Title Page

A model to determine the economic viability of water fluoridation

Authors

Jeroen Kroon

Griffith Health Institute / School of Dentistry and Oral Health, Griffith University, Australia

Philippus Johannes van Wyk

School of Dentistry, University of Pretoria, South Africa

Abstract

Objectives: In view of concerns expressed by South African local authorities the aim of this study was to develop a model to determine whether water fluoridation is economically viable to reduce dental caries in South Africa.

Methods: Microsoft Excel software was used to develop a model to determine economic viability of water fluoridation for seventeen water providers from all nine South African provinces. Input variables for this model relate to chemical cost, labour cost, maintenance cost of infrastructure, opportunity cost and capital depreciation. The following output variables were calculated to evaluate the cost of water fluoridation: per capita cost per year, cost-effectiveness and cost-benefit. In this model it is assumed that the introduction of community water fluoridation can reduce caries prevalence by an additional 15% and that the savings in cost of treatment will be equal to the average fee for a two surface restoration.

Results: Water providers included in the study serve 53.5% of the total population of South Africa. For all providers combined chemical cost contributes 64.5% to the total cost, per capita cost per year was $0.36, cost-effectiveness was calculated as $11.41 and cost-benefit of the implementation of water fluoridation was 0.34.

Conclusions: This model confirmed that water fluoridation is an economically viable option to prevent dental caries in South African communities, as well as conclusions over the last ten years that water fluoridation leads to significant cost savings and remains a cost-effective measure for reducing dental caries, even when the caries-preventive effectiveness is modest.

Key Words

fluoridation, cost-effectiveness, cost-benefit, economics

Text

Introduction

The impact of water fluoridation as a public health measure on oral health has been well reported for over 60 years. Since 1958 the World Health Organization (WHO) has on more than one occasion endorsed water fluoridation as a practical and effective health measure to reduce dental caries (1), most recently in its 2003 World Oral Health Report (2). In 2006 the WHO in collaboration with the Federation Dentaire Internationale (FDI) and the International Association for Dental Research (IADR) hosted a global consultation on “Oral Health through Fluoride”. A declaration from this consultation reaffirmed the efficiency, cost-effectiveness and safety of the daily use of optimal fluoride and that access to fluoride forms part of the basic human right to health (3).

Two reviews published a decade ago by the United Kingdom (UK) Medical Research Council (MRC) and the University of York concluded that there is a need to extensively research the economic impact of water fluoridation where the cost of the programme should be weighed against its benefits, especially in times of a trend of a reduction in dental caries and exposure to other fluoride products (4-5).

Costing water fluoridation and its benefits is a complex process looked upon differently by those responsible for its implementation, proponents of fluoridation, dental practitioners and even those opposed to fluoridation (6). At the conclusion of a 1989 workshop in Michigan health economists concluded that water fluoridation was one of a few public health measures where it actually saved more money than it costs to operate (7).

A UK study estimated that caries reduction as a result of water fluoridation would cost four times as much in a low caries area compared to a high caries area, suggesting that considerable economies of scale exist in terms of the reduction in cost per unit of benefit as the population size increases (8). A study of 44 fluoridated communities in Florida, United States of America (USA), estimated that per capita cost ranged from US $0.31 for communities with more than 50,000 residents to US $2.12 for communities with less than 10,000 residents and was still regarded as the most cost-effective approach in terms of cost per saved tooth surface (9). The prevention of dental caries, largely attributed to fluoridation and fluoride-containing products, was reported as leading to a saving of $39 billion in dental care expenditure from 1979 to 1989 (10). A study conducted in both fluoridated and non-fluoridated USA communities with observed caries reductions concluded that water fluoridation was still cost saving with the exception of communities with less than 5,000 residents (11). A New Zealand study regarded water fluoridation as cost-saving for communities with 1,000 residents or above. For more than one fluoride injection site the break-even point was reached in a community of 10,000 residents with not more than five fluoride injection points (12). A South African study on water fluoridation for the Gauteng Province concluded that even at an estimated caries reduction of 10% it would still be cost-effective and of benefit to implement water fluoridation (13). An Australian study on the feasibility, costs of installation and operation of water fluoridation plants in two remote indigenous communities in the Northern Territory with populations of 2,000 and 1,300 respectively reported that this investment should lead to a substantial and significant improvement of oral health in these communities (14). Two subsequent Australian studies concluded that water fluoridation remains a cost-effective measure for reducing dental caries, even when the caries-preventive effectiveness was modest (15-16).

