

**APPENDIX 3:
Cost-Effectiveness Studies**

Table 1: Cost-Effectiveness Studies, U.S.

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Author, Pub Date, Author Affiliation	Analytic Method (Comparators), Perspective of Analysis, Reported or Calculated Summary Measure	Study Type, Population Description	Base Year, Discount Rates, Costs included, Caries Baseline Incidence, Measure of Effectiveness & Sources	Summary Measure, Adjusted Value	Notes
Burt, BA, ed., 1989	Cost-effectiveness ratio, average (vrs. no fluoridation). Local Government/ Water District perspective. Timeframe: lifetime. Cost of fluoridation per decayed surface saved	Economic modeling using consensus estimates of U.S. cost, prevalence and effectiveness data. Children and adults to age 44.	<p>1988 US\$. CWF costs discounted at 4%. Direct costs of fluoridation were independently estimated by 5 working groups based on data from a published review (Garcia, 1989); they included operating costs, replacement costs after 15 year depreciation, and labor costs for 3 community sizes: <10,000 (\$.60-\$5.41), 10,000-200,000 (\$.18-\$.75), and >200,000 (\$.12-\$.21); they did not include overhead or political costs.</p> <p>Effectiveness estimates were based on published studies of CWF which included contemporary controls in Western Established Economies between 1983 and 1989: the estimated range of caries reduction over a lifetime (“against a background of nearly universal fluoride use”): 20-40%. Children: 30-39% primary dentition; 11-38% mixed dentition; 13-35% permanent dentition. Adults (“very little data”): age 20-44, coronal caries 20-30%, root caries 20-40%.</p> <p>Net annual caries increment (estimated only by Group 4)=0.22 DF/yr.</p> <p>Costs of disease were considered only by Group 4—included only initial 2-surface amalgam restoration (\$44). Estimated Cost of Disease Averted: \$4.36/person/year. Costs of adverse effects of water fluoridation were assumed to be negligible.</p>	<p>Cost of fluoridation per decayed surface saved ranged from \$2.60 [\$3.98 2001 Denver\$] in large and medium sized cities to \$8 to \$12 for small cities and effectiveness estimates on the low end of the range.</p> <p>It was noted that this cost is well below the cost of a surface restoration, making water fluoridation cost-saving.</p>	<p>Weaknesses: Did not explicitly state all assumptions or findings, in particular, the baseline caries rate chosen was not reported. The development of CE ratios did not include cost savings derived from caries reductions (except “preliminary work” by Group 4); no sensitivity analyses were performed. Available data for fluoridation costs and caries incidence was from pre-90s surveys.</p> <p>Oxford EBM level 4.</p>

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Griffin, SO, 2001, CDC	<p>Cost-effectiveness ratio, average (vrs. no fluoridation). Societal perspective. Timeframe: lifetime. Net cost of fluoridation per permanent decayed surface saved</p>	<p>Economic modeling using parameter estimates from published studies and U.S. epidemiologic surveys. 1995 U.S. population, ages 6 to 64. .</p>	<p>1995 US\$. All costs and benefits were discounted at 4%. Direct costs of fluoridation were taken from a 1992 report of 44 communities (Ringelberg, 1992); they included operating costs, replacement costs, maintenance and labor costs. Ranged from \$3.17/person per year (4% discount) for communities <5000 to \$0.50 for communities >20,000. Did not include overhead or political costs.</p> <p>Effectiveness estimates were based on a review of published studies from 1979-1989 and from the National Survey of Oral Health, 1987. Best-case 29%, base-case 25% and worse-case 12% reductions in caries were estimated for both adults and children.</p> <p>Annual caries increment in non-fluoridated communities was estimated by three methods to yield best-case (studies published from 1978-88), base-case (1987 National Survey of Oral Health, cross-sectional) and worse-case (NHANES I & II, 1971-74 and 1989-94, longitudinal cohort) estimates for three ages ranges: 0.49-1.4 surfaces/yr in children 6-17; 0.49-0.83 in 18-44 year olds and 0.0-1.24 in 45-65 year olds: average 0.33-1.16 surfaces/yr. Base-case net annual caries increment (increment*effectiveness)=0.76*25%=.19 DF/yr.</p> <p>Costs of disease (\$100.62/surface) included initial amalgam restorations (\$54), costs to replace restorations (every 12 years) and productivity costs (\$18/restoration). Estimated Cost of Disease Averted: \$2.99-\$56.01/person/year (base-case \$19.12). Costs of adverse effects of water fluoridation were assumed to be negligible.</p>	<p>Cost of fluoridation per decayed surface saved baseline was \$2.63 [\$3.13*] (range \$1.37-\$13.64) in cities >20,000.</p> <p>Negative net cost per decayed surface saved in large communities (>20,000) ranged from \$3.52 [\$4.19*] (worst case) to \$33.71 [\$40.10*] (best case). Water fluoridation was cost-saving under all scenarios. Break-even analyses showed CWF was cost saving for all effectiveness levels above 1% (assuming baseline caries increment of .76 surfaces/yr.), and all increments above .02 surfaces/yr. (assuming baseline effectiveness of 25%).</p>	<p>Strengths: Takes a societal perspective. Includes productivity losses (-). Attempted to estimate lifetime costs of decayed surface (-). Sensitivity analysis varied discount rate, effectiveness and caries increments—demonstrating robustness of results even considering the decline in caries incidence.</p> <p>Weaknesses: Available data for caries incidence was from pre-90s surveys (-). Limited costs of decayed surface to single-surface restorations & replacements (+). Did not account for benefit of deciduous caries prevention.</p> <p>Oxford EBM level 2b.</p>
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*Adjusted to 2001 Denver \$ by CPI-U

