# EAST LYME WATER & SEWER COMMISSION
# REGULAR MEETING
# Tuesday, FEBRUARY 24th, 2015
# MINUTES

The East Lyme Water & Sewer Commission held a Regular Meeting on Tuesday, February 24, 2015 at Town Hall, 108 Pennsylvania Avenue, Niantic, CT. Chairman Nickerson called the Regular Meeting to order at 7:47 PM following the Informational Meeting on Park Place Sewers.

PRESENT: Mark Nickerson, Chairman, Dave Bond, Steve DiGiovanna, Dave Murphy, Joe Mingo, Carol Russell, Roger Spencer

ALSO PRESENT: Joe Bragaw, Public Works Director
Attorney Edward O'Connell, Town Counsel
Anna Johnson, Finance Director
Kevin Seery, Ex-Officio, Board of Selectmen



ABSENT: Dave Zoller

**1. Call to Order**
Chairman Nickerson called the Regular Meeting of the East Lyme Water & Sewer Commission to order at 7:47 PM immediately following the Information Meeting regarding the Park Place Sewers.
The Pledge was previously observed.

**2. Approval of Minutes**
- **Special Meeting Minutes – February 3, 2015**

Mr. Nickerson called for a motion or any discussion or corrections to the Special Meeting Minutes of February 3, 2015.

****MOTION (1)**
**Mr. DiGiovanna moved to approve the Special Meeting Minutes of February 3, 2015 as presented.**
**Mr. Spencer seconded the motion.**
**Vote: 7 – 0 – 0. Motion passed.**

**3. Delegations**
Mr. Nickerson called for anyone who wished to speak under Delegations.
There were no delegations.

**4. Billing Adjustment Requests – Attachment A**
There were none.

**5. Approval of Bills – from Attachment B**
Mr. Nickerson called for a motion on the Regional Interconnection bills.

****MOTION (2)**
**Mr. DiGiovanna moved to approve payment of the following Regional Interconnection bills: Tighe & Bond, inv. #1406103 in the amount of $9,251.03 and Robinson & Cole, Inv. #50140009 in the amount of $20,000.**
**Mr. Murphy seconded the motion.**

Mr. Kargl noted that these are close out costs.

**Vote: 7 – 0 – 0. Motion passed.**

**6. Water Project Updates**

- **Regional Interconnection**

Mr. Bragaw reported that there are still a few minor punch list items that are getting wrapped up. They are pumping water to New London every day.

- **Columbus Avenue Bridge Water Main**

Mr. Bragaw said that Machnik was contracted to do repairs and has applied to Amtrak for the right of entry permit.

- **Bride lake Treatment Plant Filter Upgrades**

Mr. Bragaw reported that this project was delayed a bit due to the weather. This project will take two to four weeks to complete.

- **Sunrise Trail/Orchards Subdivision Water main Connection**

Mr. Bragaw noted that this was supposed to be a meeting that was cancelled due to Mr. Kargl's illness so there is nothing to report at this time.

- **Gold Star Bridge**

Mr. Bragaw said that Governor Malloy and Ms. Mathieu were to look into the potential of a tie-in of water systems when the repairs are done to the bridge.

**7. Finance Director Reports**

Ms. Johnson noted that they had received her report.

Ms. Russell asked if they would receive an audit report.
Ms. Johnson said that she would have something for them for their next meeting.

**8. Gateway Project Update**

Mr. Bragaw reported that last week Wednesday there was a water leak in the Gateway pump station and that a considerable amount of water was lost. Staff is working with the developer on the remedies and to make sure that something like this will not happen again. The plan is to charge for the water and for the people who were out working on it.

**9. Communications**

- **See Communications Log**

There were no comments on the log.

**10. Chairman's Report**

Mr. Nickerson noted that the Gateway leak was significant and will be at the cost of the developer. The Town's department heads were on site and worked together to remedy the situation.

He noted that Ms. Russell had provided everyone with a copy of some fluoride information and that she would briefly explain the copies that they had received.

Ms. Russell explained the emails and the 'Critique of recent economic evaluation of community water fluoridation' that she had provided them with. (All attached at end of minutes)

**11. Staff Updates**

- **Water Department Monthly Reports**

Mr. Murphy asked for any feelings they had on how the system is holding up with the brutal weather they have been having.

Mr. Bragaw said that things have held up relatively well considering the serious weather. He noted that the Water & Sewer and Public Works employees have been working together during these brutal times to keep things going.

- **Sewer Department Monthly Reports**

There were no comments.

**12. ADJOURNMENT**

Mr. Nickerson called for a motion to adjourn.

****MOTION (3)**
**Mr. DiGiovanna moved to adjourn the February 24, 2015 Regular Meeting of the East Lyme Water & Sewer Commission at 8:25 PM.**
**Mr. Bond seconded the motion.**
**Vote: 7 – 0 – 0. Motion passed.**

Respectfully submitted,

Karen Zmitruk,
Recording Secretary

**Subject:** Fluoride Research

**From:** Carol Russell (carolfrussell@sbcglobal.net)

**To:** intern@llhd.org;

**Date:** Tuesday, February 24, 2015 12:56 PM

Jessica,

Recently I became aware of two new studies related to community water fluoridation and two documents which provide additional historical background of interest.

Each of the two new studies were published in the International Journal of Occupational and Environmental Health in 2014. They are:

1. A New Perspective on Metals and Other Contaminants in Fluoridation Chemicals by Phyllis J. Mullenix. The abstract can be accessed on-line at http://www.ncbi.nim.nih.gov/pubmed/24999851. The object of the study was to provide an independent determination of the metal content of raw fluoride products, specifically focusing on samples of hydrofluorosilicic acid (HFS) and sodium fluoride (NaF). All samples tested had "a surprising amount of aluminum." In addition, all of the HFS samples contained arsenic or arsenic and lead. Two of the three NaF samples apparently did not test positive for arsenic and/or lead but did contain barium instead. Since the MCLG for both arsenic and lead in drinking water is zero, the results regarding the presence of these contaminants are troubling. Also, based on the rat study by Julie A. Varner, William Horvath, and Robert Isaacson in Brain Research (volume 784:1998), the aluminum finding in all of the samples tested is also troubling. The Varner study identified that fluoride seems to enable more aluminum to cross the blood-brain barrier and become deposited in the brain with adverse effect.

2. A Critique of Recent Economic Evaluations of Community Water Fluoridation by Lee Ko and Kathleen M. Thiessen. An abstract of this study can also be accessed through PubMed, but I accessed the full text for download at http://www.maneyonline.com/doi/pdfplus/10.1179/2049396714Y.0000000093. This economic analysis challenges the long-standing claims made by the CDC that every dollar invested in water fluoridation saves $38 in costs for dental treatment. Ko and Thiessen conclude the savings at best may be $3 per person per year (PPPY), and if the estimated costs for treating dental fluorosis are factored into the analysis, the potential savings are reduced to zero. Please note, Dr. Thiessen served on the twelve member panel of experts who issued the 2006 NAS/NRC report, Fluoride in Drinking Water, a Review of the EPA's Standards.

The two historical documents which you may find of interest are:

1. A copy of the opening statement given by Dr. J. William Hirzy on June 29, 2000 when he testified about water fluoridation concerns before the US Senate Sub-Committee on Wildlife, Fisheries, and Drinking Water. Dr. Hirzy was speaking in his capacity as the vice-president of the union which represents the scientists and other professionals at the US EPA headquarters in Washington, DC. He explains (with cited works) why his union membership recommends a national moratorium on water fluoridation pending epidemiological studies that use dental fluorosis as an index of exposure to

Submitted
Attachment Wes 2/24/15

determine if there are links between fluoride over-exposure and the large number of US children with hyperactivity-attention deficit disorder, the national rise in autism, the rise in bone fractures among our young athletes and military personnel, and the earlier onset of puberty among our young women. A copy of Dr. Hirzy's entire opening statement with cited references can be accessed on-line at http://inteu280.org/Issues/Fluoride/629FINAL.htm.

2. A copy of an excerpt from the Federal Register: December 4, 2000 (Volume 65, Number 233) which gives notice that aluminum complexes found in drinking water, specifically aluminum fluoride and aluminum citrate are recommended for testing by the National Toxicology Program. Apparently this research was requested by the US EPA and the National Institute of Environmental Health Sciences in follow-up to the concerns raised by the Varner et al study (1998). The notice in the Federal Register can be accessed on-line at http://www.actionpa.org/fluoride/aluminum.htm#fedreg.

Please confirm whether or not this information has reached you in time for consideration/inclusion in your final report. Also, please let me know if you have any difficulty accessing the referenced documents on-line.

Thank you.

Carol

February 24, 2015

To: My fellow Water & Sewer Commission Members

Fr: Carol Russell

Re: Study Challenging the Cost Effectiveness of Community Water Fluoridation

Enclosed for your information is a 2014 study published in the *International Journal of Occupational and Environmental Health* titled, A **Critique of Recent Economic Evaluations of Community Water Fluoridation**.

This detailed analysis challenges the long-standing claims made by the CDC that every dollar invested in water fluoridation saves at least $38 in costs for dental treatment. The 2014 economic assessment finds that at best the savings may be $3 per person per year (PPPY), and if the estimated costs for treating dental fluorosis are factored into the analysis, potential savings are reduced to zero. The conclusion of the study states in part:

> *"We have shown that the promise of reduced dental costs was based on flawed analyses. In particular, the primary cost-benefit analysis used to support CWF in the U.S. assumes negligible adverse effects from CWF and omits the costs of treating dental fluorosis, of accidents and overfeeds, of occupational exposures to fluoride, of promoting CWF, and of avoiding fluoridated water."*

One of the co-authors of the 2014 cost analysis is Kathleen M. Thiessen who served on the twelve member panel of the National Academies of Science/National Research Council which issued the 2006 report, **Fluoride in drinking water: a scientific review of the EPA's standards**. As you are aware, it is the findings of adverse health implications in this 2006 NAS/NRC report which triggered a US EPA re-evaluation of both the Maximum Contaminant Level (MCL) and Maximum Contaminant Level Goal (MCLG) for fluoride in drinking water, and which led HHS in January 2011 to propose a reduction of the CDC standard for optimal water fluoridation from a range of 0.7 mg/L – 1.2 mg/L to a set standard of 0.7 mg/L. To date, the EPA review remains on-going and the HHS has not yet issued a final rule regarding the reduced 0.7 mg/L standard. Pending a final rule on the proposed reduction to the CDC standard, the CT law governing mandatory water fluoridation for dental health continues to require maintaining a fluoride range of 0.8 to 1.2 mg/L.