Despite all the evidence in favour of water fluoridation and several recommendations and regulations to facilitate its implementation no artificially fluoridated water scheme currently exists in South Africa. In view of concerns expressed by South African local authorities about cost of implementation, the aim of this study was to develop a model to determine whether the implementation of water fluoridation is economically viable to reduce dental caries in South Africa.

Methods

Microsoft Excel software was used to develop a model to determine the economic viability of the implementation of water fluoridation for seventeen cities, towns and water boards from all nine South African provinces. This model is an expansion of the simulation model developed to report on cost-effectiveness and cost-benefit of water fluoridation for the Gauteng Province, South Africa (13) and principles described in other similar models (9, 17).

Information on the twenty three input variables required for the model was obtained from water providers who serve a large geographical area with more than one local authority, local authorities who are responsible for providing water to their own city or town only, the chemical industry, South African Department of Water Affairs and Forestry and the 1999-2002 National Children's Oral Health Survey of South Africa (NCOHS) (18-19). Sixteen of the input variables relate to either chemical cost, labour cost, maintenance cost of infrastructure, opportunity cost and capital depreciation. Operating cost was expressed as the sum of chemical cost, labour cost and maintenance cost. Maintenance and repair costs were calculated at 2.4% of the initial capital cost per year (9, 17). Total cost consists of the sum of operating cost, opportunity cost and capital depreciation. For opportunity cost it was argued that if the capital for the implementation of water fluoridation is available, the opportunity to use it for something else was forfeited and if the money has to be borrowed in the open market it will carry a cost. For this model it was based on the current South African Reserve Bank Prime Overdraft Rate of Banks of 9% for 2011 (20). Capital depreciation was calculated assuming a 15-year turnover for buildings (9) and an 8-year turnover on mechanical and electrical equipment and instrumentation with no salvage value. The remaining seven variables relate to the calculation of the economic outputs of this model.

The economic outputs of the model are expressed as per capita cost per year, cost-effectiveness ratio (the cost per person per year to save 1 DMFT) and cost-benefit ratio (the cost of the implementation of water fluoridation divided by the savings in cost of treatment). It was assumed that with current levels of dental caries the introduction of community water fluoridation would reduce dental caries by an additional 15% (21). Both cost-effectiveness and cost-benefit ratios were calculated for this caries reduction.

For cost-benefit analysis it was assumed that the savings in cost of treatment as a result of the introduction of water fluoridation will be equal to the average fee for a two surface restoration as calculated from the 2009 South African National Health Reference Price List (NHRPL) fee for a two surface amalgam, anterior resin and posterior resin restoration (22). The 2009 fees were adjusted by 7.9% for 2010 and a further 6.3% for 2011. The average fee for a 2 surface restoration in 2011 amounted to $33.49.

Water boards, cities and towns included in this study were classified based on their total daily water purification rate as either Category A (water purification rate of more than 700 Mega litre

(Ml) per day), B (water purification rate between 100 and 700 Ml per day) or C (water purification rate of less than 100 Ml per day) water providers.

The 2011 South African mid-year population estimates indicated the total population as 50.6 million people (23).Water purification plants managed by water providers included in this study serve 27.1 million people which represents 53.5% of the total population of South Africa.

In this model fluoride levels were adjusted to 0.7 ppm which is in line with the South African regulations for the fluoridation of water supplies (24).

All results are presented in United States Dollars (USD) based on the average exchange rate between the South Africa Rand (ZAR) and USD between 1 January 2011 to 31 December 2011 (ZAR 1 = USD 0.1385), the time this study was conducted (25).