Table 2: Cost-Effectiveness Studies, Other Countries

Cost-Effectiveness Studies, Other Countries (Page 1 of 3)

Author, Pub Date, Author Affiliation	Analytic Method (Comparators), Perspective of analysis, Reported or Calculated Summary Measure	Study Type, Population Description	Base Year, Discount Rates, Costs included, Caries Baseline Incidence, Measure of Effectiveness & Sources	Summary Measure, Adjusted Value	Notes
<p>Wright, C et.al. 2001</p> <p>Wellington School of Medicine, Envir. Sci. and Research Inst., New Zealand</p>	<p>Cost-effectiveness ratio, average (vrs. no fluoridation). Societal perspective, New Zealand communities. Timeframe 30 years. Net annual per person cost per permanent decayed surface saved</p>	<p>Economic modeling using parameter estimates from New Zealand data and a U.S. published study. 2000 New Zealand population, ages 4 to 34.</p>	<p>1999 NZ\$ (1NZ\$=.66US). All costs and benefits were discounted at 5%. Direct costs of fluoridation were obtained from equipment manufacturers and operators in NZ; they included operating costs, replacement costs at 15 years, maintenance and labor costs. Did not include overhead or political costs.</p> <p>Costs of disease included initial amalgam restorations for both deciduous and permanent teeth (based on reimbursements rates for children-\$24; on dentist labor costs for adults-\$66) and the costs to replace restorations in permanent teeth (every 8 years up to age 45). Costs of adverse effects of water fluoridation were assumed to be negligible. Did not include productivity costs.</p> <p>Effectiveness estimates were based on 1996 records of publicly funded dental care for NZ children ages 4-13 years and from a 1992 U.S. study of 20-34 y/o adults for those ages >13 (.base-case .33 surface reductions in caries/year). Net annual caries increment averaged 0.24 DMT/yr in 4-13 year olds and 0.29 DMT/yr. (95% CI .19-.39 surfaces) in 14-34 year olds.</p>	<p>Community Water Fluoridation was cost saving for communities above 1000 people under all scenarios.</p>	<p>Strengths: Recent effectiveness and baseline caries data. Included cost savings (but not non-monitized benefits) from preventing decay in deciduous teeth. Sensitivity analysis varied discount rate, number of injection sites, effectiveness and caries increments—demonstrating robustness of results even considering the decline in caries incidence.</p> <p>Weaknesses: Available data for caries incidence in children did not include decayed but untreated surfaces. Assumed no benefits after age 45 and no decay after age 34.</p>
<p>Akehurst and Sanderson 1993</p> <p>Centre for Health Economics , University of York</p>				<p>"In terms of cost, effect and the certainty of that effect the most cost-effective policy is fluoridation of water supplies"</p>	<p>Unpublished; no abstract available, report on order</p>