At our last meeting we learned that the CDC and the CT Department of Public Health, Office of Oral Health have commended the Town of East Lyme with a Water Fluoridation Award Certificate for maintaining an optimum fluoride level for 12 consecutive months in 2013. The notification letter reiterates the CDC claim regarding the $38 savings in dental costs for each $1 invested in fluoridation. The letter also makes no mention that the current standards governing the optimal levels for fluoride in drinking water may not provide a sufficient margin of safety for certain adverse health risks – and have been under review for downward modification since release of the 2006 NAS/NRC report.

Attachment Submitted WPCS 2/24/15

Review

# A critique of recent economic evaluations of community water fluoridation

**Lee Ko[1], Kathleen M. Thiessen[2]**

[1]Oakland, CA, USA, [2]Oak Ridge Center for Risk Analysis, Oak Ridge, TN, USA

**Background:** Although community water fluoridation (CWF) results in a range of potential contaminant exposures, little attention has been given to many of the possible impacts. A central argument for CWF is its cost-effectiveness. The U.S. Government states that $1 spent on CWF saves $38 in dental treatment costs.
**Objective:** To examine the reported cost-effectiveness of CWF.
**Methods:** Methods and underlying data from the primary U.S. economic evaluation of CWF are analyzed and corrected calculations are described. Other recent economic evaluations are also examined.
**Results:** Recent economic evaluations of CWF contain defective estimations of both costs and benefits. Incorrect handling of dental treatment costs and flawed estimates of effectiveness lead to overestimated benefits. The real-world costs to water treatment plants and communities are not reflected.
**Conclusions:** Minimal correction reduced the savings to $3 per person per year (PPPY) for a best-case scenario, but this savings is eliminated by the estimated cost of treating dental fluorosis.

**Keywords:** Water fluoridation, Economic evaluation, Cost of water fluoridation, Caries prevention, Cost benefit, Cost effectiveness, Effectiveness in adults, Dental fluorosis

## Introduction

The USA and several other countries practice community water fluoridation (CWF), which has been promoted as the preferred solution to reduce caries for over half a century.[1] Approximately two-thirds of the U.S. population is treated in this manner according to the Centers for Disease Control and Prevention (CDC).[2] Community water fluoridation programs have increased water fluoride concentrations to 0.7–1.2 mg/l [0.7–1.2 parts per million (ppm)], although a 2011 proposed recommendation, if finalized, would decrease this to 0.7 mg/l.[3]

Community water fluoridation is a unique delivery mode of public health care in that fluoride is administered to everyone who drinks the water, regardless of dental status or needs, and at an amount proportional to the water consumed from the fluoridated source, which can range from zero to several liters per day.[4] At the same time, because most community water is not consumed by people, CWF results in dispersion of a regulated contaminant, fluoride, to the greater environment via wastewater treatment plants, storm sewer systems, and use on lawns and gardens. Fluoridation chemicals typically contain other regulated contaminants (e.g. arsenic), extending the possibility of human exposures and environmental dispersal.[5–8]

A central argument for using CWF to reduce tooth decay is the cost savings claimed by the CDC:[9] Every $1 invested in this preventive measure yields approximately $38 savings in dental treatment costs. This argument is repeated by the majority of state governments (Appendix 1) and is frequently cited by proponents to argue for initiating or maintaining CWF.

All $ signs in this paper refer to US$ unless otherwise indicated. However, statements such as $1 saves $38 are currency neutral.

The CDC's estimate is calculated from the per person per year (PPPY) savings reported by Griffin *et al.*:[10] With base-case assumptions, the annual per person cost savings resulting from fluoridation ranged from $15.95 in very small communities to $18.62 in large communities.[10i] Table 1 summarizes Griffin *et al.*'s results by population size. The CDC derived the $1-saves-$38 claim by scaling the $0.50 cost and the $18.62 savings estimate for large systems (>20,000 people) to get $0.50 : $18.62 ≈ $1 : $38. However, this derivation is not valid because it implies

Correspondence to: Kathleen M. Thiessen, Oak Ridge Center for Risk Analysis, 102 Donner Drive, Oak Ridge, TN 37830, USA. Email: kmt@orrisk.com

[i]CDC focused on the smallest and largest systems:[9] for a population <5,000 people, the net savings is $19.12 − $3.17 = $15.95; for a population >20,000 people, the net savings is $19.12 − $0.50 = $18.62.




Attachment submitted WLOS 2/24/15

$$\$72\left(\frac{1}{1.04}+\frac{1}{1.04^{13}}+\frac{0.90}{1.04^{25}}+\frac{0.86}{1.04^{37}}+\frac{0.79}{1.04^{49}}\right) = \$159.61 \quad (1)$$

Thus the last replacement takes place at age $12.5+1+(4\times 12)=61.5$ in this example. The cost for each filling or replacement filling is adjusted by a factor (the numerator of the term) representing the probability that the tooth remains at the replacement age.

Step 3: Calculate the national average, using the population distribution in Table 3. Use the midpoint to represent the group in each bracket, e.g. Equation (1) gives the lifetime benefit of an averted decay surface for the 6–19 age group, based on the midpoint, age 12.5 years.

Step 4: The calculation is repeated for each age bracket, except the first and the last age brackets as described by Input (h) in Table 2. Summing the weighted costs gives $100.62 as the national average lifetime cost averted per decayed surface.

Step 5: As CWF averts 0.19 decayed surfaces PPPY, as described by Input (g), the benefit of CWF is thus

Gross saving=$100.62 × 0.19=$19.12 PPPY

## Costs

Griffin *et al.*[10] based their cost estimates for CWF on Ringelberg *et al.*,[14] except that the numbers were adjusted to 1995 dollars, and a different grouping of community sizes was used. Griffin *et al.* devote one paragraph to their cost estimates.[10]

### *Ringelberg* et al.[14]

Ringelberg *et al.* used data for 44 Florida communities to estimate CWF costs. (Florida's phosphate industry is the largest U.S. producer of fluoridation chemicals.)[15,16] Ringelberg *et al.*'s improved estimates included costs for bulk storage and containment, labor, and opportunity costs of capital investment, and were based on a larger number of communities than previous estimates.[13] The estimated average cost increased from $0.49 PPPY[13] to $1.25 PPPY.[14] With phrases such as "allowable initial one-time costs … were documented by copies of actual invoices for equipment and services" Ringelberg *et al.*[14] appears detailed and based on actual data. However, these invoices were obtained from the Florida public health dental program, which has the authority to approve costs for communities seeking state grants to implement CWF,[17] and thus reflect costs allowed by the state dental program rather than actual costs.

Ringelberg *et al.*[14] used a 15-year life, with no remaining value, for initial implementation costs, and used 2.4% of the initial costs to calculate the maintenance and repair costs. Labor costs provided by CDC's fluoridation engineer were based on 1 hour per day for all systems and rates of $7 per hour for small systems and $9 per hour for medium and large systems. (Note that, in contrast, Input (d) in Table 2 uses $18 per hour to calculate CWF benefit.) We will show that this is a simplistic and unrealistic view of what is involved in CWF operations.

### *Reality on the ground*

In 2010, amid a budget crisis, the City of Sacramento, CA, instructed all departments to review programs and services. Mr. Marty Hanneman, then Director of the Department of Utilities, wrote in a memo to the City Council:[18]

> *The City of Sacramento has been fluoridating its water supplies just over 10 years. Within that time, the actual cost of operating and maintaining the fluoridation systems has proven to be considerably more than the initial estimate. … The fluoridation infrastructure at the E.A. Fairbairn Water Treatment Plant is overdue for replacement and will be very expensive to replace. … Fluoridating water is a very costly and labor intensive process and requires constant monitoring of fluoride concentrations to ensure proper dosages. … The chemical is very corrosive, so all equipment that is used in the fluoridation process has a very short life expectancy and needs to be replaced frequently. … but also causes frequent and complex system failures.*

This was echoed by Mr. René Fonseca of Carroll-Boone Water District in Eureka Springs, AR, which was required by a 2011 State mandate to begin CWF (Fonseca, 2012, private communication):

Table 3 Griffin *et al.*[10] weighted per person discounted lifetime cost of carious surface initially occurring at various ages

| Age (years) | Discounted expected lifetime cost of decayed surface ($) | 1996 U.S. population (%) | Weighted cost ($) |
|---|---|---|---|
| 0–5 | | 8.4 | |
| 6–19 | 159.61 | 20.4 | 32.56 |
| 20–24 | 146.95 | 6.8 | 9.99 |
| 25–29 | 144.86 | 7.2 | 10.43 |
| 30–34 | 128.24 | 8.3 | 10.64 |
| 35–39 | 127.76 | 8.5 | 10.86 |
| 40–44 | 105.12 | 7.7 | 8.09 |
| 45–49 | 105.55 | 6.6 | 6.97 |
| 50–54 | 106.42 | 5.2 | 5.53 |
| 55–59 | 69.23 | 4.2 | 2.91 |
| 60–64 | 69.23 | 3.8 | 2.63 |
| 65+ | | 12.8 | |
| Total | | 100 | 100.62 |

**Table 4 Examples of fluoridation cost estimates**

| Water districts | Year Est | Pop (In thousands) | Reported Implementation (I) and annual operation and maintenance (O) costs | PPPY ($) 15 years, 4% (I) |
|---|---|---|---|---|
| Napa, CA[34] | 2003 | 77 | I: $1M; O: $150,000 | 3.07 |
| New York, NY[35] | 2008 | 8,350 | I: $12.57M (2 plants); O: $11.14M (chemicals) | 1.45 |
| San Jose, CA[36] | 2011 | 1,000 | I: $23M; O: $1.732M (Wells only) | 3.72 |
| Watsonville, CA[32] | 2011 | 51 | I: $50/person; O: $4/person | 8.33 |
| Portland, OR[37] | 2012 | 900 | I:$3.5M–$7.6M, O: $575,000 | 0.98–1.37 |
| Carroll-Boone, AR[33,38] | 2012 | 25 | I: $894,000–$1.23M | 3.09–4.26† |
| Davis, CA[39] | 2013 | 67 | I: $1.1M–$2.4M; O: $228,800–$240,700 | 4.84–6.69 |
| Riverton, UT[20] | 2000 | 35 | I: $90,000 (estimate) | 0.22† |
| | 2001 | | I: $200,000 (actual) | 0.49† |
| | 2008 | | I: $1,174,278 (actual w/2 new buildings) | 2.90† |
| Jordan Valley, UT[40] | 2000 | 82 | I: $56,000–$2.1M (estimates) | 0.06–2.22† |
| | 2004 | | I: $2.45M; O: $297,000 (actual) | 6.21 |

†Estimates do not include operation and maintenance costs.