Table 1 presents the model, indicating all input variables, formulas, source of information and assumptions made. Each variable is allocated a unique number (in square brackets) which assists in indicating where it is used in the different formulas.

Results

Based on their daily water purification rate, of the seventeen cities, towns and water boards from all nine South African provinces included in the study, six are classified as Category A, six as Category B and five as Category C water providers.

Table 2 presents a summary of chemical cost, labour cost, maintenance cost, opportunity cost, capital depreciation and operating cost as a percentage of total cost for the various categories of water providers. For all water providers combined chemical cost contributes 64.5% to the total cost and is higher for Category A (70.4%) compared to Category B (62.8%) and C providers (58.3%). The opposite applies to labour cost where this represents 17.4% of the total cost for Category C providers compared to only 4.6% for Category A providers. The average contribution of labour cost to total cost for all water providers combined is 11%. Operating cost contributes 78.2% to the total cost and only varies slightly between the different categories of water providers. On average opportunity cost and capital depreciation contribute 9.9% and 11.9% respectively to the total cost. For all water providers combined the total annual cost for water fluoridation amounts to approximately $860,000 per year.

Table 3 present results for per capita cost per year, cost-effectiveness ratio and cost-benefit ratio for all seventeen water providers included in the study based on the formulas, assumptions and values listed and described in Table 1, as well as an average value for each category of water provider and for all water providers combined.

Water providers included in this study serve 53.5% of the estimated total population of South Africa of 50.6 million in 2011 (23). The average per capita cost per year of water fluoridation for the population served by all categories of water providers combined is $0.36. The average per capita cost is slightly higher for Category A ($0.40) compared to Category B ($0.34) and C ($0.30) providers. The highest per capita cost is $0.65 for a Category C provider (Mbombela) followed by $0.62 for a Category B provider (Kimberley).

Cost-effectiveness ratio is presented as the cost per person per year to save 1 DMFT and was calculated based on an assumed caries reduction of 15% (21). When comparing different categories of water providers, it is slightly more cost-effective to introduce water fluoridation for Category C ($10.73) compared to Category A ($12.09) and B ($11.18) providers. Cost-effectiveness ratio varies from $4.81 for Amatola Water (Category B provider) to $17.27 for Mbombela (Category C provider).

Cost-benefit ratio is presented as the cost of the implementation of water fluoridation divided by the savings in cost of treatment. It is assumed that the savings in cost of treatment as a result of the introduction of water fluoridation will be equal to the average fee for a two surface restoration of $33.49 (22). It is recommended that water fluoridation should not be considered if the cost-benefit ratio approaches, equals or exceeds one (13). For all water providers combined cost-benefit ratio is 0.34. The highest cost-benefit ratio of 0.52 is found for a Category C water provider (Mbombela) followed by 0.49 for a Category B water provider (Pietermaritzburg).

Discussion

Water fluoridation is generally regarded as one of the ten greatest public health achievements in the 20th century (26). The 2003 World Oral Health Report confirmed the evidence that long-term exposure to an optimal level of fluoride results in diminishing levels of caries in both children and adults (2). It is estimated that only 20% of the world's population benefit from an appropriate exposure to fluoride despite fluoride being available from a range of options (3).

Before 1980 communities with fluoridated water supplies typically experienced 50% less dental caries compared to non-fluoridated communities during which time economic evaluations of water fluoridation revealed this measure to be highly cost-effective (27). A review of caries trends between 1953 and 2003 from several Western European countries reported a decline in caries prevalence to low or very low levels for both fluoridated and non-fluoridated communities. This review concluded that caries prevalence is set to increase again due an increase in the number of children of low social-economic status and an increase in immigrants from outside Western Europe (28). Another review on available epidemiological data since 2000 for several countries also expressed a concern about a possible increase in caries prevalence and emphasised that dental caries remains a serious health problem. Twenty-one countries from across the world were listed in this review who have not achieved the WHO goal of a DMFT of less than 3.0 for 12-year-olds post 1995 (29). Both these reviews call for a renewed campaign emphasising the use of fluoride as part of a caries prevention approach.

