HHS Public Access

Author manuscript

Am J Prev Med. Author manuscript; available in PMC 2018 October 04.

Published in final edited form as:

Am J Prev Med. 2016 June ; 50(6): 790–796. doi:10.1016/j.amepre.2015.10.014.

Economic Evaluation of Community Water Fluoridation: A Community Guide Systematic Review

Tao Ran, PhD on behalf of Community Preventive Services Task Force and Community Guide Branch, Division of Public Health Information Dissemination, CDC, Atlanta, Georgia

Sajal Chattopadhyay, PhD

Community Guide Branch, Division of Public Health Information Dissemination, CDC, Atlanta, Georgia

Abstract

Context: A recently updated Community Guide systematic review of the effectiveness of community water fluoridation (CWF) still found strong evidence that CWF reduced dental caries across populations. Although CWF was found to have saved money in a 2002 Community Guide review, the conclusion was based on studies before year 1995. Given the update to the effectiveness review and changes in the economic environment, re-examination of the benefit and cost of CWF is necessary.

Evidence acquisition: Using methods developed for Community Guide economic reviews, 564 potentially relevant papers were identified within a search period from January 1995 to November 2013. Ten studies were included in the current review, with four covering CWF benefits only and another six providing both cost and benefit information. Additionally, two of the six studies analyzed the cost-effectiveness of CWF. The economic review was conducted in 2014.

Evidence synthesis: For all four benefit–only studies, which used regression analysis, dental costs in various forms were lower in communities with water fluoridation. For the remaining six studies, per capita annual intervention cost ranged from $0.11 to $4.89 in 2013 U.S dollars. Variation in cost was caused mainly by community population size, with decreasing per capita cost associated with increasing community population. Per capita annual benefit in the six studies ranged from $5.45 to $139.78. Variation in benefit was mainly due to the numbers and types of benefit components included in the benefit calculation. Benefit–cost ratios ranged from 1.12:1 to 135:1, and these ratios were positively associated with community population size.

Conclusions: Recent evidence continues to indicate that the economic benefit of community water fluoridation exceeds the intervention cost. Further, the benefit–cost ratio increases with the community population size.

Address correspondence and reprint requests to: Tao Ran, Community Guide Branch, CDC, 1600 Clifton Road, Mailstop E69, Atlanta, GA 30333, xgy2@cdc.gov.

The work of Tao Ran was supported with funds from the Oak Ridge Institute for Scientific Education.

The names and affiliations of the Task Force members are at http://www.thecommunityguide.org/about/task-force-members.html

Context

Dental caries is a disease that leads to demineralization and decay of the hard tissues of the tooth through the action of bacterial acid.[1] It can lead to loss of tooth structure and discomfort, or severe pain and bacterial infection. In particular, childhood decay can result in poorer health, loss of school time, and emergency room visits; and adulthood decay can be associated with poorer productivity and quality of life. As a result, dental caries can impose significant economic burden both to the individual and society as a whole. In 2013, expenditure on dental services in the U.S. reached $111 billion.[2]

Fluoride is an adjustable factor that can decrease the incidence of dental caries. It acts in various ways to prevent tooth decay by inhibiting bacterial metabolism, demineralization, and enhancing re-mineralization by impacting the surface of the tooth, especially when low concentrations of fluoride are consistently maintained in the mouth.[3] Community water fluoridation (CWF) involves adding controlled amounts of concentrated fluoride to a water supply to prevent dental caries. It is regarded as the single most effective public health measure to prevent tooth decay in the U.S., and it was among the top ten greatest public health achievements of the 20th century.[4] From the individual perspective, CWF frequently delivers low levels of fluoride to saliva in addition to the fluoride incorporated into developing teeth.[5] Therefore, CWF helps to improve chewing, reduce tooth loss, and enhance quality of life. From the societal perspective, CWF can reduce health inequalities by making fluoridated water available to people living in disadvantageous environments.[1] Moreover, CWF requires only changes in environment and policy instead of individual behavior. In addition, it is population-based, covering large segments of a population at a low cost.[5] In fact, a Chilean analysis[6] found CWF to be the second most cost effective oral health intervention next to salt fluoridation (which is not currently used in the U.S.).