To calculate the PPPY costs, we allocated the total population of Sacramento, 466,000 people (2010 U.S. Census), to the 27 wells and to the Fairbairn WTP using the percentages of total water supplied of 14% and 42%, respectively. The allocated populations are 65,000 and 196,000, respectively. Dividing the total costs by population and number of injection sites, we obtain a cost estimate of $15.38 and $2.37 PPPY for a single-injection point water system serving 2,400 and 196,000 people, respectively. (Systems serving 2,400 people are not rare. Of the 44 systems in Ringelberg *et al.*[14] three systems had smaller populations and seven systems had smaller populations per injection site.)

We considered whether to adjust for the cost of living in Sacramento and determined that there was no need. The cost of living for Sacramento is 8% higher than the U.S. average.[31] This differential, however, is easily offset by other considerations, e.g. the use of a 2.5% instead of 4% discount rate. The cost projection also assumes that the Health Department continues to waive a requirement for certain standard equipment. In addition, actual bids for construction may turn out to be much higher than the engineer's estimates.[32,33] Finally, it was unknown whether implementing the recommendations would solve the city's fluoridation issues.[29]

A small water system serving more than 2,400 people is expected to cost less than $15.38 PPPY. Similarly, many large systems serve less than 196,000 people and are expected to cost more than $2.37 PPPY. (Note that large water districts serving more than 196,000 people will not necessarily cost much less than $2.37 PPPY, because such water districts often have multiple treatment plants and/or auxiliary wells, which make them equivalent to a smaller single-injection point system). Therefore, reasonable cost estimates for the smallest (<5,000 people) and largest (>20,000) systems in Table 1 would be about $10 and $3 PPPY, respectively.

Strictly speaking the annual cost projections provided by Black and Veatch are 20-year financing costs. At the end of the 20-year period, components such as new buildings may still have value. However, given the ability of the chemicals to degrade concrete (Appendix 3 items 17 and 19), significant annual maintenance and repair costs after the financing period are expected. In addition, circumstances could require a water system to implement major infrastructure changes to their fluoridation facilities. Sacramento is such an example. Despite implementing fluoridation comparatively late (around 2000), the city has already endured major infrastructure adjustments and is considering more, long before the 20-years projection period. Finally, it is possible that a system may discontinue CWF; in that case, buildings constructed specifically for CWF may hold little value.

### *Other estimates*

The Black and Veatch report cited above is valuable in that it is recent, comprehensive, detailed, and authored by a firm that has consulted on other fluoridation programs. In general, reliable cost information for CWF programs is difficult to obtain, and information provided in response to a request is often limited to the cost of the fluoride chemicals. In Table 4, we present additional cost information and estimates collected from various sources.[20,32–40] The majority of these are cost estimates prior to implementation; New York and some Utah figures show actual costs. Costs are reported either for implementation (*I*) or for annual operation and maintenance (*O*). For convenience, we calculate a PPPY cost by annualizing the implementation cost (*I*) using a 4% discount rate over 15 years[vi] (meaning $100 annualizes to $8.65) and normalizing the total, i.e., dividing the annualized *I* plus *O*, if available, by

[vi] The service life of fluoridation equipment depends very much on the component and on the service conditions. According to Black and Veatch,[29] only a few components in indoor setups can expect a service life of 15 years or more, and some components have a service life of only 5–10 years in an outdoor setup.

Crowns are "usually used as a last resort because they can be a threat to tooth vitality."[44]

For this analysis, we assume that each moderate or severe fluorosis tooth receives a porcelain veneer treatment. We further assume that a child with the condition gets the first treatment at age 13.5 years, and the veneers are replaced every 12 years. The lifetime cost of a veneer is calculated using equation (1), except the $72 is replaced by the cost of a veneer, for which we use a lower-end number of $1,000. This gives a lifetime cost of $2,217. Dean's Enamel Fluorosis Index, the most widely used classification of dental fluorosis, is assigned on the basis of the two most-affected teeth.[44] Thus, the lifetime cost of veneers for a child with moderate or severe fluorosis would be at least $4,434.

Beltrán-Aguilar *et al.*[47] reported that 3.6% of U.S. children ages 12–15 years in 1999–2004 had moderate or severe dental fluorosis, but did not provide information on the fluoridation status of the affected children. At most about 60% of the U.S. population received fluoridated water during the time period when these children were susceptible to development of fluorosis.[viii] Both the prevalence and the severity of dental fluorosis are correlated with the fluoride concentration in drinking water.[45,49,55] If all of the cases of moderate and severe dental fluorosis occurred in fluoridated rather than nonfluoridated areas, then at least 6% of children in fluoridated areas would have moderate or severe fluorosis.[ix] For our calculations, we have assumed that 5% of children in fluoridated areas have moderate or severe fluorosis. From Table 3, the percentage of children at age 13.5 years is about 20.4% / 14 = 1.46%. Thus the minimum cost of treating dental fluorosis is estimated to be $4,434 × 1.46% × 5% = $3.24 PPPY.

### Other costs

There are other costs missing from the conventional cost-benefit analyses of CWF (Appendix 2). The NRC's 2006 report on fluoride exposures and toxicity found that the U.S. Environmental Protection Agency's (EPA) drinking water standard for fluoride was not protective of human health.[44] The NRC did not evaluate CWF for safety or efficacy, but the report showed that the average fluoride exposures associated with adverse health effects are within the expected range of fluoride intake for populations with fluoridated water, especially for infants, young children, and people with high water intake.[44,56x] Peckham and Awofeso's recent review specifically concluded that fluoridation has "significant costs" in relation to adverse effects on human health, although these costs were not quantified.[57]

Health risks to water plant operators are not included in most discussions of CWF, but these individuals may receive substantial occupational exposures to fluoride if the safety infrastructure or training is not adequate or if equipment malfunctions.[58,59]

Most of the fluoridation chemicals used in the U.S. are byproducts of the phosphate fertilizer industry in North America or Asia.[15,16,60] Since only a small percentage of municipal water is actually consumed by people, the practice results in wide dispersion of a regulated pollutant into the environment via local water districts. Fluoride pollution may result in serious ecological risks to aquatic organisms.[61]

Fluoride is regulated by the U.S. EPA as a contaminant in drinking water[62] and as an air pollutant.[63] A number of fluoride compounds are considered hazardous substances with assigned Reportable Quantities.[64] In addition, fluoridation chemicals often contain other regulated contaminants.[5–8] Hirzy *et al.*[65] estimated that the typical concentration of arsenic in the major fluoridation chemical (HFSA) could be responsible for several excess lung and bladder cancers per year in the U.S. and the consequent costs of treatment.

Political costs have at times been acknowledged but not included in CWF analysis.[10] This category goes beyond costs associated with fluoridation referenda to include government expenditures for promoting fluoridation programs, costs associated with lobbying elected officials on this issue, legal challenges to fluoridation programs, and possible personal injury litigation involving workers or members of the public.[66–70]

There are also costs associated with avoiding fluoridated tap water, either by need or by choice. These are all societal costs of CWF that should not simply be excluded or assumed negligible without examination.

## Benefits

The primary benefit attributed to CWF is prevention of caries, although a major review in the United Kingdom reported no relevant studies of "evidence level A (high quality, bias unlikely)" and expressed surprise that little high quality research had been undertaken.[71] Caries prevention is commonly assessed in terms of a reduction of decayed, missing, or filled

[viii] Infants and young children are most at risk for exposures leading to dental fluorosis.[45] Children ages 12–15 years when surveyed between 1999 and 2004 were born between 1984 and 1992. Centers for Disease Control and Prevention's data indicate that 53–60% of the U.S. population between 1984 and 2002 received fluoridated water.[54]

[ix] 3.6 / 53% = 6.8% and 3.6 / 60% = 6%.

[x] People with high water intake include athletes, outdoor workers, military personnel, and people with medical conditions such as diabetes insipidus or diabetes mellitus.[44] People with impaired kidney function may have high water intake and might also have reduced urinary excretion of fluoride.[44]

may or may not be included. Study parameters are often poorly defined and confounding factors not typically examined.

Often a percentage value is produced from some relative differentials and referred to as CWF effectiveness, despite that the percentages come from different situations. Some may argue that since all the different kinds of studies point to similar ranges of effectiveness, it is proof that the effectiveness estimates are robust. However, the premise of this argument is false.

*First: Units.* Units of measures do affect the results. An independent investigation of the 1987 NIDR data using DMFT instead of DMFS led to the conclusion of no effectiveness.[78] When asked about results for teeth, Brunelle was quoted to have said that they "are in a box somewhere" and she "could not remember what exactly the results were" and that the decay rate for teeth "is rather low so that there is very little difference in most anything."[79] Truman *et al.*[80] estimated effectiveness in units of teeth from data reported in a number of studies (Table 5) even if a study reported data in both teeth and surfaces.

Studies reporting results in teeth were more common in the past. The focus shifted toward surfaces as the prevalence of caries dropped and caries became concentrated in a small subset of the population.[81] Measuring caries in units of surfaces gives heavy weight to the small percentage of people with high levels of decay.[xii]

*Second: Lengths of exposure.* There are two relevant exposures: exposure to carious influence and exposure to CWF.

Exposure to caries is determined in part by the time a tooth erupts. Usually age is used as a surrogate for the length of this exposure. If a study examines subjects of a range of ages and one effectiveness number is to be presented, which age is selected or how different age groups are weighted to calculate an average can produce different results. Appendix 4 provides examples of studies showing differences in caries experience that were attributed to CWF exposures, when the results may be better explained by differences in age distributions of the populations being compared.