Both the United Kingdom MRC and University of York reviews into water fluoridation identified a need to research the economic impact of water fluoridation at a time of reductions in dental caries and exposure to other fluoride products (4-5). Caries prevalence for 12-year-old South African children declined to 1.05 in the 1999-2002 NCOHS. The NCOHS report recommended that the implementation of water fluoridation be evaluated for South Africa taking into account current caries levels and the cost of water fluoridation (18). Despite all the evidence in favour of water fluoridation as well as regulations for the introduction of water fluoridation which compel water providers to fluoridate public water supplies (24), no artificially fluoridated water scheme exists in South Africa. This can mainly be ascribed to concerns raised by South African local authorities about cost and reports urging further investigation into the effectiveness of water fluoridation.

The model presented in this paper took into consideration twenty three input variables linked to chemical cost, labour cost, maintenance cost of infrastructure, opportunity cost, capital depreciation as well as the calculation of the economic outputs of the model (per capita cost, cost-effectiveness ratio and cost-benefit ratio). The model was applied to seventeen cities, towns and water boards from all nine South African provinces.

Results for all water providers included in this study combined, which serve 53.5% of the total population of South Africa, showed that chemical cost is responsible for 64.5% of total cost, per capita cost per year is $0.36, the cost-effectiveness ratio is calculated as $11.41 and the cost-benefit ratio of the implementation of water fluoridation is 0.34. This study confirms that along with worldwide fluctuations in caries prevalence water fluoridation remains an important public health measure in populations where oral hygiene is poor, lifestyle habits can lead to increases in caries levels and access to a well-functioning oral health care system is limited (30). Results from this study further confirm that water fluoridation is still an economically viable option to prevent dental caries in South African communities, as well as conclusions over the last ten years that water fluoridation leads to significant cost savings and remains a cost-effective measure for reducing dental caries, even when the caries-preventive effectiveness is modest (11-12, 15-16, 31).

The model presented in this paper provides a basis for estimating the cost and viability of water fluoridation. It should however be kept in mind that costs can and will vary between countries, with system design, the availability of and the type of chemical used, equipment, adjustment of natural fluoride levels, the number of fluoride injection points and population size. The benefits of fluoridation should always be measured against the cost and if the cost-benefit ratio approaches or is larger than one water fluoridation should not be considered as an economically viable option.

A limitation of cost-benefit analysis is that it would not be possible to express all the benefits linked to an intervention in monetary terms which will result in certain immeasurable, intangible or indirect benefits therefore often being ignored. In this model the benefits of water fluoridation are only measured in terms of dental caries averted. Some of the intangible benefits of water fluoridation not accounted for in this model may include social acceptability due to retention of teeth, avoidance of extractions, saving in oral health workers' time or salaries and less pain and discomfort with a resulting reduction in loss of time from school or work.

References

1. World Health Organization. Report on Expert Committee on Water Fluoridation. WHO Technical Report Series No. 146. Geneva: World Health Organization; 1958.
2. Petersen PE. The World Oral Health Report 2003: continuous improvement of oral health in the 21st century--the approach of the WHO Global Oral Health Programme. *Community Dent Oral Epidemiol*. 2003;**1**:3-23.
3. World Health Organization. Global consultation on oral health through fluoride. World Health Organization; 2006 [cited 2010 March 12]; Available from: http://www.who.int/oral_health/events/Global_consultation/en/index.html.
4. Medical Research Council. Water fluoridation and health. London: Medical Research Council; 2002.
5. NHS Centre for Review and Dissemination. A Systematic Review of Public Water Fluoridation (Report No. 18). York: University of York; 2000.
6. Burt BA, Eklund SA. Fluoride: Human Health and Caries Prevention; Fluoridation of Drinking Water. St. Louis: Elsevier/Saunders; 2005.
7. Anonymous. Results of the workshop. *J Public Health Dent*. 1989;**49 (Special Issue)**:331-7.
8. Birch S. The relative cost effectiveness of water fluoridation across communities: analysis of variations according to underlying caries levels. *Community Dental Hlth*. 1990;**7**:3-10.
9. Ringelberg ML, Allen SJ, Brown LJ. Cost of fluoridation: 44 Florida communities. *J Public Health Dent*. 1992;**52**:75-80.
10. Brown LJ, Beazoglou T, Heffley D. Estimated savings in U.S. dental expenditures, 1979-89. *Public Health Rep*. 1994;**109**:195-203.