Following an updated systematic review on the effectiveness of CWF in April 2013, the Community Preventive Services Task Force recommended CWF based on strong evidence of effectiveness in reducing dental caries across populations (www.thecommunityguide.org/oral/fluoridation.html). Evidence showed that the prevalence of caries was substantially lower in communities with CWF. In addition, there was no evidence that CWF resulted in severe dental fluorosis.

A 2002[7] comprehensive review of oral health interventions indicated that CWF saved money from a societal perspective. The nine included studies in the review were conducted from the early 1970s to the end of 1994. Given the updated review on the effectiveness of CWF and the change in economic environment, an up-to-date systematic review on the cost and benefit of CWF is necessary. This review focuses on the economic studies of CWF conducted after January 1995. The research questions are: what is the cost of CWF based on information after January 1995? What are the relevant cost-effectiveness or cost-benefit estimates for CWF?

Evidence Acquisition

General methods for Community Guide systematic economic reviews are available at www.thecommunityguide.org/about/economics.html. This review was conducted under the oversight of the Task Force, Federal and non-Federal scientists, and specialists in systematic review methods, and in research and policy related to oral health.

Multiple databases were used for the systematic search: PubMed, EconLit, ERIC, JSTOR, Social Sciences Citation Index (SSCI), databases at the Centre for Reviews & Dissemination at the University of York, and the Health Economic Evaluations Database (HEED) from Wiley. To identify relevant studies, the economic search terms (as in Appendix 1) were used in the search strategy, in addition to the effectiveness and subject keywords. Further, a secondary manual search was conducted using Google Scholar. Finally, a subject matter expert from the Division of Oral Health, CDC, was consulted for additional studies.

The definition of CWF in this review is at www.thecommunityguide.org/oral/fluoridation.html. The inclusion criteria for this review followed the standard for economic evaluation studies adopted by the Community Guide.[8] Studies were considered relevant if they evaluated a community water fluoridation intervention and:

- Provided information on costs or benefits of CWF;
- were primary studies, in the form of a peer-reviewed paper or report;
- were conducted in high-income countries as defined by the World Bank
- (data.worldbank.org/about/country-and-lending-groups); and
- were written in English and published between January 1995 and November 2013.

Once the preliminary list of papers was identified, title, abstract and full text screening were conducted to finalize the selected studies. The final studies used one or more of the following economic measures: intervention cost, change in treatment cost or dental visits/claims, benefit–cost ratio, and dollars per disability–adjusted life year (DALY) averted. For studies having cost and benefit information but not benefit–cost ratios, the ratio was calculated by the reviewers. The calculation was conducted in 2014.

To ensure comparability among the studies, costs and expenditures were adjusted to 2013 U.S. dollars using the consumer price index (CPI) from the Bureau of Labor Statistics (data.bls.gov/pdq/querytool.jsp?survey=cu). International currencies were converted to U.S. dollars using purchasing power parity rates from the World Bank (data.worldbank.org/indicator/PA.NUS.PPP). Purchasing power parity rates were used because “they are less susceptible to financial flows and governmental exchange rate manipulation than are market exchange rates.”[8]

Once the intervention cost and benefit were comparable among the studies, major contributors to the variation in cost and benefit were identified. Finally, economic evidence was summarized to provide information on the value of the intervention for the money invested. Evidence gaps of the studies were also listed.

Evidence Synthesis

Search Results

A total of 564 papers were identified in the initial literature search, of which 508 were excluded after the first screening of titles and abstracts because they did not meet the inclusion criteria. Another 48 papers were excluded after the second screening on the full text review. This yielded eight papers from the database search. With two additional papers recommended by the subject matter expert, the final search yield included ten studies (Figure 1). A summary evidence table with details of the ten studies can be found:www.thecommunityguide.org/oral/supportingmaterials/et-waterfluoridation.html (to be posted).