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<p>Birch, S., 1990 McMaster University, Ontario, Canada</p>	<p>Cost-effectiveness analysis; England and Wales, 1985, Time horizon: 14 years.</p>	<p>Economic modeling using data from England calculated for three hypothetical population sizes. Ages 4 to 14, primary and permanent dentition.</p>	<p>British pounds, unspecified year. All costs and benefits were discounted at 5% and 10%. Direct costs of fluoridation were attributed to a personal communication.</p> <p>Caries incidence and effectiveness data taken from several epidemiological studies conducted in Great Britain in the 1980s. Net annual caries increment averaged 1.82 dmftDMFT/yr. in high caries areas and 0.47 dmftDMFT/yr in low caries areas.</p> <p>Costs of disease were not considered.</p>	<p>“Cost-per unit benefit varies by a factor of four according to the existing level of caries prevalence”.</p>	<p>A simple model is used to show how cost-effectiveness varies by underlying caries risk and community size.</p>
<p>O’Mullane, DM, 1990: University Dental School, Wilton, Cork, Ireland</p>	<p>Not an economic analysis. Effectiveness (vrs. no fluoridation). Net annual caries increment calculable from data presented.</p>	<p>Nation-wide estimates of program cost, prevalence and effectiveness data. Children 8 to age 15.</p>	<p>1987 UK Pounds. No discounting. Average direct costs included operating costs, capital costs and labor costs; they did not include overhead or political costs. 33 pence=\$0.81/capita in 1995 U.S. dollars.</p> <p>Effectiveness estimates were based on national surveys in 1961-64 and 1984: ages 8-12: 40%; ages 12-15: 25% permanent dentition.</p> <p>Annual caries increment in non-fluoridated communities was estimated from table 2: ages 8-12: 1.05 surfaces/yr. ages 12-15: 1.4 surfaces/yr.</p> <p>Net annual caries increment averaged 0.39 DMFS/yr.</p> <p>Costs of disease not reported.</p>	<p>Authors stated that this cost makes water fluoridation cost-effective.</p>	<p>Weaknesses: Not an economic analysis (cost of treatment averted was not considered). Demonstrated that benefits of fluoridation persisted in spite of a downward secular trend in caries prevalence in both communities.</p>

Cost-Effectiveness Studies, Other Countries (Page 3 of 3)

Author, Pub Date, Author Affiliation	Analytic Method (Comparators), Perspective of analysis, Reported or Calculated Summary Measure	Study Type, Population Description	Base Year, Discount Rates, Costs included, Caries Baseline Incidence, Measure of Effectiveness & Sources	Summary Measure, Adjusted Value	Notes
Attwood and Blinkhorn, 1989: Royal Hospital for Sick Children, Scotland	Cost Analysis (fluoridated vrs recently non-fluoridated community); Government dental services perspective; Difference in mean cost of restoring carious teeth	Epidemiologic study; Comparison of DMFT scores and treatment costs for 5 & 10 year olds life-time residents in 2 areas: a non-fluoridated community and a community that stopped fluoridating in 1983.	1980 and 1986, no discounting; included cost of restorations and total dental treatment costs. Baseline caries prevalence (non-fluoridated): 1980: 4.38 in 5 y/os, 3.82 in 10 y/os. 1986: 3.35 in 5 y/os, 2.22 in 10 y/os.	1) Mean DMFT/ dmft and treatment costs for caries were lower in all age groups in the fluoride site in both 1980 and 3 years after suspending CWF in 1986, compared to the non-CWF site. 2) Caries prevalence fell by 13% and 16% in the 5 and 10y/o groups, respectively, in the non-CWF site from 1980-86. 3) There was no drop in DMFT (+4%) and an increase in restoration costs (+115%) in 10 year olds in the site suspending CWF from 1980 to 1986, compared to a fall in prevalence (-16%) and no change in costs (+9%) in 10 y/o in the non-CWF site.	Not an economic analysis (cost of fluoridation was not considered). Demonstrated that benefits of fluoridation persisted, though attenuated, 3 years after suspension of CWF in children, even in the context of a downward secular trend in caries prevalence in both communities.

Table 3: Other Delivery Strategies for Fluoride

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Fluoride Modality	Material Cost of Fluoride/ Person/ Year (2001 \$)	Total Cost of a Community Based Program / Person/ Year (2001 \$)	Annual Cost Per Single Surface Cavity Averted	Efficacy in Reducing Caries	Applicability as a Public Health Intervention	Comments
Community Water Fluoridation	\$.47	\$0.76	-\$4.42 (\$3.35 to 10.72)	Up to 60% reduction in caries in early studies; more recent estimates 18-40%. Many studies; moderate to low quality.	High	Cost-saving; most effective method of reaching whole population; requires no active participation by individuals; benefits all ages. Water fluoridation was “strongly recommended” by the Task Force on Community Preventive Services (Centers for Disease Control and Prevention 2001a, p. 8)
School water Fluoridation	Similar to comm. water fluoridation	\$6 (\$1-\$14)*	No reports located	Up to 40% reduction in caries; more recent estimates lower.	Moderate	Practical and logistical difficulties; no benefit to adults.
Fluoridated salt	Similar to community water fluoridation ^v	Similar to community water fluoridation ^v	No reports located	Similar to community water fluoridation ^v	Low in US; but well accepted in France, Germany, Switzerland, and others ^v	Has advantage that it does not require a community water supply and is simpler for individuals to accept or reject. Difficulties arise when there are multiple sources of drinking water with varying levels of Fl.—not feasible in the U.S.