11. Griffin SO, Jones K, Tomar SL. An economic evaluation of community water fluoridation. *J Public Health Dent*. 2001;**61**:78-86.

12. Wright JC, Bates MN, Cutress T, Lee M. The cost-effectiveness of fluoridating water supplies in New Zealand. *Aust N Z J Public Health*. 2001;**25**:170-8.

13. Van Wyk PJ, Kroon J, Holtshousen WS. Cost evaluation for the implementation of water fluoridation in Gauteng. *SADJ*. 2001;**56**:71-6.

14. Ehsani JP, Bailie R. Feasibility and costs of water fluoridation in remote Australian Aboriginal communities. *BioMed Central Public Health*. 2007;**7**:100.

15. Campain AC, Marino RJ, Wright FAC, Harrison D, Bailey DL, Morgan MV. The impact of changing dental needs on cost savings from fluoridation. *Aust Dent J*. 2010;**55**:37-44.

16. Ciketic S, Hayatbakhsh MR, Doran CM. Drinking water fluoridation in South East Queensland: a cost-effectiveness evaluation. *Health Promot J Aust*. 2010;**21**:51-6.

17. White BA, Antczak-Bouckoms AA, Weinstein MC. Issues in the economic evaluation of community water fluoridation. *J Dent Educ*. 1989;**53**:646-57.

18. Department of Health. Report: National Children's Oral Health Survey South Africa. 1999 - 2002. Pretoria: UP Printers; 2003.

19. Van Wyk PJ, Louw AJ, Du Plessis JB. Caries status and treatment needs in South Africa: report of the 1999-2002 National Children's Oral Health Survey. *SADJ*. 2004;**59**:240-2.

20. South African Reserve Bank. Dates of Change in the Prime Overdraft Rate of Banks. South African Reserve Bank; 2011 [cited 2012 January 6]; Available from: http://www.resbank.co.za/Research/Rates/Pages/Rates-Home.aspx.

21. Petersen PE, Lennon MA. Effective use of fluorides for the prevention of dental caries in the 21st century: the WHO approach. *Community Dent Oral Epidemiol*. 2004;**32**:319-21.

22. Council for Medical Schemes. National Health Reference Price List. Council for Medical Schemes; 2010 [cited 2011 January 24]; Available from: http://www.medicalschemes.com/Publications.aspx.

23. Statistics South Africa. Mid-year population estimates, South Africa 2011. Statistics South Africa; 2011 [cited 2012 January 6]; Available from: http://www.statssa.gov.za/publications/P0302/P03022011.pdf.

24. Republic of South Africa. Regulations on fluoridating water supplies. Government Gazette Vol. 423, No. 21533. Pretoria: Government Printer; 2000.

25. OANDA. Currency Converter. OANDA; 2011 [cited 2012 January 6]; Available from: http://www.oanda.com/currency/converter/.

26. Centers for Disease Control and Prevention. Achievements in Public Health, 1900-1999: Fluoridation of Drinking Water to Prevent Dental Caries. *MMWR Morb Mortal Wkly Rep*. 1999;**48**:933-40.

27. Ripa LW. A half-century of community water fluoridation in the United States: review and commentary. *J Public Health Dent*. 1993;**53**:17-44.

28. Marthaler TM. Changes in dental caries 1953-2003. *Caries Res*. 2004;**38**:173-81.

29. Bagramian RA, Garcia-Godoy F, Volpe AR. The global increase in dental caries. A pending public health crisis. *Am J Dent*. 2009;**22**:3-8.

30. Pizzo G, Piscopo MR, Pizzo I, Giuliana G. Community water fluoridation and caries prevention: a critical review. *Clin Oral Investig*. 2007;**11**:189-93.