Exposure to CWF is often handled by comparing only those with lifetime exposure to those with no exposure. However, if a result is contingent on excluding partial exposure it weakens the argument for CWF as a public policy. More importantly, this approach introduces a probable bias if the two exposures (to caries and to CWF) are not independent. Evidence indicates that ingested fluoride may delay tooth eruption,[44,45,85] which would affect caries scoring by giving the appearance of less decay for a given age.[44,45] Komárek *et al.*[86] used data for actual tooth eruption time and found no convincing effect of fluoride intake on caries development. Weaver[87] indicated that "the caries inhibitory property of fluorine seems to be of rather short duration," consistent with a delay in the exposure of permanent teeth to a cariogenic environment.

*Third: Methods.* The methods of determining an effectiveness value are even more problematic, especially in regard to policy references. This is best demonstrated by an examination of Truman *et al.*,[80] which was co-authored by Griffin, other CDC personnel, and a Task Force appointed by the Director of the CDC. The Task Force was established by the U.S. Department of Health and Human Services (HHS) in 1996 to provide recommendations for community preventive services, programs, and policies. Reported in 2000, the findings of the Task Force's systematic review[88] became the main results of Truman *et al.*[80] on CWF effectiveness, as well as the basis for Healthy People[xiii]2010's goal of increasing CWF in the U.S. to cover 75% of the population.[91] Healthy People 2020[92] continues with a goal of increasing coverage to 79.6%.

Truman *et al.*[80] based their conclusion on 14 studies in three groups (Table 5):[76,93–105]

- Studies starting or continuing CWF with before and after measurements (Group A-On)
- Studies stopping CWF with before and after measurements (Group A-Off)
- Studies starting or continuing CWF with only post measurements (Group B-On)

They calculated a number of "estimates of effectiveness" from the studies using two formulas, one for Group A (before-and-after) and one for Group B (post measurements only). The measures were mostly DMFT or dft.

The median of estimates was taken to represent the CWF effectiveness for each study type; the results were 29.1% for Group A-On, 50.7% for Group B-On, and 17.9% for Group A-Off. (The 29.1% and 50.7% figures were presented by the Task Force.)[88] With these numbers the authors concluded "strong evidence shows that CWF is effective." This conclusion is not valid. We describe three areas of problems below (details provided in Appendix 5).

[xii] Proponents often appeal to sympathy for young children with high levels of tooth decay to argue for CWF.[82] However, early childhood caries (ECC) is not prevented by fluoride.[83,84]

[xiii] CDC's "Healthy People" series "provides science-based, national goals and objectives with 10-year targets designed to guide national health promotion and disease prevention efforts to improve the health of all people in the United States."[89] One goal of Healthy People 2000, 2010, and 2020 has been to "increase the proportion of the U.S. population served by community water systems with optimally fluoridated water."[90–92]

caries increment from the NSOH would overestimate current increment. Secular decline[11,72] refers to the widespread decline in caries observed in nonfluoridated areas. It means that when a 6-year old living in a nonfluoridated area today grows up to be 17 years old, he will likely have fewer caries than his 17-year old neighbor has today. Thus using the latter to represent the former (cross-sectional data) overstates the incidence of caries.

### The Effectiveness

As with the Incidence, Griffin *et al.*[10] presented three cases for Effectiveness, all essentially from Brunelle and Carlos.[77] The 1987 NIDR Survey examined 39,206 children, of whom about 92% had complete residence histories. Brunelle and Carlos[77] analyzed data from 16,398 children with either lifelong exposure or no exposure to CWF and presented mean DMFS by age (see Table 12) and by region (Table 7). The national averages from this subset of data showed a difference of 0.6 DMFS, or 18%, between the two exposure groups. By further restricting their sample to a subset of 5,954 children (reportedly by removing all data points with any supplemental fluoride exposure), the 18% difference was raised to 25%. No age or regional distribution was shown for this restricted set of data. Griffin *et al.*[10] took this 25% as the base-case Effectiveness.

Brunelle and Carlos[77] ignored 58% of the total data (or 55% of those with complete residence histories), despite that partial exposure data from this national survey can be analyzed and are informative.[78] It is therefore questionable if the 18% reduction in DMFS represents the findings of the survey. Even more troublesome is the 25% adopted as the base-case Effectiveness, as it ignores 85% of the survey data.

The best- and worst-case Effectiveness, 29% and 12%, respectively, were supposed to be calculated from the best three and the worst four effective regions. However, the worst four regions (I, II, III, and V in Table 7) would average closer to 6% than 12% using regional population data found elsewhere.[106] It appears that Griffin *et al.*[10] may have removed Region III (Midwest) from the calculation given the comment: "The negative effectiveness value in the Midwest may have been due to small sample size because few children living in this region actually received nonfluoridated water." This criticism would equally apply to the highest-effectiveness Region VII (Pacific), as few children in this region received fluoridated water, but it was not considered a problem.

### *Lack of evidence for adults*

Assumption (2) and Input (h) in Table 2 assume the same CWF benefit to age 64 years, despite that estimates of Effectiveness were derived from a children's survey. Two adult studies[51,107] were cited to support this extrapolation. However, the data presented in Grembowski *et al.*[107] do not support its conclusion, and Eklund *et al.*[51] appear to be mis-cited in addition to the fact that the concentrations involved, 3.5 versus 0.7 mg/l, are irrelevant to an evaluation of CWF. We examine each of these studies below.

That few adult studies are available has been noted elsewhere. Garcia[13] stated that very limited information exists in the literature about caries incidence in adults, and Newbrun[108] identified only seven adult studies; he commented that very few acceptable data exist and that the comparison was either between those living in low-fluoridated and high-fluoridated (greater than optimal) communities or between those living in optimally fluoridated and high-fluoridated communities. Thus, it is not surprising that Truman *et al.*[80] included "What is the effectiveness of CWF among adults aged $\geq$ 18 years?" among important unanswered questions.

More recently Slade *et al.*[109] presented an analysis of Australian data from a 2004–2006 survey, and Griffin *et al.*[110] did a meta-analysis of several earlier studies. We examine these papers in detail in Appendix 4. Among other problems, both articles (and several studies included in the latter) failed to properly account for different age distributions.

### Grembowski *et al.*[107]

This study examined Washington state employees and spouse-dependents aged 20–34 years living in Olympia, Seattle, or the Pullman, WA/Moscow,

**Table 7 Mean DMFS of each U.S. region by CWF status (1986–1987) from Brunelle and Carlos[77]**

| Region | Lifelong exposure | No CWF exposure | Population with CWF (%) | Relative Diff (%) |
|---|---|---|---|---|
| I | 3.11 | 3.45 | 55 | 9.9 |
| II | 3.08 | 3.42 | 49 | 9.9 |
| III | 2.86 | 2.69 | 74 | −6.3 |
| IV | 2.75 | 3.60 | 54 | 23.6 |
| V | 2.49 | 2.71 | 59 | 8.1 |
| VI | 2.36 | 3.07 | 34 | 23.1 |
| VII | 1.42 | 3.61 | 19 | 60.7 |
| U.S. | 2.79 | 3.39 | 53 | 17.7 |

DMFS: decayed, missing, or filled tooth surfaces; CWF: community water fluoridation.

**Table 10** Comparison of mean decayed, missing, or filled teeth (DMFT) and selected components by city and age of lifelong resident adults from Eklund *et al.*[51]

| Age group | Decayed | | Missing | | Filled | | DMFT | |
|---|---|---|---|---|---|---|---|---|
| | L | D | L | D | L | D | L | D |
| All | 0.8 | 0.6 | 2.8 | 2.4 | 2.9 | 5.4 | 7.0 | 8.7 |
| 27–40 | 0.4 | 0.7 | 1.3 | 1.6 | 3.6 | 4.4 | 5.9 | 6.9 |
| 41–50 | 1.5 | 0.5 | 2.4 | 3.7 | 2.4 | 6.6 | 7.1 | 11.1 |
| 51–65 | 0.6 | 0.2 | 5.6 | 3.3 | 2.2 | 7.3 | 8.8 | 11.1 |

L: Lordsburg; D: Deming

*possible to determine whether all filled teeth had a carious lesion as defined by the diagnostic criteria.*

In contrast, they concluded that differences between the communities are "obvious and unequivocal" for dental fluorosis. Indeed, no one from Lordsburg escaped dental fluorosis and 76% of them were severe or very severe. At the lower concentration of 0.7 mg/l, Deming had 16% dental fluorosis, including some moderate cases.

Table 10 shows that the higher DMFT in Deming was due to a much higher filled component across all age groups. As with Grembowski *et al.*,[107] Eklund *et al.*[51] noted that the filled component is influenced by dentists' treatment decisions. On the other hand, the oldest age group in Lordsburg had many more missing teeth, similar to other studies that found a relationship between high fluoride exposure and tooth loss.[112,113]

## *Costs of dental treatments*

Costs of dental treatments consist of dental fees and lost productivity. Griffin *et al.*[10] used survey data for the dental charge,[114] which may differ from the charge in a competitive market, and therefore not be representative of the resource costs. Assumption (6) holds that all fillings are single-surface fillings. This overestimates dental costs, since a three-surface cavity does not require three times more resources than a one-surface cavity requires, in terms of either time lost or dentist's effort. In fact, the fees in the survey were $53.60 and $83.27 for one- and three-surface amalgam fillings, respectively.[114] Griffin *et al.* used the U.S. average hourly wage for the productivity cost. Average hourly wage overestimates productivity cost, since another central argument for CWF is equity, i.e. it is supposed to be particularly beneficial to low-income people.

## *Minimal corrections*

In this section, we show how the defects in the derivation of CWF benefits, or gross savings, discussed above can be corrected.

### Costs of dental treatments

The resource value of a treatment is best represented by the allowable charge from a widely accepted insurance fee schedule. Fee schedules may vary for a number of reasons, but the relative values among closely related procedures tend to be stable.

Table 11 shows the allowable charges for amalgam fillings from two large payers, one from a public payer[115] and one from the largest commercial payer (private communication). The payments are not proportional to the number of surfaces involved, and Assumption (6) in Table 2 clearly overestimates the dental charges. Using these relativities and two assumptions a new gross savings estimate will be provided.