Table 3: Other Delivery Strategies for Fluoride (Page 2 of 2)

Fluoride Toothpaste	\$7-\$13*	NA	No reports located	15-30% over 2-3 years; similar to CWF (25%) over lifetime*; many high quality studies [∇]	Low	Safe and effective in older children and adults; additive effectiveness with CWF. Use of toothpaste in young children is associated with enamel fluorosis—therefore requires parental supervision in children <6.
Dietary fluoride supplements	\$3.50*	NA	No reports located	Mixed results*; 4 studies showed caries reductions of 39-80% in younger children but low study quality [∇] . Higher risk-benefit ratio in younger children.	Low Public campaigns often unsuccessful; least effective in lower SES groups. [∇]	Requires prescription & complex dosing schedule in childhood—inappropriate dosing is reported to be common, making use in young children an important cause of fluorosis in the US [∇] . Requires a high-level of parental motivation [∇] . Not studied in adults*.
Fluoride mouth rinse	\$1.50*	NA	No reports located	Consistently 20%+ in early studies [∇] ; estimated 31% in one review*. Good quality studies.	Low (Minimal effect in a large US demonstration project, 1976-81).	Public health programs (e.g., school-based) require supervisors and weekly or monthly applications; fluorosis risk in school-based programs (ages is low*.
Professionally applied fluoride compounds (gel, varnish)	\$72*	NA	No reports located	26% reduction in caries in non-fluoridated areas*.	Low	Requires professional application, at least 6 mo. intervals; indicated for high-risk caries patients. Risk for fluorosis is low*.
Slow-release fluoride (in dental materials)	NA	NA	NA	Not effective [∇]	Low	

*Adapted from Centers for Disease Control and Prevention 2001b.

[∇]Adapted from World Health Organization 1994.

Table 4: Other Strategies for Primary Prevention of Dental Caries

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Modality	Material Cost/ Person/ Year (2001 \$)	Total Cost of a Community Based Program/ Person/ Year (2001 \$)	Annual Cost Per Single Surface Cavity Averted	Efficacy in Reducing Caries	Applicability as a Public Health Intervention	Comments
Dental sealants ¹			Single U.S. report: cost- saving in a school-based program for low- SES children (Zabos, Glied, Tobin, Amato, Turgeon, Mootabar and Nolon 2002)	Median percent decrease in occlusal caries in posterior teeth 60%, (range 5%-93%), good study quality. ¹	Moderate; school- based sealant delivery programs	School-based sealant delivery programs, but not community- wide sealant promotion programs, were found to be effective and were “strongly recommended” by the Task Force on Community Preventive Services (Centers for Disease Control and Prevention 2001a, p.9)
Products containing noncariogenic sweeteners [#]				“...have been delivered to teeth as constituents of chewing gum, hard candy, and dentifrices. Evidence for both sorbitol and xylitol is positive” [#]	Low to Moderate	

¹Adapted from Centers for Disease Control and Prevention 2001a, pp.9-10.

[#]Adapted from National Institute of Health, Office of the Director 2001, p 15.

Economic Analysis of Community Water Fluoridation in Fort Collins, Colorado

[The following is an economic analysis of community water fluoridation in Fort Collins based on the model of Griffin, et. al, provided to the Fort Collins Fluoridation Technical Study Group by Susan Griffin, PhD, Centers for Disease Control and Prevention on July 3, 2001. The analysis was based on estimates of the “net present value” average per person costs of community water fluoridation in Fort Collins provided to Dr. Griffin by FTSG members Kevin Gertig and Bruce Cooper.]

Community water fluoridation actually saves Fort Collins money. Fort Collins has approximately 100,968 residents, who benefit from community water fluoridation.¹ Using data on caries increment from region V of the National Survey of the Oral Health of U.S. School Children [2] and cost data specific to Ft. Collins, the annual cost savings per person from community water fluoridation equals \$4.25 (year 2000 US\$). Thus after netting out the amortized capital costs as well as annual operating expenses, the annual cost savings to the Fort Collins community attributable to community water fluoridation would be approximately \$429,000 (2000 US\$). Because we did not have caries data specific to Ft. Collins we allowed caries increment to vary between the 1986-1987 estimates for the US adjusted for the secular decline in caries (best-case scenario) and the 1986-1987 Region V estimates adjusted for the secular decline in caries (worst-case scenario). Our findings suggest that the annual cost savings to the Ft. Collins community could vary from \$325,000 to \$1,041,000.

