Review Article

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Community Water Fluoridation: Revisiting a Cost-Effective Measure

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Abstract

Community water fluoridation (CWF) is one of the options for the prevention of dental caries. The equitable nature of this measure is a proven strength. As this measure, presently requires implementation in the low-income countries due to the increase in the incidence of dental caries, an overview of the economic aspects becomes a mandate. Thus, this review addresses the cost-effectiveness of this measure on the global scale, as capital costs and operating costs are different for each country depending on the availability of water and fluoride resources. The feasibility of fluoridation of drinking water, the availability of central water supply, and the population served will determine the cost-effectiveness of this measure for each country.

Key words: Community water fluoridation, Cost-effectiveness analysis, Equitable, Prevention

INTRODUCTION

Prevention is the solution for controlling health care costs and improving national health.[1] In preventive dentistry, fluoride is a benchmark in caries reduction. The history of water fluoridation is a classic example of clinical observation leading to community-based public health intervention.[2] Water fluoridation, has been a major contributor to the documented decline in dental caries in the 1950s-1980s, with the fluoridated dentifrice.[3] Although, average annual expenditure on fluoride toothpaste is related not only to the price of toothpaste per region but also to the number of people using toothpaste and the amount used per person per year.[4] A study concluded that fluoride toothpaste is prohibitively expensive for the world's poorest people in developing nations.[5] Significant health inequalities can result due to the issues of affordability of this essential preventive care product and thus, indicates the need for community water fluoridation (CWF) that facilitates more uniformly distribution of fluoride.

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The behavior of fluoride ions in the human organism is a classic example of the double-edged sword since it acts as a preventive factor for caries and a causative factor for fluorosis above a threshold concentration.[6] However, with routine monitoring, this "mass medication" of CWF is the most equitable option for the low-income countries, regardless of age, educational attainment, or income level.[7]

STATUS OF CWF IN THE VARIOUS COUNTRIES

Populations in many developing countries do not have access to fluorides for the prevention of dental caries for practical or economic reasons.[8] About 210 million people benefit from fluoridated water across the globe. Water fluoridation has been supported by World Health Organization (WHO), which recommends water fluoridation wherever, it is politically and technically feasible. Where water fluoridation is not possible, WHO recommends salt fluoridation as a next best option. Currently, some 40 countries have artificial water fluoridation schemes in existence.[9]

In Vietnam, water fluoridation at a concentration of 0.7 mg Fluoride/Liter (F/L) has been available in Ho Chi Minh City since 1990. A step-by-step approach was used for implementing this measure, and fluoridation has resulted in a decrease of dental caries in children, but 70% of the rural population does not benefit from the water fluoridation program.

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In Brunei (high-income country), water fluoridation at a concentration of 0.5-0.7 mg F/L was implemented in 1987; currently, approximately 95% of the population receives benefits of water fluoridation. Toothpaste containing fluoride is also available in the country; also fluoride varnishes are applied to children within the school setting.

A survey indicated that 83% of children in Singapore used toothpaste containing fluoride. Thus, Ministry of Health decided to lower the concentration of fluoride in water from 0.7 to 0.6 mg F/L in 1992 and further to 0.5 mg F/L in 2008. Other vehicles of fluoride are also available to the population of Singapore. A multi-disciplinary committee was established in the country, and its responsibilities were to generate recommendations, through the review of literature for the Ministry of Health as the island has one central water supply for the whole population. Effectiveness in dental caries reduction and enamel fluorosis status is assessed every 10 years through an oral health survey. In Hong Kong, the treatment of public water supply for total population consists of chemical coagulation, sedimentation, filtration, pH correction, chlorination, and fluoridation. The water fluoridation experience has been similar to that of Singapore. CWF is not currently adopted in Italy because in some areas throughout the country, water naturally contains fluoride, reaching the optimal levels for caries prevention. Furthermore, the expansion of the use of bottled water, with a wide range of fluoride concentration, is the major source of drinking water in this country.[10] Nepal has not implemented any automatic fluoridation systems, but with the multiple sources of water supplies and the inability to utilize a central supply system, this method is not feasible at this time. Besides, CWF requires an epidemiological surveillance, with regard to the distribution network and monitoring of water at the processing plant and at the consumer end to ensure that the correct amount of fluoride is being delivered to the user. Government-subsidized community fluoride prevention programs may face privatization in some countries, and careful management of the situation should be considered. In countries, where water fluoridation is limited and is not feasible to implement, salt or milk fluoridation can be considered.[11]