Our first assumption is that the average number of decayed surfaces per filling is two and the average dental fee is about that of a two-surface filling. For example, a 40% : 30% : 20% : 10% distribution of one-, two-, three-, and four-or-more-surface fillings, respectively, produces such averages using the relativities in Table 11. Our second assumption is that each equivalent two-surface filling costs 1 hour in lost wages.

Brown and Lazar[114] reported that there were more two-surface fillings than one-surface fillings in the 1990 survey and that the number of one-surface fillings has been dropping faster despite a vastly increased number of examinations. Since the more the distribution is weighted toward more-surface decays the less gross savings there are, our first assumption likely overestimates gross savings.

**Table 11** Allowed charges and their relativities for amalgam fillings from two insurance fee schedules

| Surfaces | Denti-Cal (CA Medicaid, $) | Delta Dental (San Diego area, $) |
|---|---|---|
| One | 39 (1) | 72 (1) |
| Two | 48 (1.23) | 87 (1.21) |
| Three | 57 (1.46) | 108 (1.50) |
| Four or more | 60 (1.54) | 118 (1.64) |

Thus the gross savings of $6.08 PPPY becomes $1.97, $3.20, $4.50, or $6.08 PPPY if the CWF benefit extends to age 19, 29, 39, or 64 years, respectively.

## Discussion

### Corrected net savings

In the previous section, we showed how several defects in the derivation of the $19.12 PPPY estimate of CWF benefit can be corrected. The corrected gross savings estimate is $1.97, $3.20, $4.50, or $6.08, if the CWF benefit extends to age 19, 29, 39, or 64 years, respectively.

As described earlier, the cost estimates of $0.50 for large water systems and $3.17 for small systems[10] were not based on reality. We used a detailed engineering projection report prepared for a system that has a decade of CWF experience and has characteristics of both large and small systems to obtain a more reasonable estimate of $3 and $10 PPPY, respectively.

The net savings are summarized in Table 13. In short, there is minor savings only if the caries aversion attributed to CWF extends to old ages and only in large systems. Thus minimal correction to several methodological problems eliminates most of the savings. When we include the estimated cost of treatment of dental fluorosis of at least $3.24 PPPY, there are no savings left in any scenario in Table 13.

### Topical effect

There is a question whether any savings for averted caries are real, because the mechanism by which fluoride is thought to help prevent caries is topical. Griffin *et al.*[10] explained that Assumption (1) in Table 2 was due to the benefit from water fluoridation being primarily "topical and post-eruptive." The CDC[1] states that fluoride prevents dental caries predominantly after eruption of the tooth into the mouth, and its actions are primarily topical. Both articles referenced Featherstone,[117] who stated that the effect of ingested fluoride on caries is minimal.

Current official justification for continuing promotion of CWF is that fluoride in tap water provides teeth with continuous exposure from water, beverages, and foods prepared with tap water, and that a constant low concentration of fluoride is maintained in the dental plaque and saliva all day.[118] The first point can be left to common sense. The second point contradicts current oral hygiene recommendations concerning plaque and has been refuted concerning saliva. The concentrations of fluoride in ductal saliva, approximately 0.016 ppm in flouridated areas and 0.006 ppm in nonfluoridated areas, are "not likely to affect cariogenic activity."[119]

In addition, fluoride, by ingestion or by contact, negatively affects enamel remineralization in individuals with low calcium and magnesium in teeth enamel (usually due to undernutrition).[57] Hence, CWF may increase caries in people with poor nutritional status.

### Equitable?

That CWF particularly helps the poor at a very low average cost to all has been an integral argument for CWF. We briefly examine the equity aspect.

A major review of the effectiveness of CWF states "There is some evidence [strength of evidence=C] that water fluoridation reduces inequality in dental health across social classes in 5- and 12-year-olds [in England] ... The small quantity of studies, differences between these studies, and their low quality rating, suggest caution in interpreting these results."[71]

In Appendix 5, we point out two studies missing from the review of Truman *et al.*[80] In the first study Szpunar and Burt[49] reported that a fluoride concentration of 1.0 or 1.2 mg/l prevented caries, but 0.8 mg/l did not. (The current CWF range is 0.7–1.2 mg/l, and HHS proposed to decrease it to 0.7 mg/l.)[3] This study chose a predominately white township bordering Detroit, instead of the largely black and long fluoridated Detroit, to represent a fluoridated community. Burt *et al.*[120] reported that only 0.2% of low-income adults in Detroit in the 14–35 age group (born after CWF started in 1967) were caries free (compared to 55% of children up to age 12+ in the unfluoridated community in Szpunar and Burt).[49]

In the second study, Shiboski *et al.*[121] found that the prevalence of early childhood caries was not affected by fluoridation status. Among Head Start (low income) children, the most fluoridated ethnic group (Asians, with 69% in fluoridated areas) had the worst tooth decay status. Among non-Head Start children, the most fluoridated ethnic group (Asians, with 81% in fluoridated areas) had tooth decay rates similar to those of white Head Start children, with 12% in fluoridated areas.

Truman *et al.*[80] stated: "The current burden of poor oral health continues to disproportionately

**Table 13 Present-day, corrected estimates of net savings ($) per person per year from water fluoridation**

| | | | CWF benefit extends to age | | | |
|---|---|---|---|---|---|---|
| | | | 19 | 29 | 39 | 64 |
| System size | Cost ($) | Benefit ($) ⇒ | 1.97 | 3.20 | 4.50 | 6.08 |
| Large | 3 | | −1.03 | 0.20 | 1.50 | 3.08 |
| Small | 10 | | −8.03 | −6.80 | −5.50 | −3.92 |

dental expenditures for each $1 invested in fluoridation." http://www.dph.ga.gov/programs/oral/index.asp

11. *Illinois*: "Studies have shown that for every dollar invested in fluoridation, as much as $38 is saved in dental treatment costs." http://www3.illinois.gov/PressReleases/PrintPressRelease.cfm?RecNum=2846
12. *Indiana*: "CDC data shows that for every dollar spent on water fluoridation, $38 are saved in reduced costs for dental care." http://www.in.gov/isdh/23287.htm
13. *Iowa*: "In fact, every $1 invested in water fluoridation saves $38 in dental treatment costs." http://publications.iowa.gov/6430/1/may_jun2008%5B1%5D.pdf
14. *Kansas*: "For most cities, on average, every $1 spent toward community water fluoridation saves $38 in dental treatment costs." http://www.kdheks.gov/ohi/download/Burden_of_oral_disease_in_Kansas.pdf
15. *Louisiana*: "Each $1 spent saves $38 in future dental treatment costs." http://new.dhh.louisiana.gov/assets/oph/Center-EH/operator/04-FlouridePresentation_Exercise.pdf
16. *Maine*: "In fact, for every dollar spent on community water fluoridation up to $42 is saved in treatment costs for tooth decay." http://www.maine.gov/dhhs/mecdc/population-health/odh/water-fluoridation.shtml
17. *Maryland*: "For most cities, every $1 invested in community water fluoridation saves $38 in dental treatment costs." http://phpa.dhmh.maryland.gov/oralhealth/docs1/community-water-fluoridation.pdf
18. *Massachusetts*: "In fact, for every dollar spent on community water fluoridation, up to $38 is saved in treatment costs for tooth decay." http://www.mass.gov/eohhs/docs/dph/com-health/oral-fluoride-community-water-factsheet.pdf
19. *Michigan*: "For most cities, every $1 invested in water fluoridation saves $38 in dental treatment costs." http://www.michigan.gov/documents/mdch/2012_MOHC_CWF_Tool_Kit_395210_7.pdf
20. *Minnesota*: "Recently published CDC studies have indicated that, for most cities, every $1 invested in water fluoridation saves $38 in dental treatment costs." http://mn.gov/health-reform/images/WG-PPH-2012-04-Public-Comments-Minnesota-Fluoridation-Plan.pdf
21. *Mississippi*: "In Mississippi, the cost of water fluoridation is usually between one and two dollars per person per year and saves $16 – $19 per person per year in dental treatment costs." http://www.msdh.state.ms.us/msdhsite/_static/resources/1067.pdf
22. *Missouri*: "For most cities, every $1 invested in water fluoridation saves $38 in dental treatment costs." http://health.mo.gov/living/families/oralhealth/pdf/oralhealthbrochure.pdf
23. *Nevada*: "It has been estimated that for every one dollar invested in community water fluoridation there is a savings of approximately $38 or more in averted dental treatment costs." http://health.nv.gov/PDFs/OH/BurdenOfOralDisease2012.pdf
24. *New Jersey*[†]: "An analysis by the CDC has found that, in communities of more than 20,000 people where it costs about 50 cents per person to fluoridate the water, every one dollar invested yields $38 savings in dental treatment costs." ftp://www.njleg.state.nj.us/20082009/A4000/3709_I1.DOC
25. *New York*: "Every dollar spent on fluoridation on average saves $38 in avoided dental bills." http://www.health.ny.gov/prevention/dental/fluoridation/cost.htm
26. *North Carolina*: "For every dollar spent on community water fluoridation, approximately $38 is saved in treatment costs for tooth decay." http://www.ncdhhs.gov/dph/oralhealth/services/fluoride.htm
27. *North Dakota*: "According to the U.S. Centers for Disease Control and Prevention, for every dollar spent on community water fluoridation, up to $38 is saved in treatment costs for tooth decay." http://www.ndhealth.gov/oralhealth/Publications/2012-2017_Oral_Health_State_Plan.pdf
28. *Ohio*: "Every dollar spent on fluoridation saves more than $40 in dental care." http://www.odh.ohio.gov/features/odhfeatures/PublicHealthWeek/Friday.aspx
29. *Oklahoma*: "For most cities, every $1 invested in water fluoridation saves $38 in dental treatment costs." http://www.ok.gov/health/Child_and_Family_Health/Dental_Health_Service/Community_Water_Fluoridation_Program/
30. *Oregon*: "Saves per person per year: $15.95 in small communities; $18.62 in large communities." http://public.health.oregon.gov/PreventionWellness/oralhealth/Documents/fluoride-program-module1.pdf
31. *Pennsylvania*[†]: "However, for most cities, every $1.00 invested in water fluoridation saves $38.00 in dental treatment costs." http://www.legis.state.pa.us/WU01/LI/CSM/2009/0/25_X.pdf
32. *Rhode Island*: "For every dollar spent on community water fluoridation, up to $38 is saved in treatment costs for tooth decay." http://www.health.ri.gov/healthyliving/oralhealth/about/fluoridation/
33. *South Carolina*: "For most cities, every $1 invested in community water fluoridation saves $38 in dental treatment costs." http://www.scdhec.gov/health/mch/oral/docs/water_fluoridation_flyer.pdf
34. *Tennessee*: "Every dollar spent on fluoridation saves $38 in avoided dental bills." http://health.tn.gov/oralhealth/communityBenefits.html
35. *Texas*: "A CDC study found that for communities with 20,000+ residents, every $1 invested in community water systems with fluoridation yields $38 in savings from fewer cavities treated." http://www.dshs.state.tx.us/dental/Oral-Health-in-Texas-2008-Report.doc
36. *Utah*: "... in most communities, every $1 invested in fluoridation saves $38 or more in treatment costs." http://health.utah.gov/oralhealth/resources/oralHealthReport_2011webFinal.pdf
37. *Vermont*: "For every dollar spent on fluoridation, up to $38 is saved in costs associated with dental care." http://healthvermont.gov/family/dental/fluoride/
38. *Virginia*: "CDC recommends water fluoridation as a safe, effective, and inexpensive method of preventing decay; every $1 invested in fluoridation saves approximately $38 in costs for dental treatment." https://www.vdh.virginia.gov/news/PressReleases/2011/110411FlouridationAward.htm
39. *Washington*: "For most communities, every $1 invested in water fluoridation saves $38 in dental

