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CUSTO-BENEFÍCIO DA FLUORETAÇÃO DA ÁGUA DE ABASTECIMENTO PÚBLICO

LORRAYNE BELOTTI

Tese apresentada ao Programa de Pós-Graduação em Saúde Pública da Universidade de São Paulo para obtenção do título de Doutora em Ciências.

Área de Concentração: Saúde Pública

Orientador: Prof. Dr. Paulo Frazão (FSP-USP)

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Ao meu pai, minha luz, que antes de partir me ensinou a ter a coragem das estrelas e me explicou o infinito com a sua generosidade.

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“Lembrei que quando eu aprendi a ler entrei em desespero, porque descobri que não era mais possível olhar as palavras sem ler. Tentei muitas vezes, queria de volta os desenhos-letras jogados pelas ruas. Foi uma lição sem volta. Tudo o que as palavras dissessem me tornei obrigada a ouvir. Fico pensando quantas coisas não vou poder nunca mais deixar de saber.”

— *Mariana Salomão Carrara, Se Deus Me Chamar Não Vou*

RESUMO

BELOTTI, L. **Custo-benefício da fluoretação da água de abastecimento público**. Tese de doutorado – Faculdade de Saúde Pública, Universidade de São Paulo, 2022.

OBJETIVO: Analisar potenciais fatores ligados à qualidade da fluoretação da água de abastecimento público, seu custo-benefício e custo-efetividade em diferentes portes populacionais e grupos etários no Brasil. **MÉTODO:** Foi realizado um estudo de avaliação econômica, em que tanto consumo de recursos, quanto os benefícios em saúde foram medidos. Inicialmente, foi realizado um estudo ecológico para avaliar fatores associados a qualidade da fluoretação, utilizando regressão de Poisson. Os custos com a medida foram analisados por meio de um estudo de caso e, foram considerados dados referentes aos custos de instalação inicial, do produto químico, da operacionalização do sistema e do controle dos teores de flúor. Para análise da efetividade da fluoretação, foi realizado uma revisão sistemática com estudos brasileiros que comparam a experiência de cárie em áreas fluoretadas e não fluoretadas. A avaliação econômica foi conduzida na perspectiva da sociedade, foram calculados o custo-efetividade e custo-benefício, e foram incluídos os custos diretos e indiretos dos procedimentos que poderiam ser evitados, com uma taxa de desconto de 3,5%. Foi realizada análise de sensibilidade para avaliar a robustez dos resultados. **RESULTADOS:** Os fatores associados a qualidade da fluoretação foram, porte populacional do município, conformidade da concentração de cloro, renda *per capita* e tipo de empresa de saneamento. O custo *per capita* anual da fluoretação variou de US$ 7,32 para o porte com menos de 2 mil habitantes a US$ 0,14 para o porte com cerca de 520 mil habitantes. Nos sistemas que servem até 30 mil habitantes, o custo de operacionalização foi responsável por maior parte dos gastos, variando de 98,20 a 84,00%. No porte de 520 mil habitantes, os custos com o produto químico corresponderam a 74,7% dos gastos. A diferença média do ceod entre áreas fluoretadas e não fluoretadas foi -2,28 (IC95% -3,26; -1,30) para crianças de 5 a 8 anos e -1,12 (IC95% CI -1,93; -0,32) para 3 a 12 anos. A diferença média no CPOD foi -0.61 (IC95% -0,80; -0,42) e a prevalência de cárie foi 1,4 vezes e 57% menor na dentição decídua e permanente, respectivamente. Os custos evitados decorrentes da fluoretação foram de US$ 174,40 e US$ 85,67 para crianças de 5-8 e 3-12 anos, respectivamente, e US$ 46,66 para crianças de 7-12 anos. Os resultados do custo-efetividade e custo-benefício foram favoráveis em todos os cenários onde o tamanho da população atendida foi de 6.000 ou mais habitantes. Cenários desfavoráveis foram observados apenas em tamanho até 2.000 habitantes. **CONCLUSÃO:** A fluoretação se mantem como uma medida de baixo custo *per capita* e efetiva contra a cárie dentária mesmo com o amplo uso do dentifrício fluoretado. Além disso, é economicamente vantajosa principalmente em áreas mais populosas, tanto na dentição decídua quanto permanente. Como o processo de tomada de decisão no campo das políticas públicas sofre múltiplas influências em torno de diferentes alternativas de políticas, conhecer os fatores relacionados a qualidade da fluoretação, seus custos e sua efetividade é essencial para uma tomada de decisão informada.