COST-EFFECTIVENESS

The average annual cost of water fluoridation in the United States was calculated in 1989 workshop as $0.51 per person (range: $0.12-$5.41). In 1999, this cost would be $0.72 per person (range: $0.17-$7.62).

Following estimates are required for conducting a cost-effectiveness analysis of CWF:

Capital Costs

Fluoridation schemes require capital expenditure to:

- Establish a plant and equipment
- Consultant engineering fees
- To replace and upgrade those facilities when necessary.

Operating Costs

Annual running costs:

- Fluoride materials
- Labor
- Maintenance.

Cost-effectiveness takes account of the outcomes in terms of the health units gained. This analysis can give, a cost to effect ratio for a particular intervention, incremental cost-effectiveness to compare different scenarios for the same intervention, and can further lead to a cost-benefit analysis where a monetary value can be assigned to each health outcome, although it is difficult. The study of the effect unit for CWF is in terms of number of teeth prevented from decay, the number of individuals prevented from decay, or as treatment cost that could be avoided.

Factors reported to influence the per capita cost include:

- Size of the community (the larger the population reached, the lower the per capita cost)
- The level of tooth decay in population
- Age and treatment of the water treatment works
- Number of fluoride injection points in the water supply system
- Amount and type of system feeder and monitoring equipment used
- Amount and type of fluoride chemical used, its price, and its cost of transportation and storage; and
- Expertise of personnel at the water plant.

In 1998, York Health Economics Consortium study concluded that calculating capital and revenue costs for water fluoridation for a population is simple. However, one needs to discount the costs to determine equivalent annual costs of installations life. Discounting of costs is done for the monetary values of the health outcomes. The expected reduction in the tooth decay will help one to estimate the cost-effectiveness of CWF. Population projections and knowledge of underlying status will make it possible to predict decay, restorations, and the extractions of the teeth prevented within 14 years of installation of the system for those born after fluoridation. As the outcome measures the health of the population, more is the population, more will be a denominator and better (lower quantity) will be the cost-effectiveness ratio[12] (Table 1).

Reduction on an average by 25% in tooth decay in children, i.e., 6 years and over and adults up to 65-years-old were

reported in an economic evaluation. They also calculated for a "worst case" scenario based on only a 12% reduction and best case scenario based on 29% average reduction. The costs in this study included the capital and operating costs. The American Dental Association reported the price of $54 for the filling of the single decayed tooth surface by 1995. Including the costs of loss of wages, i.e., an indirect cost; the total cost averted per tooth was calculated to be $72. Using the above-mentioned costs, the three scenarios were estimated (Table 2).

The US researchers concluded a larger population size and the higher incidence of tooth decay existing made this intervention more cost-effective. However, the halo effect of the intervention, i.e., processed and canned foods and drinks, provides a preventive effect for an extra population that cannot be estimated directly. Thus, these economic models are not efficient to include the total health outcome after implementing water fluoridation.[13]

Economic evaluation also forecasts the costs and benefits of CWF as done in Southampton and parts of neighboring Hampshire, as it prepared, to implement CWF in 2008 for 1,95,000 people. The analysis assumed that up to and including the age of 17, fluoridation would reduce the decay by an average of 25%. The analysis included the primary and permanent dentition, but the adults were excluded. They developed an economic model, computed the capital costs, and anticipated 20-year life span of plant and equipment. This figure was estimated to be £1.49 million, and it would further reduce the dental treatment costs of £1.48 million. They based on the analysis of an instance that 36,032 instances of tooth decay were prevented as a direct result of fluoridation. The difference £10,000 was then divided by 36,032 to produce a cost per instance of tooth decay avoided of £0.32. This report identified that a reduction of less than 25% would reduce the cost-effectiveness. The study stated the limitation that the exclusion of adults from the model leads to underestimation of the CWF. It was concluded that decision making for implementing CWF, this economic picture should be considered as "cost neutral."[14]