method, according to Kroon and van Wyk,[135] is to divide the DMFT survey of, say, 15-year-olds by 15–6 = 9 and assume it is the same for people of all ages, including those age 6 years and less. The authors noted that the mean DMFT for 12-year-old South African children decreased from 1.73 in 1988–1989 to 1.05 in 1999–2002 in this unfluoridated country.

Wright *et al.*[130] did not try to estimate a value for Effectiveness. For children aged 4–13 years, they compared treatment data for restorations and extractions for both deciduous and permanent teeth to calculate savings on dental fees. They used 1996 Wellington and Canterbury data without supporting the selection, since such data are available for all New Zealand and for all years. For ages 14–34 years, they used a 0.29 averted DFS number from Grembowski *et al.*[107] (but increased it to 0.59 surfaces for Maori) and assumed no effectiveness after age 34 years.

### *Costs of dental treatments*

On productivity loss, Campain *et al.*[128] and O'Connell *et al.*[129] used approaches similar to Griffin *et al.*[10] Wright *et al.*[130] and Kroon and van Wyk[131] did not include productivity cost. Below, we note the variations in the methods of estimating dental fees in these studies.

Kroon and van Wyk[131] estimated caries in DMFT and used the average cost of two-surface fillings for the dental charge for each DMFT. Wright *et al.*[130] used the treatment database from Wellington and Canterbury for children ages 4–13 years and included both deciduous and permanent teeth. For those ages 14–34 years, they calculated the cost of a single-surface filling using an average dentist hourly rate (with inflation) and the 15 minutes time needed to put in the filling. They assumed that fillings are replaced every 8 years.

Campain *et al.*[128] and O'Connell *et al.*[129] attempted to include more-surface fillings, composite fillings, and crown or extraction costs. However, the calculations lack transparency, and there are questions as to whether the interaction between extractions and restorations is handled properly in the latter. The most serious problem with the two studies is that they calculated the dental fees plus productivity cost on a *per visit* or *per service* basis, rather than normalizing that cost to a *per surface* basis, because one visit or service may treat more than one surface. By multiplying the estimated averted DMFS by a cost per visit or service rather than a cost per surface, they overestimated the averted costs of dental services. In addition, crowns or extractions are not always due to caries, but may have other causes. Thus these approaches lead to a far worse overestimation than Assumption (6) in Griffin *et al.*'s analysis.[10]

### *Tchouaket* et al.[132]

A paper by Tchouaket *et al.* claims to use an "innovative approach" to assess the economic value of water fluoridation for Quebec, in which only 2.7% of the population is fluoridated.[132] The presentation lacks critical information and contains fundamental errors. The authors claim that their analysis "adopted a societal perspective that allowed us to track all the costs and effects of the intervention." However, they did not include or mention the costs of treating dental fluorosis or any of the costs we discussed under "Other costs." All $ signs in this section are Canadian dollar, C$.

Tchouaket *et al.* produced $1.93, $2.05, or $2.25 PPPY as the costs of CWF, using information from the few fluoridated municipalities in Quebec. Supposedly, the three values correspond to using 3%, 5%, or 8% to amortize the subsidies received by these municipalities over 20 years. They listed several salary rates but provided no other quantitative information, thus readers are not able to repeat any calculations or confirm the numbers.

For CWF benefits, Tchouaket *et al.* did not try to estimate averted caries. Instead, they estimated the yearly costs associated with restorative dental treatments in Quebec to be $532.08, $532.87, or $534.05 PPPY, depending on discount rates. They compared these with the cost values above at various hypothetical values of CWF effectiveness, and claimed that CWF is cost-effective even at 1% effectiveness and that Quebec saves more than $560 million a year at an "expected average effectiveness of 30%."

It should be noted that the $532–$534 PPPY *restorative* expense exceeds the actual per capita spending on *all* dental services in Canada, which was reported to be $380.83 in 2009 and $399.10 in 2011.[136,137] Tchouaket *et al.* confused untreated tooth decay and dmft/DMFT (decayed, missing, or filled teeth) — only untreated decay ("d" or "D" in dmft/DMFT) requires a restoration service. A filled tooth might need a replacement at some point in the future, but definitely not every year.

The authors calculated the number of teeth restored in a year by multiplying the number of persons who used dental services within the past year, by age group, times the dmft/DMFT index for that age group. First, the average dmft/DMFT values given in the paper are clearly cumulative, not an annual increment. Only a small percentage of these would correspond to untreated decay that requires a restoration service.[xv] Second, Tchouaket *et al.*

[xv] While the level of caries experience is very high in Quebec adults aged 35–44 years, only 1.8 out of 148 surfaces are decayed (in need of treatment), on the average, and more than half of the people (55.5%) have no decayed surfaces.[138]

**Table 14 Continued**

| Location and date | Description |
|---|---|
| 5. Wakefield, MA August, 2000 | An overdose of fluoride seeped into the town water supply. Officials made door-to-door warnings around the pumping station. The public became aware only after a local news station called the town. Authorities said there were no reports of illness; but Linda Collins disagreed, "I was crazy dizzy and I had the runs. I think it was woefully inadequate the way they notified us," she said. "Because they didn't." |
| 6. Coos Bay, OR October, 2000 | At least 3.5 million gallons of partially treated sewage has spewed into the Coos Bay after 400 gallons of fluorosilicic acid flowed into a sewage treatment plant, killing its bacteria-munching organisms. |
| 7. Fort Wayne, IN February, 2001 | About 6,000 gallons of fluorosilicic acid drained from the lower level of the filtration plant into the sewer. The fluoride tank overflowed, and caustic fumes filled the area causing difficulty breathing, chest pains, severe headache and sore eyes in plant workers. Four workers were treated in the hospital. |
| 8. Marlboro, MA October, 2003 | A valve malfunction allowed a concentrated level of fluoride to flow into the water system. Workers went door to door to alert nearby customers, flushed water mains, and shut down the plant for some time. Residents and businesses were advised to take extreme care when flushing their pipes, and not to come into contact with the water, which could cause burning, skin irritation, or both. |
| 9. Westminster, MA November, 2005 | Emergency crews responded to a chemical spill at the Regional Water Treatment Facility after one of the storage tanks leaked about 750 gallons of fluorosilicic acid. An operator and two colleagues were transported to the hospital. |
| 10. Moncks Corner, SC April, 2006 | In the Santee Cooper water treatment plant, a water plant security guard became sick after she walked through a cloud of sodium fluorosilicate. The complaints included having trouble breathing, feeling like something was constantly caught in her throat, and "in the following weeks, Morris's hair started falling out, she developed a rash on her arms and back, and she continued to be wracked with convulsive fits of coughing." |
| 11. Nashville, TN March, 2007 | Valve malfunctions caused a fluoride overfeed in Harpeth Valley Utilities District. The Incident Event Log showed that an operator noted abnormal measurements starting at 12:40 a.m. 9 March 2007. Plant workers went through the facility shutting off equipment, conducted frequent water samplings and measurements, performed aggressive and continuous flushing, and contacted authorities. They also prepared for door to door public notifications, fielded incoming calls, responded to media requests, and continued sampling throughout the distribution systems until 17 March 2007. They also retained an outside engineering service to review and provide recommendations for the chemical feed systems. |
| 12. Salt Lake City, UT August, 2007 | A fluoride tank overflowed at a water treatment plant. Fluoride (1,500 gallons) spilled into a pond, resulting in an advisory to avoid Parleys Creek for several days. Utility workers used sandbags and a makeshift earthen dam to contain the chemical. Four hazmat teams worked to keep the fluoride from flowing beyond a park at the base of Parleys Canyon. Water was released from a reservoir to flush the chemical from the creek. |
| 13. Conway, AR July, 2008 | A 42-inch water pipe corroded to the point of failure, due to the fluoride injection port being mounted too close to a chlorine injection port, necessitating the shutdown of a portion of the plant that was completed only in 2005. |
| 14. Chesterfield, MO February, 2009 | Approximately 200 gallons of fluoride spilled from a ruptured tanker truck, which was carrying 4,000 gallons of the chemical at Missouri American Water's central plant. The truck's driver and two employees from the plant were taken to an area hospital. |
| 15. Anchorage, AK April, 2010 | A system malfunction at Fort Richardson Water Treatment Plant caused excess fluoride in the drinking water supply. Officials warned "anyone who lives, works on or visits the two posts in Anchorage not to drink the water ... The water also should not be used to brush teeth and wash or cook food. Any ice cubes ... should be thrown out." |
| 16. Asheboro, NC June, 2010 | Tank malfunction caused approximately 60 gallons of fluoride to be dispersed into the water system. The news release said: "Residents who consumed a large quantity of water during this period may possibly experience short-term effects such as an upset stomach, vomiting, or diarrhea. The temporary effect from skin contact, such as showering, might include slightly irritated skin." |
| 17. Rock Island, IL March, 2011 | Hazmat crews were called to the Rock Island water treatment plant for a spill of hydrofluorosilicic acid from a tanker truck. As plant employees evacuated, crews began suiting up, working quickly to stop the leak that had begun eating through concrete. |
| 18. England, AR April, 2011 | A worker mistakenly poured about 10 to 20 gallons of fluoride into a container holding around 150 gallons of bleach. It created a dangerous gas and led to an evacuation of several businesses near the water treatment plant. The worker and an employee from a nearby business were treated for breathing problems. The county Hazmat team cleaned up the area 3 hours later. |
| 19. Hickory, NC August, 2011 | The City transferred $106,713 from capital reserve to maintenance and repair to pay for refurbishing the chemical room and to replace two fluoride tanks. The tanks leaked enough fluoride to degrade the concrete around the containment area and floor. |
| 20. Martinsville, VA February, 2012 | The city had to pay $16,450 in penalties after about 1,000 gallons of fluorosilicic acid leaked from a tank at the city water treatment plant. The spill caused the deaths of an estimated 4,445 fish. Officials said that the ground near the spill absorbed quite a bit of the acid, and how much went into the creek was unknown. "Fluorosilicic acid is 'a very strong acid ... with a very corrosive effect on any metals it touches,' and corrosion caused the pump to fail." |
| 21. Memphis, TN July, 2012 | Fluorosilicic acid tank failure along with containment failure caused approximately 1,500 gallons of the acid to be released onto ground at the public utility. Approximately 1.5 acres were impacted. Workers cordoned off the area and placed berm along the west property line to prevent further runoff. The impacted area was to be excavated and soil properly disposed of. |