Characteristics of Studies

The final ten studies were composed of nine peer-reviewed journal articles[5, 9–16] plus a report[17]. Geographically, six of the studies were from the U.S.[5, 9–11, 15, 17], with the rest from Australia[13, 14], Canada[16], and New Zealand[12]. Six papers[9, 11–14, 16] provided cost and benefit information, two[13, 14] of which also conducted cost-effectiveness analysis using DALY. The remaining four papers[5, 10, 15, 17] provided only benefit information and used regression models to analyze the change in treatment cost or dental claims with the presence of CWF.

Intervention Cost

Conceptually, the intervention cost of CWF is composed of a one-time fixed cost and annual recurrent costs. *One-time fixed cost* refers to investments in fluoridation facilities. *Annual recurrent costs* include cost of maintenance, operation (including staff cost), or monitoring. Six of the ten final studies provided cost information. Two (Wright et al.[12] and Tchouaket et al.[16]) of the six studies used actual cost data. The remaining four studies used estimated cost data. Table 1 provides the details of intervention cost for six studies.[9, 11–14, 16]

Of the two studies that used actual cost data, Tchouaket et al.[16] provided information on the salary and working hours of the technicians and consulting dentists, based on which the recurrent fixed cost was calculated. They also mentioned the cost of using public health laboratory, as well as that of purchasing supplies as variable recurrent cost. The annual per capita cost was calculated by dividing the total annual cost by total population of Quebec as $1.63 at 3% discount rate (the rate at which a future monetary value is converted to the present value). Wright et al.[12] provided detailed information on capital investment and annual cost for different community sizes. Their per capita annual cost ranged from $0.11 for community population of 300,000 to $4.92 for community population of 1,000.

The remaining four studies used different methods to estimate costs. Both Griffin, Jones and Tomar[9] (whose cost ranged from $0.76 to $4.85 for population size of 5,000 to over 20,000) and O'Connell et al[11]. (whose cost ranged from $0.54 to $3.36 for population size of 1,000 to over 20,000.) used the cost data in Rinelberg et al.[18] in 1988, arguing that fluoridation technology had not changed much since then. Cobiac and Vos[14] ($0.24 for urban area) used the cost information in Campain et al.[19]; and Ciketic, Hayatbakhsh and Doran[13] ($0.81)

used a scoping report on fluoridation in Queensland, Australia. The estimated costs were comparable to the actual costs in the two above-mentioned studies.

Per capita cost ranged from $0.11 to $4.92 in 2013 U.S dollars. The variation in per capita annual cost was mainly attributable to community population size. Specifically, per capita annual cost decreased as population size increased, after adjusting other factors such as discount rate. The same pattern was shown in the original review [7], where the median per capita cost for a community with <=5000 people was $2.70 (assumedly in 2001 U.S. dollars) and that for a community with >=20000 people was $0.4. This implies economies of scale on the cost side. Graphical illustrations of the pattern in this study are presented in Appendix Figures 1 and 2 (available online). Both figures show that per capita annual cost was the highest when population size was around 1,000. As community population size increased, per capita annual cost decreased. In particular, per capita annual cost for communities >20,000 population was less than $1.

Most of the studies in this review focused on communities with population size ≥1,000, with the exception of Cobiac and Vos[14] in which per capita cost for a population <1,000 was $24. The author attributed the high cost to the rural nature of the community, where people are more scattered compared with urban communities.

Intervention Benefit

Generally, intervention benefit was composed of health care cost averted, productivity loss averted, and other losses averted. Health care cost included expenditure on examination, restoration (including lifetime treatment of the second, or further restoration of the tooth), and extraction. Productivity loss was mainly related to work time loss due to dental visits. Other losses included transportation cost to dental facilities. All ten studies provided benefit information. Four[5, 10, 15, 17] of them covered benefit only, the remaining six[9, 11–14, 16] also provided estimates of intervention cost.