Another study took into account a rare health outcome, which included a number of extractions avoided under general anesthesia with respect to the effects of CWF. Tooth decay being a common problem in North West of England and each year in Manchester Dental Hospital, 1500 general anesthetics are required for extraction. The cost per case is £160 with a total annual cost of £2,40,000. Fluoridation can reduce these cases to 500-1000/year, i.e., a reduction of 35% and 67% of the cases in Manchester. The cash savings account to £84,000-£1,60,000 per annum. This study included an "opportunity cost" of considerable resources being tied up in hospital's general anesthetic sessions for dental extractions

Table 1: Published estimates of population coverage in countries

Country	Income group (World Bank 2012)	Percentage of population covered by CWF (%)
USA	Higher income countries	64
Canada		43
(Quebec < 3%)		
Republic of Ireland		73
Australia		61
New Zealand		61
Israel		75
United Kingdom		10
Singapore		100
Chile		40
Spain		10
Hong Kong		100
Panama	Upper middle-income countries	18
Malaysia		70
Brazil		41
Argentina		41
Columbia		80

CWF: Community water fluoridation

Table 2: Three scenario estimated for cost-effective measures

Decay reduction Scenario	Population < 5000 (annual cost saving per person)	Population > 20,000 (annual cost saving per person)
12% (worst scenario)	$0.85	$3.52
25% (scenario epidemiological evidence)	$15.95	$18.62
29% (best scenario)	$31.04	$33.71

rather than being available for the treatment of conditions other than tooth decay. This technical resource once freed from the burden of extractions can further be used to reduce waiting lists and delays for the other treatments. North-West region of England was compared with fluoridated West Midlands revealed significant differences amongst the patterns of expenditure on general anesthetic sessions for dental extractions. Similar results were shown by an analysis that stated 27 times greater costs are spent over tooth decay in Liverpool Primary Care Trust (non-fluoridated) as compared to Birmingham Primary Care Trust (fluoridated).[15]

A Scottish study conducted in 1980 reported that CWF resulted in a 49% saving in dental treatment costs for children aged 4-5 years and a 54% saving for children aged 11-12 years. The savings maintained even after the secular decline in the prevalence of dental caries were recognized.[16]

In Africa, a model was developed to determine the economic viability to reduce dental caries in South Africa. The model confirmed that water fluoridation is an economically viable option to prevent dental caries in South African communities even when the caries preventive effectiveness is modest.[17] Even in an era with widespread availability of fluoride from other sources, studies prove water fluoridation continues to be effective in reducing dental decay by 20-40%.[18]

A systematic review of published studies conducted in 2001 by a team of experts on behalf of the U.S. Task Force on Community Preventive Services found that fluoridation was effective in reducing tooth decay among populations. Based on the strong evidence of effectiveness, the Task Force strongly recommends that CWF should be included as a part of a comprehensive population-based strategy to prevent or control tooth decay in communities. Many authors conclude that there is strong evidence that CWF is effective in reducing the cumulative experience of dental caries within communities. On the other hand, some systematic reviews also concluded that caries preventive action should be considered along with increased prevalence of dental fluorosis. However, there was no clear evidence of the other side effects.[19]

Fluoridated water reduces the occurrence of cavities in the population by 20-40%. For some people who are more vulnerable to cavities, including the underprivileged, the elderly, and children with poor eating habits and oral hygiene, it can reduce cavities by up to 64%. Treating cavities is extremely costly. A 20-40% reduction in cavities would save a Québec family of four $320 a year on oral care. Also, being economical for everyone, water fluoridation is beneficial for society as a whole. It lightens the burden on the public health system and private insurers. It also leads to increased productivity and quality of life across society as the need for dental visits and care is reduced. 62% of Québecers supported water fluoridation in a 2010 survey.[20]