CWF: community water fluoridation.

and very different from CWF in many respects, e.g. the applications or dosages are controllable; it does not appear reasonable to combine them in a meta-analysis. They "used a random-effects model, which assumes that each study was randomly selected from a hypothetical population of studies," without discussing the applicability of the model. We focus on the CWF-related studies. These authors concluded that the CWF effectiveness was a 27.2% reduction in caries. We are not able to reproduce this result, which was based on four studies reporting DMFT and one study reporting DMFS; there was no explanation how the different units were handled. As with Slade *et al.*,[109] Griffin *et al.*[110] failed to adequately account for different age distributions.

### *Slade* et al.[109]

Thirty dentist-examiners conducted the oral examination in this national survey. For participants aged <45 years, only teeth extracted because of dental caries or periodontitis were counted as missing, but all absent teeth for older people were counted. Fluoridation exposure was determined by residential history, and a value of 0, 0.5, or 1 was assigned if the fluoride concentration at the location was less than 0.3, between 0.3 and 0.7, or greater than 0.7 mg/l, respectively. A value of 0.5 was assigned to all localities in New Zealand, Canada, or the U.S. and 0 to all other foreign localities, without regard to the actual CWF status of the locality.

A significant portion of CWF exposure status was imputed: 3,779 people were considered to have valid exposure data (Complete case), meaning less than 50% of the person's residential data were missing; the missing years were assumed to be their average observed fluoridation exposure. The exposure status of the remaining 1,726 people with more than 50% missing residential data was imputed by substituting with the status of a random sample from the 3,779 people who belonged to the same geographical stratum and 10-year age group.

Samples were divided into four levels of CWF exposure, i.e. <25% (negligible), 25 to <50%, 50 to <75%, and ≥75% (prolonged) of lifetime. Given the way CWF exposure was determined, the accuracy of this classification is questionable.

Slade *et al.* use unspecified linear regression models to "age-adjust" caries experience and fluoridation exposure. They draw the main conclusion of effectiveness by comparing the "age-adjusted" DMFT/DFS scores of the "prolonged" and "negligible" groups for the cohorts born before 1960 and those born between 1960 and 1990, respectively. The observed DMFT/DFS scores are not provided. The "age-adjusted" DMFT/DFS scores are given by birth cohort and exposure group (Table 15).

**Table 15 "Age-adjusted" DMFT and DFS from Slade *et al.*[109]**

| | % of Lifetime exposed to CWF | | | |
|---|---|---|---|---|
| | <25% | 25–50% | 50–75% | ≥75% |
| Pre-1960 birth cohort | | | | |
| DMFT | 21.75 | 20.90 | 21.62 | 19.21 |
| DFS | 37.90 | 35.83 | 37.00 | 29.97 |
| 1960–1990 birth cohort | | | | |
| DMFT | 8.91 | 9.53 | 8.88 | 7.61 |
| DFS | 15.89 | 18.01 | 15.65 | 12.41 |

CWF: community water fluoridation; DMFT: decayed, missing, or filled teeth.

The scores reported in Table 15 are not consistent with the conclusion that CWF exposure is effective. The scores for the two middle exposure levels were interpreted as "suggested a dose-response relationship." This is an unreasonable explanation, as an apparent difference in DMFT/DFS is lacking among the first three exposure categories. In addition, exposure levels were defined by cumulative residential status relative to age. For example, a person who lived in places with a fluoride concentration of 1 mg/l for 50 years and 0.25 mg/l for 20 years (treated as 0 mg/l, as 0.25 is less than 0.3) would have been assigned to the 50 to <75% exposure group, which, according to their results, gets no benefit relative to someone living all 70 years in nonfluoridated areas.

There are also questions regarding the validity of their use of linear regression models to "age-adjust." Calculation from data provided by Slade *et al.* (shown in Table 16) reveals that some cells have few or no people. In particular, the category of ≥75% exposure level is clearly much younger than the other three exposure categories. Given the large difference in DMFT/DFS between the pre-1960 and 1960–1990 birth cohorts (Table 15), and the large difference in age distributions between the first three exposure categories and the fourth category (Table 16), it is not surprising that the ≥75% exposure category would have lower DMFT/DFS scores than the other exposure categories. Hence the differences in caries attributed to CWF between the <25% and

**Table 16 Number of people and age distributions in the 2004–2006 Australian National Survey (calculated from information in Slade *et al.*[109])**

| | % of lifetime exposed to CWF | | | | |
|---|---|---|---|---|---|
| | <25 | 25–50 | 50–75 | ≥75 | All categories |
| 15–24 | 65 | 10 | 17 | 154 | 246 |
| 25–34 | 91 | 19 | 39 | 268 | 416 |
| 35–44 | 174 | 103 | 187 | 301 | 765 |
| 45–54 | 177 | 143 | 365 | 108 | 792 |
| 55–64 | 212 | 236 | 394 | 0 | 842 |
| ≥65 | 192 | 393 | 134 | 0 | 718 |
| Total | 910 | 903 | 1,135 | 831 | 3,779 |

CWF: community water fluoridation.

2% and 14% toothless figures into the DMFT figures to raise the total percentage difference.

Englander and Wallace[142] reported their results in DMFT as well as in DMFS. (They wrote that differences in dental caries experience were more striking when evaluated by means of DMF tooth surfaces.) Griffin *et al.*[110] chose to use the numbers in DMFS. (The ratio of DMFT between the two towns appears to be similar to the ratio of DMFS according to Griffin *et al.*,[110] but that is because they incorrectly listed the value for the filled component instead of the DMF for Aurora.)

Hunt *et al.*[143] reported new caries incidence over an 18-month period for 424 adults aged 65 years and older from a "narrowly defined geographical area" in two rural Iowa counties. Of these subjects, 174 were lifelong residents of "fluoride deficient" nonfluoridated communities, and 250 had lived in fluoridated communities (0.7–1.5 mg/l) for various lengths of time. Those who had 5–30 years of residence in fluoridated communities had comparable or worse new caries incidence compared to the lifelong nonfluoridated subjects. The authors thus focused on the remaining 101 persons with more than 30 years of residency in fluoridated communities (40% of the fluoridated sample) to draw the conclusion of effectiveness. Griffin *et al.*[110] used only the 77 persons with more than 40 years of residency in fluoridated communities (31% of the fluoridated sample). As mentioned above, one would be tempted to conclude from Englander and Wallace[142] that drinking fluoridated water after age 29 years does not work. Here, we learn that drinking it for less than 30 or 40 years does not work.

Hunt *et al.*[143] used a cross-sectional approach to compare baseline characteristics of the two groups for those with more than 30 years of residence. After at least 30 years of exposure to fluoridated water, no statistically significant difference in DFS (coronal or root caries) was noticed. In fact, Hamasha *et al.*, describing the same study population, did not even mention fluoride as a possible factor in the long-term caries experience.[148] Apparently, only in this 18-month period was a difference observed and attributed to fluoride. In a companion paper from the same study, Hunt *et al.* indicated no significant correlation between tooth loss and residence in a nonfluoridated community.[149]

Murray[133] reported on two towns in Great Britain, one with high fluoride (1.5–2 mg/l) and one with low fluoride (0.2 mg/l). Data were reported in 5-year age groups for general samples and for dentate samples. One interesting finding was that the prevalence of edentulous persons by age was strikingly similar between the two towns, reaching about two-thirds by age 60–65 years. In the author's terms, the "M" component of the DMFT score was similar in both groups. However, one way to look at this is that fluoride ingestion had little or no effect on the likelihood that a person would have a full set of dentures by age 60–65 years. The difference in mean DMFT was fairly constant in the earlier age groups and significantly narrowed from around age 40 years in the general sample. (The pattern of narrowing difference in DMFT persists after removing edentulous samples.) Murray's samples differed greatly in their age distributions, with the high fluoride group having approximately twice the fraction (33.2% vs. 16.5%) of people in the 20–24 age group and a substantially smaller fraction (27.1% vs. 44.3%) in the 40–65 age groups. Griffin *et al.*[110] apparently included these samples without considering that it might not be appropriate.

Wiktorsson *et al.*[144] compared adults 30–40 years old in Swedish towns with 1 or 0.3 mg/l fluoride. Griffin *et al.*[107] indicate blinded examiners and unspecified fluoride concentrations, but these descriptions do not fit the actual paper — a single examiner performed examinations in the respective communities and was unlikely to have been blind to subjects' geography. Persons with non-representative water sources were not examined. After discussing difficulties in scoring caries in adults, Wiktorsson *et al.*[144] report that the community with "optimal" fluoride had "significantly better" dental health status. However, without summary data for age subgroups, the picture is not entirely clear — the presented scatter plots for filled surfaces and for decayed surfaces (for ages 31–43 years) do not appear to suggest a benefit for continuing consumption of fluoridated water. (This study reports in tooth surfaces only and uses linear regression analysis.)