Regression analysis was used in the four benefit-only studies[5, 10, 15, 17] (findings listed in Appendix Table 1), whose benefit was mainly composed of treatment cost averted, either as dental treatment averted or claims avoided. Although differences existed in their dependent variables and magnitudes of the estimates, all studies reached similar conclusions: the presence of CWF was related to fewer dental treatment cost/claims.

Benefit components for the six studies[9, 11–14, 16] that provided both benefit and cost information are presented in Appendix Table 2 (available online). Detailed per capita annual benefit in each study is shown in Table 2. One of the main causes of variation in benefit was the numbers of benefit components included in the studies. For example, Tchouaket et al.[16] included the most benefit components among the studies (five components), and their per capita annual benefit was the highest. In contrast, Wright et al.[12] only had two components, excluding lifetime treatment cost averted. Consequently, the benefit in Wright et al. was the lowest. In addition, per unit dental treatment cost and labor cost, varied with locations, contributed to some extent different cost averted among the studies. Information on per unit cost of dental treatment and of productivity is available in Appendix Table 3 (available online).

Of note, the majority of the studies assumed similar effectiveness rates, based on which the caries reduction rates and benefits were estimated. Specifically, both O'Connell et al.[11] and the base case in Griffin, Jones and Tomar[9] assumed 25% effectiveness of CWF. Tchouaket et al.[16] provided sensitivity analysis of the benefit with effectiveness ranging from 1% to 50%, and the 20% was used in this review. Wright et al. [12] had 33% effectiveness due to the 15% Maori population in New Zealand. Cobiac and Vos assumed 15% effectiveness based on the McDonagh et al.[20] systematic review. The 2013 Community Guide effectiveness review updated McDonagh et al.[20], with a median effectiveness of 25.1%. Overall, the effectiveness assumptions in the benefit studies were consistent with the result from the effectiveness review.

Benefit-Cost Ratios

Table 3 lists the benefit–cost ratios of the six studies that provided cost and benefit information. Some benefit–cost ratios were presented in the papers (such as O'Connell et al. [11] and Tchouaket et al.[16]), whereas others were calculated based on information available in the studies (Wright et al.[12], Griffin, Jones and Tomar[9], Cobiac and Vos[14], and Ciketc, Hayatbakhsh, and Doran[13]). The benefit–cost ratios varied with community sizes. Additionally, factors (such as the number of benefit components) contributing to the variations in benefit also played a role in varied benefit–cost ratios.

Despite other causes of variation, benefit–cost ratios generally increased with community population sizes, mainly due to the economies of scale on the cost side. Graphical illustrations of the association are presented in Appendix Figures 3 and 4 (available online). The most frequently cited benefit–cost ratio (38:1) in the U.S. was calculated using a 4% discount rate and 19% caries reduction from Griffin, Jones and Tomar[18], for communities with populations >20,000.

In conclusion, benefit-cost ratios were larger than one for communities of at least 1,000 people, indicating that CWF was cost-beneficial for communities larger than 1,000.

Cost-Effectiveness Analysis Results

Disability Adjusted Life Year (DALY) averted was used in two studies[13, 14] on cost-effectiveness analysis (see Online Appendix Table 4). For both studies, the cost/DALYs averted were well below annual per capita income of Australia (approximately $30,000 in 2013 dollars), which was used as a threshold for cost comparison with DALY averted.

Conclusion

Evidence Summary

Recent evidence continues to indicate that the economic benefit of CWF exceeds the intervention cost. Further, the benefit–cost ratio increases with the population of the community.

Discussion

The benefit of CWF exceeding cost suggests a positive rate of return for investment in CWF interventions. This is consistent with the findings from the previous Community Guide review (Truman et al.), which indicated that CWF saved money from a societal perspective and also reduced caries.