Systematic reviews from 2000 to 2007 have confirmed that fluoridation does, indeed, reduce both the severity and prevalence of tooth decay. Tooth decay can be costly to the individual and the public, not only through health insurance premiums, health departments, and community health clinics but also through indirect costs.[21]

A 2004 Canadian study concluded that every dollar invested in water fluoridation saves approximately $38 in dental treatment costs. Results from a Quebec study showed the cost-effectiveness of water fluoridation even with the conservative estimation of a 1% decrease in cavities. According to the United States Centers for disease control and prevention the costs of restorative care to avert disease outweighed the cost of water fluoridation in towns of any size, even with the widespread availability of many forms of fluoride today. Under typical conditions, the annual per person cost savings in fluoridated communities is $16 in communities of under 5,000 people and $19 in communities over 20,000. In Toronto, water fluoridation costs $0.77 annually per person while, in Peterborough, costs are $0.63. The lifetime cost of water fluoridation for one person is less than the cost of one dental filling. A cost analysis by Public Health Services in Hamilton, Ontario, found that water fluoridation reduces the costs for existing dental programs run by the city. The public health team compared four potential methods to deliver fluoride to the city's populations at high risk of oral problems, including children, seniors, and those with low income.[22]

As 69% of Australian population were receiving fluoridated water at the recommended minimum concentration of 0.7 mg/L, the study estimated that extending public water fluoridation to all Australian communities with a population of at least 1,000 people will equate to an Australian coverage of 89%. They evaluated population health impacts and cost-effectiveness of this coverage, compared to the baseline coverage of 69% in 2003. Further, they evaluated population health impacts and cost-effectiveness of extending fluoridation to all communities in Australia, regardless of population size (i.e., 100% coverage of the Australian population). Costs of public water fluoridation include the capital costs of dosing equipment and associated engineering, and the on-going operational costs of chemicals and equipment maintenance. All the three types sodium fluoride, hydrofluosilicic acid or sodium silicofluoride are used in Australia. Costs were separately computed for urban and rural Australia owing to the additional complexities of providing fluoridated water in smaller communities, such as the distance of delivering fluoridated water, hot climate, and retention of trained personnel. Cost for urban areas was A$0.26 per person based on the installation done in

Melbourne and in a trial installation in two remote Australian indigenous communities annual cost of water fluoridation was A$26 per person. Health outcomes were the disability adjusted life years and with the help of Monte Carlo simulation model probability of cost-effectiveness against a threshold of A$50,000 per DALY was calculated. The study concluded 100% probability of extending the coverage of public water supply fluoridation to all communities of 1,000 people will be cost saving to the health sector. 60% more DALYs could be avoided if CWF is extended to all communities in Australia, but the intervention has only a 10% probability of being below the cost-effectiveness threshold of A$50,000 per DALY. The addition of costs of X-ray in the treatment of dental caries adds little to the cost-effectiveness. However, if reduction in caries is demonstrated to be similar to children in adults, then the cost-saving due to fluoridation extended to all communities in Australia, regardless of community size.[23]

Drawbacks of Cost-effectiveness Analysis for CWF

Health outcomes of those born after CWF were included in studies, but there could also be a significant improvement in the health outcome in those born before it, as it might decrease decay in permanent teeth in young children and root surface decay in adults. The diffusion effect is mostly difficult to account for and has not been considered in the economic models. Moreover, none of the models have been including the intangible costs; hours lost from school and the cost of waiting period, for tooth extraction under general anesthesia. Many studies have not accounted for the indirect costs of the loss of wages by the parents when attending to dental needs of their children. These factors lead to an underestimation of the benefits conferred by the CWF.

CONCLUSION

In the scenarios where fluoride can change the chapter of oral health, a political will should be inculcated in developing countries for CWF. Significant disease risk and large population size add to the cost-effectiveness of the intervention. Therefore, larger is the population; more cost-effective is the fluoridation of drinking water. Thus, developing countries need to prioritize the interventions for preventing dental caries according to their affordability, the cost-effectiveness of the intervention, and the existing political will of the country. Availability and the population coverage of the communal water supplies should further guide the decision of adding fluoride to water.

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