Stamm *et al.*[145] deal with 1.6 and 0.2 mg/l fluoride in Canada, and the examiners were not blind to their subjects' place of residence. The study excluded people with fewer than eight teeth. Griffin *et al.*[110] included the 17–19 year old group in the total sample from Stamm *et al.*,[140] although the 15–19 year olds in Murray[133] were excluded. The low fluoride group included only 1.5% in that age group, versus 6% in the fluoride group. Ages 60+ years made up nearly 18% of the low fluoride group but only 12% of the fluoride group. With respect to progression, the differences in mean DMFT between the high and low fluoride groups decreased with the older age groups, from 5.1 at ages 30–39 years to 1.7 for ages 60+ years.

Thomas and Kassab[146] included only females up to 32 years old, while they were hospitalized to give birth. A single hospital was used by women from a fluoridated island community (Anglesey) and several nonfluoridated mainland communities in Wales (United Kingdom); lifelong residents were included in the study. Although the authors indicate no

70 Graham JR, Morin PJ. Highlights in North American litigation during the twentieth century on artificial fluoridation of public water supplies. J Land Use Environ Law. 1999;14(2):195–242.
71 McDonagh MS, Whiting PF, Wilson PM, Sutton AJ, Chestnutt I, Cooper J, *et al*. Systematic review of water fluoridation. BMJ. 2000;321:855–9.
72 Diesendorf M. The mystery of declining tooth decay. Nature. 1986;322:125–9.
73 Finn SB. Prevalence of dental caries. In: A survey of the literature of dental caries. Washington, DC: National Academy of Sciences; 1952. p. 117–73. Publication 225.
74 Hagan TL. Dental caries prevalence and tooth mortality. A study of 24,092 Georgia children in 12 communities. Public Health Reports. 1947;62:1757–72.
75 Colquhoun J. Fluorides and the decline in tooth decay in New Zealand. Fluoride. 1993;26:125–34.
76 Guo MK, Hsieh CC, Hong YC, Chen RS. Effect of water fluoridation on prevalence of dental caries in Chung-Hsing New Village, Taiwan, after 9 years. J Formosa Med Assoc. 1984;83:1035–43.
77 Brunelle JA, Carlos JP. Recent trends in dental caries in U.S. children and the effect of water fluoridation. J Dent Res. 1990;69:723–7.
78 Yiamouyiannis JA. Water fluoridation and tooth decay: Results from the 1986–1987 national survey of U.S. schoolchildren. Fluoride. 1990;23(2):55–67.
79 Hileman B. New studies cast doubt on fluoridation benefits. Chemical & Engineering News. 1989 [cited 2013 Aug 8]; Available from: http://www.slweb.org/NIDR.html
80 Truman BI, Gooch BF, Sulemana I, Gift HC, Horowitz AM, Evans CA, *et al*. Reviews of evidence on interventions to prevent dental caries, oral and pharyngeal cancers, and sports-related craniofacial injuries. Am J Prev Med. 2002;23:21–54.
81 Macek MD, Heller KE, Selwitz RH, Manz MC. Is 75 percent of dental caries really found in 25 percent of the population? J Public Health Dent. 2004;64(1):20–5.
82 Santa Clara County Public Health Department. Water Fluoridation in Santa Clara County. 2009 [cited 2014 Apr 20]; Available from: http://www.sccagingcollaborative.org/documents/WaterFluoridation.pdf
83 Harris R, Nicoll AD, Adair PM, Pine CM. Risk factors for dental caries in young children: a systematic review of the literature. Community Dent Health. 2004;21(1):71–85.
84 Barnes GP, Parker WA, Lyon TC, Drum MA, Coleman GC. Ethnicity, location, age, and fluoridation factors in baby bottle tooth decay and caries prevalence of Head Start children. Public Heath Reports. 1992;107(2):167–73.
85 Feltman R, Kosel G. Prenatal and postnatal ingestion of fluorides — fourteen years of investigation — final report. J Dent Med. 1961;16(4):190–8.
86 Komárek A, Lesaffre E, Härkänen T, Declerck D, Virtanen JI. A Bayesian analysis of multivariate doubly-interval-censored dental data. Biostatistics. 2005;6:145–55.
87 Weaver R. The inhibition of dental caries by fluorine. Proc R Soc Med. 1948;41(5):284–90.
88 Community Preventive Services Task Force. Preventing dental caries: community water fluoridation. Community Preventive Services Task Force. 2000 [cited 2013 Aug 8]; Available from: http://www.thecommunityguide.org/oral/fluoridation_archive.html
89 Centers for Disease Control and Prevention. Healthy people. 2013 [cited 2014 July 29]; Available from: http://www.cdc.gov/nchs/healthy_people.htm
90 USDHHS. Healthy People 2000. National Health Promotion and Disease Prevention Objectives. Washington, DC: DHHS Publication No. (PHS) 91-50212; 1991.
91 U.S. Department of Health and Human Services. Healthy people 2010. 21. Oral Health; 2000. Available from: http://www.healthypeople.gov/2010/document/HTML/Volume2/21Oral.htm
92 U.S. Department of Health and Human Services. Healthy people 2020. Oral Health: Objectives; 2013. Available from: http://www.healthypeople.gov/2020/topics-objectives/topic/oral-health/objectives
93 Arnold FJ, Dean HT. Effect of fluoridated public water supply on dental caries prevalence. Public Health Reports. 1956;71:652–8.
94 Beal JF, James PM. Dental caries prevalence in 5-year-old children following five and a half years of water fluoridation in Birmingham. Br Dent J. 1971;130:284–8.
95 Beal JF, Clayton M. Fluoridation. A clinical survey in Corby and Scunthorpe. Public Health. 1981;95:152–60.
96 Loh T. Thirty-eight years of water fluoridation — the Singapore scenario. Community Dent Health. 1996;13(Suppl 2):47–50.
97 Evans DJ, Rugg-Gunn AJ, Tabari ED, Butler T. The effect of fluoridation and social class on caries experience in 5-year-old Newcastle children in 1994 compared with results over the previous 18 years. Community Dent Health. 1996;13:5–10.
98 Künzel W, Fischer T. Rise and fall of caries prevalence in German towns with different F concentrations in drinking water. Caries Res. 1997;31:166–73.
99 Attwood D, Blinkhorn AS. Trends in dental health of ten-year-old school children in south-west Scotland after cessation of water fluoridation. Lancet. 1988;2:266–7.
100 Kalsbeek H, Kwant GW, Groeneveld A, Dirks OB, van Eck AA, Theuns HM. Caries experience of 15-year-old children in the Netherlands after discontinuation of water fluoridation. Caries Res. 1993;27:201–5.
101 Brown H, Poplove M. The Brantford-Sarnia-Stratford fluoridation caries study: Final survey, 1963. Can J Public Health. 1965;56:319–24.
102 Fanning EA, Cellier KM, Somerville CM. South Australian kindergarten children: effects of fluoride tablets and fluoridated water on dental caries in primary teeth. Aust Dent J. 1980;25:259–63.
103 Hawew RM, Ellwood RP, Hawley GM, Worthington HV, Blinkhorn AS. Dental caries in children from two Libyan cities with different levels of fluoride in their drinking water. Community Dent Health. 1996;13:175–7.
104 Provart SJ, Carmichael CL. The relationship between caries, fluoridation and material deprivation in five-year-old children in County Durham. Community Dent Health. 1995;12:200–3.
105 Rugg-Gunn A, Nicholas K. Caries experience of 5-year-old children living in four communities in North East England receiving differing water fluoride levels. Br Dent J. 1981;150:9–12.
106 Ripa LW. A half-century of community water fluoridation in the United States: review and commentary. J Public Health Dent. 1993;53:17–44.
107 Grembowski D, Fiset L, Spadafora A. How fluoridation affects adult dental caries. JADA. 1992;123:49–54.
108 Newbrun E. Effectiveness of water fluoridation. J Public Health Dent. 1989;49(5):279–89.
109 Slade GD, Sanders AE, Do L, Roberts-Thomson K, Spencer AJ. Effects of fluoridated drinking water on dental caries in Australian adults. J Dent Res. 2013;92(4):376–82; and appendices.
110 Griffin SO, Regnier E, Griffin PM, Huntley V. Effectiveness of fluoride in preventing caries in adults. J Dent Res. 2007;86(5):410–5; and appendices.
111 Centers for Disease Control and Prevention. Surveillance for dental caries, dental sealants, tooth retention, edentulism, and enamel fluorosis — United States, 1988–1994 and 1999–2002. MMWR. 2005;54(No. SS-3):1–44.
112 Zimmermann ER, Leone NC, Arnold FA Jr. Oral aspects of excessive fluorides in a water supply. JADA. 1955;50:272–7.
113 Russell AL. Fluoride domestic water and periodontal disease. Am J Public Health. 1957;47:688–94.
114 Brown LJ, Lazar V. Dental procedure fees 1975 through 1995: how much have they changed? JADA. 1998;129:1291–5.
115 California Department of Health Care Services. 2012 Denti-Cal Schedule of Maximum Allowances. In: Medi-Cal Dental Program Provider Handbook. California Department of Health Care Services; 2012. p. 5–112.
116 Johnston DC. First look at US pay data, it's awful. 2011 [cited 2013 Aug 8]; Available from: http://blogs.reuters.com/david-cay-johnston/2011/10/19/first-look-at-us-pay-data-its-awful/
117 Featherstone JD. Prevention and reversal of dental caries: Role of low level fluoride. Community Dent Oral Epidemiol. 1999;27:31–40.
118 Centers for Disease Control and Prevention. Community Water Fluoridation: Questions and Answers. 2013 [cited 2013 Aug 8]; Available from: http://www.cdc.gov/fluoridation/factsheets/cwf_qa.htm
119 Centers for Disease Control and Prevention. Recommendations for using fluoride to prevent and control dental caries in the United States. MMWR. 2001;50(RR–14):1–42.