Palavras chaves: fluoretação da água; abastecimento de água; análise de custos; meta-análise; avaliação econômica.

ABSTRACT

BELOTTI, L. **Cost-benefit analysis of community water fluoridation.** Thesis - School of Public Health University of São Paulo, 2022.

OBJECTIVE: To analyze potential factors associated to the quality of fluoridation of public water supply, its cost-effectiveness and cost-effectiveness in different population sizes and age groups in Brazil. **METHOD:** An economic evaluation study was carried out, in which both resource consumption and health benefits were measured. Initially, an ecological study was carried out to evaluate factors associated with the quality of fluoridation, using Poisson regression. A case study was carried out to analyze the costs of fluoridation, and data referring to the costs of initial installation, chemical product, system operationalization and control of fluoride levels were considered. To analyze the effectiveness of fluoridation, a systematic review was carried out with Brazilian studies comparing the experience of caries in fluoridated and non-fluoridated areas. The economic evaluation was conducted from the perspective of society, cost-effectiveness and cost-benefit were calculated, and direct and indirect costs of procedures that could be avoided were included, with a discount rate of 3.5%. Sensitivity analysis was performed to assess the robustness of the results. **RESULTS**: The factors associated with the quality of fluoridation were population size of the municipality, compliance with chlorine concentration, *per capita* income, and type of sanitation company. The annual *per capita* cost of fluoridation ranged from US$ 7.32 for municipalities with less than 2 thousand inhabitants to US$ 0.14 for municipalities with approximately 520 thousand inhabitants. In systems that serve up to 30 thousand inhabitants, the cost of operation was responsible for most of the expenses, ranging from 98.2 to 84%. In the size of 520 thousand inhabitants, the costs with the chemical product corresponded to 74.7% of the expenses. The mean difference in dmft between fluoridated and non-fluoridated areas was -2.28 (95%CI -3.26; -1.30) for children aged 5 to 8 years and -1.12 (95%CI -1.93; -0.32) for 3 to 12 years. The mean difference in DMFT was -0.61 (95%CI -0.80; -0.42) and caries prevalence was 1.4 times and 57% lower in primary and permanent dentition, respectively. Avoided costs from fluoridation were US$174.40 and US$85.67 for children aged 5-8 and 3-12 years, respectively, and US$46.66 for children aged 7-12 years. The cost-effectiveness and cost-benefit results were favorable in all scenarios where the population size served was 6,000 or more inhabitants. Unfavorable scenarios were observed only in size up to 2,000 inhabitants. **CONCLUSION**: Fluoridation remains a low-cost *per capita* and effective measure against dental caries even with the widespread use of fluoride toothpaste. In addition, it is economically advantageous mainly in more populated areas, both in deciduous and permanent dentition. As the decision-making process in the field of public policies is complex and decision-makers suffer multiple influences around different policy alternatives, knowing the factors related to the quality of fluoridation, its costs and its effectiveness is essential for an informed decision making.

Key-words: Fluoridation; water supply; cost-analysis; meta-analysis; health economics.

