppl. 1), 9-18.

Whiting, P., McDonagh, M., & Kleijnen. (2001) Association of Down's syndrome and water fluoride level: a systematic review of the evidence. *BMC Public Health*. Retrieved from <http://www.biomedcentral.com/1471-2458/1/6>