31. Kumar JV. Is water fluoridation still necessary? *Adv Dent Res*. 2008;**20**:8-12.

32. Grobler SR, Chikte UME, Louw AJ. Fluoride Concentrations of Drinking Water in the Nine Provinces of South Africa. *SADJ*. 2006;**61**:446.

Individual tables and figures

Table 1 A model to calculate total cost, per capita cost, cost-effectiveness ratio and cost-benefit ratio of the implementation of water fluoridation

	Variable	Formula	Source of information, fixed values and assumptions
	(A) CHEMICAL COST		
	Chemical used Available fluoride Purity		Fluorosilicic acid 79.1% 40% This chemical is produced in South Africa, is relatively inexpensive, requires a simple dosing technique and it is suitability for both large and small water plants
[1]	Daily water purification rate (litre per day)		Water providers Water boards, cities and town are classified into Category A, B or C providers based on the daily water purification rate
[2]	Natural fluoride content of water (mg F/litre)		(32)
[3]	Adjustment of fluoride level (mg F/litre) to:		0.7 ppm (24)
[4]	Fluoride needed per day (metric tonne)	[1] x ([3] - [2]) / (1 x 10^9)	
[5]	Fluoride needed per year (metric tonne)	[4] x 365	
[6]	Chemical needed per year (metric tonne)	[5] / (% available fluoride x % purity)	
[7]	Cost of chemical (metric tonne)		Chemical industry $1,385 per metric tonne
[8]	Percentage handling fee by agent		Chemical industry 12.5%
[9]	Delivery cost (metric tonne)		Varies based on the distance from the chemical plant to the water provider
[10]	Total delivery cost of chemical	[7] + ([7] x [8] / 100) + [9]	

(A)	**Cost of chemical per year**	[6] x [10]	
	(B) LABOUR COST		
[11]	Average operator salary		Water providers
[12]	Number of operators needed		It is assumed that this would be based on the water purification rate of the plant: >250 Ml/day: 4 operators 100-249 Ml/day: 3 operators 50-99 Ml/day: 2 operators <50 Ml/day: 1 operator
[13]	Annual operator salary for number of operators needed	[11] x [12]	
[14]	Number of hours needed per operator per day		1 hour per day (or 8 hour shift) (9)
(B)	**Annual labour cost for number of hours needed per day**	[13] / 8 x [14]	
	(C) MAINTENANCE COST		
[15]	Capital cost per Mega litre of water processed daily		$1,626 per Ml This value is based on South African estimates and is adjusted to Ml of water purified per day (13)
[16]	Percentage cost of buildings and storage		It is assumed to be a % of capital cost Category A: 21% Category B: 29% Category C: 36%
[17]	Cost of buildings and storage	[1] / 1,000,000 x [15] x [16] / 100	
[18]	Percentage cost of mechanical and electrical plant		It is assumed to be a % of capital cost Category A: 79% Category B: 71% Category C: 64%
[19]	Cost of mechanical and electrical plant	[1] / 1,000,000 x [15] x [18] / 100	
[20]	Total capital cost	[17] + [19]	
[21]	Maintenance as a % of capital cost		2.4% (9)
(C)	**Maintenance cost**	[20] x [21] / 100	

(D) OPPORTUNITY COST		
[22] Prime Overdraft Rate of Banks		South African Reserve Bank 9% (20)
(D) Opportunity cost as a percentage of total capital cost	[20] x [22] / 100	
(E) CAPITAL DEPRECIATION		
[23] Years for building and storage		15 years (9)
[24] Capital depreciation of buildings and storage	[17] / [23]	
[25] Years for mechanical and electrical plant		8 years (13)
[26] Capital depreciation of mechanical and electrical plant	[19] / [25]	
(E) Total capital depreciation per annum	[24] + [26]	
(F) OPERATING COST		
(F) Operating Cost = Chemical cost + Labour cost + Maintenance cost	(A) + (B) + (C)	
(G) TOTAL COST		
(G) Total cost = Opportunity cost + Capital depreciation + Operating cost	(D) + (E) + (F)	
(H) PER CAPITA COST		
[27] Population served by water provider		Water providers
[28] Per capita cost for total population	(G) / [27]	
(I) CARIES DATA		
[29] DMFT		1999-2002 National Children's Oral Health Survey of South Africa (18-19)
[30] Age for DMFT score used		15-year-olds
[31] DMFT increment per year	[29] / ([30] - 6)	It is assumed that the annual caries increment will be identical for all ages