Due to the nature of the intervention, it would be very costly to obtain the actual benefit information of CWF. Therefore, the benefits of CWF in all the included economic studies were estimated, based on similar assumptions of effectiveness rates. Further, four of six studies used estimated cost instead of actual cost data. However, the variation among them was small, after adjusting for discount rate and population size. Nevertheless, future studies should focus on actual cost data if they are available.

Additionally, little evidence was found for communities with population <1,000, with the exception of two studies (Wright et al.[12], Griffin, Jones and Tomar[9]), which did sensitivity analyses and indicated that per capita annual cost exceeded per capita annual benefit for small communities with <1,000 population. Cost could be even higher if the residents were remote and scattered. As Cobiac and Vos[14] showed, per capita annual cost for rural communities with <1,000 people was $24. Future studies can provide more evidence on the benefit and cost information of smaller communities with less than 1,000 people. Lastly, only DALY was used for cost-effectiveness analysis. Future studies should provide further evidence on cost-effectiveness using QALY as a measurement of effectiveness.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

The authors acknowledge Susan Griffin from the Division of Oral Health (CDC) for her support at various steps of the review. Randy Elder, David Hopkins, Mona Patel, Verughese Jacob, Anilkrishna Thota, and Onnalee Gomez from the Community Guide Branch, CDC, provided helpful input in the literature search and the presentation of the review.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of CDC.

References

1. FC ML. water fluoridation: an analysis of the health benefits and risks: Institut National de Sante Publique du Quebec; 2007.
2. Hartman M, Martin AB, Lassman D, & Catlin A National health spending in 2013: growth slows, remains in step with the overall economy. Health Affairs 2014;10–1377.
3. Kohn WG MW, Malvitz DM, Presson SM, Shaddix KK. Recommendations for using fluoride to prevent and control dental caries in the United States. Morbidity and mortality weekly report 2001;50.
4. Control CfD P Ten great public health achievements--United States, 1900–1999. Morbidity and mortality weekly report 1999;48(12):241. [PubMed: 10220250]
5. Kumar JV AO, Melnik TA. . Geographic variation in medicaid claims for dental procedures in New York State: role of fluoridation under contemporary conditions. Public Health Reports 2010;125(5).

6. Mariño R FJ, Morgan M. Cost-effectiveness models for dental caries prevention programmes among Chilean schoolchildren. Community dental health 2012;29(4):302–308. [PubMed: 23488214]
7. Truman BI GB, Sulemana I, Gift HC, Horowitz AM, Evans CA, Jr, et al. Reviews of evidence on interventions to prevent dental caries, oral and pharyngeal cancers, and sports-related craniofacial injuries. American journal of preventive medicine 2002;23(1):21–54. [PubMed: 12091093]
8. Carande-Kulis VG MM, Briss PA, Teutsch SM, Zaza S, Truman BI, et al. Methods for systematic reviews of economic evaluations for the guide to community preventive services. American Journal of Preventive Medicine 2000;18(1):75–91. [PubMed: 10806980]
9. Griffin SO JK, Tomar SL. An economic evaluation of community water fluoridation. Journal of Public Health Dentistry 2001;61(2):78–86. [PubMed: 11474918]
10. Control CfD P Water fluoridation and costs of Medicaid treatment for dental decay--Louisiana, 1995–1996. Morbidity and mortality weekly report 1999;48(34).
11. O'Connell J, Brunson D, Anselmo T, Sullivan PW. . Costs and savings associated with community water fluoridation programs in Colorado. . Prev Chronic Dis 2005;2.
12. Wright JC BM, Cutress T, Lee M. . The cost-effectiveness of fluoridating water supplies in New Zealand. Australian and New Zealand Journal of Public Health 2001;25(2):170–178. [PubMed: 11357915]
13. Ciketic S HMR, Doran C M. Drinking water fluoridation in South East Queensland: a cost-effectiveness evaluation. Health Promotion Journal of Australia 2010;21(1):51–56. [PubMed: 20406153]
14. Cobiac LJ, Vos T. Cost-effectiveness of extending the coverage of water supply fluoridation for the prevention of dental caries in Australia. Community Dent Oral Epidemiol 2012;40(4):369–76. [PubMed: 22452320]
15. Maupomé G, Gullion CM, Peters D, Little SJ. A Comparison of Dental Treatment Utilization and Costs by HMO Members Living in Fluoridated and Nonfluoridated Areas. Journal of Public Health Dentistry 2007;67(4):224–233. [PubMed: 18087993]
16. Tchouaket E, Brousselle A, Fansi A, Dionne PA, Bertrand E, Fortin C. The economic value of Quebec's water fluoridation program. Z Gesundh Wiss 2013;21(6):523–533. [PubMed: 24293810]
17. Department TH. Water Fluoridation Costs in Texas. Report to fulfill House Consurrent Resolution 145 2000;Texas 75th Legislation.
18. Ringelberg ML, Allen SJ, & Brown LJ Cost of fluoridation: 44 Florida communities. Journal of public health dentistry 1992;52(2):75–80. [PubMed: 1564695]
19. Campain A MR, Wright F, Harrison D, Bailey D, Morgan M. The impact of changing dental needs on cost savings from fluoridation. Australian dental journal 2010;2010(55):37–44.
20. McDonough M WP, Bradley M, Cooper J, Sutton A, Chestnutt I, Misso K, Wilson P, Treasure E, Kleinjen J. A Systematic Review of Public Water Fluoridation. York(UK): University of York: National Health Service Centre for Reviews and Dissemination; 2000.