Estimated Annual Per Person Cost Savings² Attributable to Fluoridation of Fort Collins Water System

Baseline Analysis: Under the assumptions below, the annual cost savings per person from community water fluoridation would equal \$3.40 (1995 US\$). This value translates to \$4.25 in year 2000 US dollars³.

The following values are in 1995 US\$:

1. The average **per person cost of fluoridation** in Ft. Collins equals **\$0.71**.
2. We used data from Region V of the 1986-1987 Survey of Oral Health in U.S. School Children. Mean DMFS among 12-year-olds in *nonfluoridated* areas of Region V⁴ [2] equals **2.71** surfaces. We assumed that permanent teeth begin to erupt at age **6** and thus the **annual caries increment, nonfluoridated**, would equal **0.4517 (or 2.71/6) surfaces**.
3. Mean DMFS among 12-year-olds in *fluoridated* areas of Region V equals **2.49** surfaces. Thus, **annual caries increment, fluoridated** equals **0.415 (or 2.49/6) surfaces**.
4. **Annual averted caries attributable to fluoridation** equals **0.0367 (or 0.4517-0.415) surfaces**. Because there were no data on caries increment among adults and the annual caries increment among children in Region V was lower than published estimates of caries increment among adults [2], to be conservative, we assumed that individuals, aged 18 to 64 would receive the same benefit from fluoridation as would children.
5. Assuming the **weighted per person discounted lifetime cost of a carious surface** across the life span equals **\$112.00**, the **annual cost of averted disease** equals **\$4.11 (or 0.0367*\$112.00)**.
6. **Annual cost savings per person from community water fluoridation** equals **\$3.40 (or \$4.11 - \$0.71)**.

¹ According to the 2000 Census Ft. Collins had 100,968 residents, aged 6 to 64 years. According to Griffin [1] water fluoridation has been shown to be effective in reducing tooth decay in the permanent dentition of individuals, aged 6 to 64 years.

² Analysis limited to individuals, aged 6 to 64 years.

³ The Dental CPI for all urban consumers equaled 206.8 in 1995 and equaled 258.5 in 2000.

<http://data.bls.gov/servlet/SurveyOutputServlet?jrnsessionid=10240602552965171> [accessed 6/14/02]

⁴ This data comes from the 1986-1987 Survey of Oral Health in U.S. School Children. The sample age ranged from 5 to 17. The mean age of the sample was 12 years. Region V includes Texas, Oklahoma, New Mexico, and Colorado.

Sensitivity Analysis: Because we did not have data specific to Ft. Collins and because the caries data was collected in 1986-1987 we calculated the cost savings under a best-case scenario and worst-case scenario.

1. Under the best-case scenario we assumed that the annual averted caries in Ft. Collins attributable to fluoridation equaled that of the US in 1986-1987, adjusted for the secular decline in caries⁵, or 0.08 DMFS [2]⁶. The resulting annual cost savings per person would equal \$8.25 (or $0.08 * \$112 - \0.71). Converted to year 2000 dollars, this value would equal \$10.31 per person or approximately \$1,041,000 for the community (year 2000 US\$).
2. Under the worst-case scenario we assumed that the annual averted caries in Ft. Collins attributable to fluoridation equaled that of region V but factored in a secular decline in caries of 20%. Thus the annual averted decay would equal 0.0294 surfaces (or $0.80 * 0.0367$). The resulting annual cost savings per person would equal \$2.58 (or $0.0294 * \$112 - \0.71). Converted to year 2000 dollars, this value would equal \$3.22 per person or approximately \$325,000 for the community (year 2000 US\$).

⁵ We calculated the percentage reduction in mean DMFS among US schoolchildren, ages 5 to 17 from 1986-1987 [2] to 1988-1994 [3]. These values equaled 1.74 in 1987-1987 and 1.4 in 1988-1994. Thus children in 1988-1994 had 20% fewer DMFS.

⁶ Brunelle, et al. found that the mean DMFS among US schoolchildren, ages 5 to 17 (mean age equal 12) equaled 3.39 in nonfluoridated communities and 2.79 in fluoridated communities. Thus the annual increment would equal $(3.39 - 2.79) / 6 = 0.1$. Adjusting for the secular decline in caries this value would equal 0.08.

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