(J) COST-EFFECTIVENESS RATIO (the cost per person per year to save 1 DMFT)		
[32] Anticipated percentage decrease in dental caries		15% (21)
[33] Decrease in DMFT per child per year	[32] / 100 x [31]	
(J) Cost-effectiveness for total population	[28] / [33]	
(K) COST-BENEFIT RATIO (the cost of the implementation of water fluoridation divided by the savings in cost of treatment)		
[34] Cost of a two surface amalgam restoration		2009 NHRPL fee (22) adjusted for 2010 and 2011 $30.31
[35] Cost of a two surface anterior resin restoration		2009 NHRPL fee (22) adjusted for 2010 and 2011 $33.95
[36] Cost of a two surface posterior resin restoration		2009 NHRPL fee (22) adjusted for 2010 and 2011 $36.20
[37] Average cost of a two surface restoration	([34] + [35] + [36]) / 3	$33.49 It is assumed that the savings in cost of treatment as a result of the introduction of water fluoridation will be equal to the average cost for a two surface restoration
(K) Cost-benefit ratio for total population	[28] / ([33] x [37])	

Table 2 An analysis of the cost of water fluoridation for the different categories of water providers

	Category A providers (n=6)	Category B providers (n=6)	Category C providers (n=5)	Category A, B, C providers combined (n=17)
(A) Chemical cost	70.4%	62.8%	58.3%	**64.5%**
(B) Labour cost	4.6%	13.2%	17.4%	**11.0%**
(C) Maintenance cost	2.6%	2.6%	2.7%	**2.6%**
(D) Opportunity cost	9.9%	9.7%	10.0%	**9.9%**
(E) Capital depreciation	12.4%	11.7%	11.6%	**11.9%**
(F) Operating cost (A)+(B)+(C)	77.6%	78.6%	78.4%	**78.2%**
(G) Total cost (D)+(E)+(F)	**$1,965,305.69**	**$234,838.05**	**$62,991.34**	**$860,062.49**

Table 3 Per capita cost, cost-effectiveness ratio and cost-benefit ratio

	Per capita cost per year	**Cost-effectiveness ratio**	**Cost-benefit ratio**
Cape Town	$0.37	$5.43	0.16
Umgeni Water	$0.47	$15.02	0.45
Durban	$0.45	$13.96	0.42
Rand Water	$0.30	$9.98	0.30
Johannesburg	$0.40	$13.36	0.40
Tshwane	$0.36	$11.94	0.36
Category A Average	**$0.40**	**$12.09**	**0.36**
Port Elizabeth	$0.42	$12.53	0.37
Amatola Water	$0.16	$4.81	0.14
Pietermaritzburg	$0.35	$16.53	0.49
Bloem Water	$0.25	$9.81	0.29
Bloemfontein	$0.27	$10.49	0.31
Kimberley	$0.62	$12.94	0.39
Category B Average	**$0.34**	**$11.18**	**0.33**
Buffalo City	$0.18	$5.43	0.16
Botshabelo	$0.13	$5.00	0.15
Mafikeng	$0.40	$10.54	0.31
Mbombela	$0.65	$17.27	0.52
Polokwane	$0.16	$15.39	0.46
Category C Average	**$0.30**	**$10.73**	**0.32**
Category A, B, C Average	**$0.36**	**$11.41**	**0.34**

Cost-effectiveness ratio: The cost per person per year to save 1 DMFT

Cost-benefit ratio: The cost of the implementation of water fluoridation divided by the savings in cost of treatment