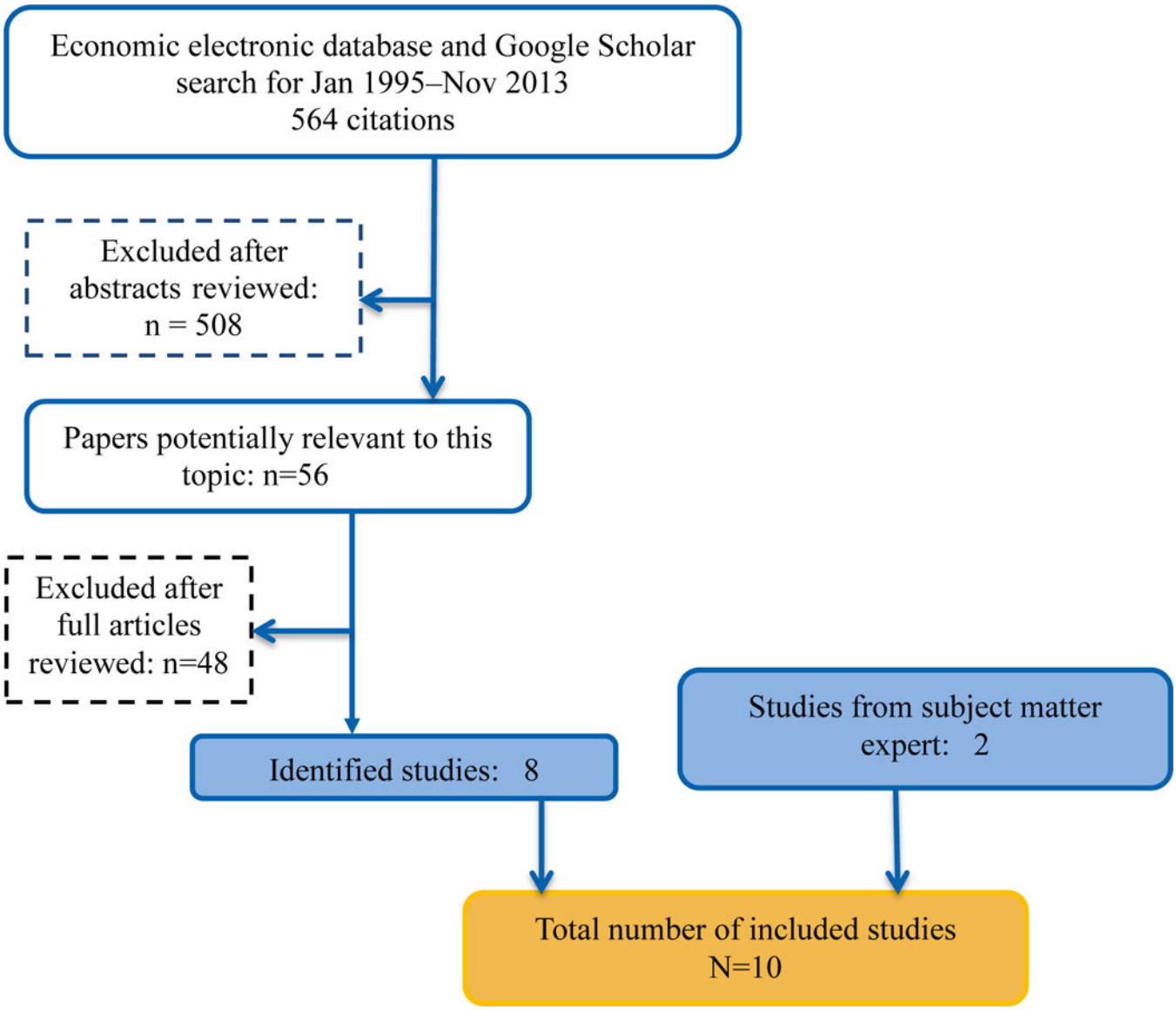

Figure 1.
Flowchart showing economic evidence search yield

Table1.

Per Capita Annual Cost of Community Water Fluoridation

Study	Location	Community population size	Actual cost?	Time horizon (years)	Per capita annual cost (2013$)
Tchouaket 2013	Quebec, Canada	—	Yes	20	1.63
O'Connell 2005	Colorado, U.S.	1,000	No	15	3.36
		≥20,000	No	15	0.54
Wright 2001[a]	New Zealand	1,000	Yes	30	4.92
		>300,000	Yes	30	0.11
Griffin 2001[b]	U.S.	<5,000	No	15	4.85
		>20,000	No	15	0.76
Cobiac 2012	Australia	<1,000	No	15	24.00
		≥1,000	No	15	0.24
Ciketic 2010	SE Queensland, Australia	—	No	15	0.81

[a] 5% discount rate.

[b] 4% discount rate.

— Not reported.

Table 2.

Community Water Fluoridation Per Capita Annual Benefit

Study	Location	Number of components	Caries reduction rate (%)	Per capita annual benefits (2013$)
Tchouaket 2013	Quebec, Canada	Yes (5)	20	93.19
O'Connell 2005	Colorado, U.S.	Yes (4)	20	73.50
Griffin 2001	U.S.	Yes (3)	19	29.23
Cobiac 2012	Australia	No (2)	15	--
Wright 2001	New Zealand	No (2)	33	5.49
Ciketic 2010	Australia	No (1)	—	14.19

—Not reported

Table 3.

Benefit–Cost Ratio

Study	Location	Community size	Caries reduction rate (%)	Benefit–Cost ratio
Tchouaket 2013	Quebec, Canada	--	30	82.71:1
O'Connell 2005	Colorado, U.S.	1,000	20	21.82:1
		≥20,000	20	135:1
Wright 2001	New Zealand	1,000	33	1.12[a]:1
		>300,000	33	48.79[a]:1
Griffin 2001	U.S.	<5,000	19	6.03[b]:1
		>20,000	19	38.24[b]:1
Cobiac 2012	Australia	≥1,000	15	37.69:1
Ciketic 2010	SE Queensland, Australia	—	—	16.51:1

[a]5% discount rate

[b]4% discount rate

—Not reported