SUMÁRIO

1 INTRODUÇÃO

A fluoretação da água de abastecimento público é uma das medidas mais amplas de promoção de saúde e prevenção da doença cárie e foi reconhecida como uma das dez medidas mais importantes de saúde pública no século XX, nos EUA, ao lado de programas de vacinação, alimentação e nutrição (CDC,1999). Diante da sua relevância, é parte da agenda política internacional sendo considerada uma estratégia equitativa que deve ser desenvolvida e implantada em países que ainda não apresentam programas de fluoretação da água de abastecimento público (WHO, 2017).

Tem sido recomendada por mais de 150 organizações de ciência e saúde na segunda metade do século XX (CDC,1999), incluindo a Federação Dentária Internacional, a Organização Mundial de Saúde e a Organização Pan Americana de Saúde. Em maio de 2021, na 74ª Assembleia da Organização Mundial da Saúde, foi reafirmada a importância da promoção de intervenções baseadas na comunidade, tais como a fluoretação da água e acessibilidade ao creme dental fluoretado (WHO, 2021).

Em 2022, a Associação Internacional para Pesquisa Odontológica (International Association for Dental Research - IADR) atualizou sua posição de apoio à fluoretação da água de abastecimento público (DO et al., 2022). No Brasil, fluoretação da água de abastecimento público foi implementada pela primeira vez em Baixo Guandu (ES) em 1953 e tornou-se obrigatória em Estações de Tratamento de Água em 1974, sendo desde então recomendada pelo Ministério da Saúde do Brasil e também por entidades de odontologia e de saúde pública que indicam ser a tecnologia eficiente, eficaz e efetiva para a prevenção da cárie dentária, além de ser segura para a saúde humana e animal (CECOL, 2021).

Estudos sobre a fluoretação da água e sua relação com a prevenção de cárie dentária, têm sido desenvolvidos desde a implementação dessa medida. Entre os anos de 2000 e 2015, cinco revisões foram publicadas sobre o assunto, sendo três revisões sistemáticas (McDONAGH et al, 2000; TRUMAN et al., 2002; AUSTRALIAN GOVERNMENT, 2007; EUROPEAN COMMISSION, 2011; IHEOZOR-EJIOFOR et al., 2015)

Pesquisas epidemiológicas realizadas em nível nacional no Brasil têm mostrado redução do índice de dentes cariados, perdidos e obturados (CPOD), que mede a experiência de cárie numa população (ANTUNES; NARVAI, 2010). O índice reduziu de 6,7 em 1986 para 2,8 em 2003 e para 2,1 em 2010, entre crianças de 12 anos de idade (BRASIL, 2012). Em populações adultas, observou-se aumento no número de dentes hígidos e o declínio no número de dentes perdidos (NASCIMENTO et al., 2013). Pesquisadores atribuem a melhora no perfil da saúde bucal ao maior acesso ao flúor incluindo os efeitos da fluoretação da água (NARVAI et al 2006; NASCIMENTO et al., 2013).

Apesar de inegáveis avanços na redução do CPOD no Brasil, cerca de 40% dos municípios não asseguram a provisão do benefício (IBGE, 2008). Essa distribuição desigual do recurso preventivo pode contribuir para aumentar o viés socioeconômico na prevalência da doença (ANTUNES; NARVAI, 2010).

Comparando-se as regiões, são expressivas as diferenças nas médias do CPOD aos 12 anos: as regiões Norte (com 3,16) e Nordeste (com 2,63) e também o Centro-Oeste (com 2,63) têm situação mais desfavorável que as regiões Sudeste (1,72) e Sul (2,06) (BRASIL, 2012). Ao mesmo tempo, essa desigualdade se estende para cobertura da população beneficiada por água fluoretada, principalmente entre as capitais das regiões Norte e Nordeste em relação ao Sudeste e Sul (GABARDO et al., 2008).

Um estudo realizado por Peres, Antunes e Peres (2006), demonstrou que o índice CPOD aos 12 anos é menor em áreas fluoretadas (2,4) quando comparado a áreas não fluoretadas (3,5). Os autores também revelaram que quanto maior a cobertura do sistema de abastecimento de água, menor o CPOD aos 12 anos. Segundo Frazão, Antunes e Narvai (2003), em um estudo conduzido em São Paulo, a experiência de cárie dentária em adultos que residem em cidades com água de abastecimento público fluoretada também foi menor em comparação com adultos de cidades sem esse benefício. Essa diferença mostra que a medida continua efetiva. O descumprimento da determinação legal de prover a fluoretação é fator de injustiça social para uma parcela da população (FRAZÃO; ANTUNES; NARVAI, 2003).

Um motivo alegado pelas companhias de abastecimento de água que impede o aumento da cobertura da população beneficiada pela fluoretação está relacionado com os custos da instalação do sistema de ajuste da concentração, da aquisição do produto químico e da capacitação profissional (FRIAS et al., 2006; RAMOS; VALENTIM, 2012).

Estudo realizado no município de São Paulo, em que apenas os custos foram avaliados, encontrou um valor médio *per capita*/ano de R$ 0,08 (US$ 0,03) em 2003 e um valor acumulado em 18 anos de implantação do sistema de fluoretação (período de 1983 a 2005) de R$ 1,44 (US$ 0,97) *per capita* (FRIAS et al., 2006). Martinez et al. (2015), analisaram os custos da fluoretação no município de Sorocaba, e encontraram que o custo *per capita* foi R$ 1,49 (US$ 0,72) em 2009, e em estimativas para o período de 1989 a 2008, o custo variou de R$ 1,19 a R$ 1,43 (US$ 0,59 a US$ 0,72).

Em que pese a importância dos casos estudados, para produção de informações em áreas demográficas de grande porte, falta no Brasil análises para áreas de médio e pequeno porte e estudos de avaliação do custo em relação à efetividade e ao benefício.

Fyfe et al. (2015) em estudo na Nova Zelândia sobre o custo-efetividade da fluoretação em diferentes portes populacionais, encontraram que o custo variou de U$0,37 a U$5,53 *per capita* anual e que a fluoretação foi custo-efetiva na maioria dos perfis populacionais. Entretanto, para as comunidades com menos de cinco mil habitantes, a relação custo-efetividade foi mais dependente do perfil de risco da população sob a intervenção.

Griffin et al. (2001) realizaram uma avaliação econômica do tipo custo-efetividade baseada em dados obtidos desde a década de 1980 e concluíram que a redução anual de custo líquido *per capita* foi U$ 15,95 em comunidades com menos de 5 mil habitantes e U$ 18,62 nas com mais de 20 mil habitantes. Ademais, a redução de cárie dentária encontrada em crianças e adultos foi cerca de 25% em áreas fluoretadas.

Estudo realizado em Colorado, nos Estados Unidos da América (EUA), comparou os custos da fluoretação com os tratamentos evitados associados a cárie dentária e encontrou que a medida promoveu reduções de U$ 148,9 milhões nos gastos com tratamentos odontológicos em 2003, com uma média de U$60,78 *per capita* Além disso, o estado do Colorado pouparia U$ 46,6 milhões de dólares anuais se a medida fosse implantada em áreas não fluoretadas (O’CONNELL et al., 2005). Estudo semelhante, realizado em Quebec, demonstrou que um dólar canadense investido no programa economizou entre $71,05 a $82,83 por habitante com gastos de tratamento restauradores, caso as lesões cariosas não fossem prevenidas (TCHOUAKET et al., 2013).

Após a interrupção da fluoretação de água na cidade de Stranraer, na Escócia, pesquisadores encontraram um aumento na prevalência de cárie dentária em crianças de 10 anos de idade, ao comparar o índice de cárie antes e após a interrupção. Com base no aumento do nível de cárie, foi calculado o custo do tratamento odontológico a partir de uma escala de preços padrão e observou-se um aumento de 115% nos custos relacionados a restauração dentária em decorrência da cárie e um aumento de 21% no custo médio de todos os tratamentos dentários (ATTWOOD; BLINKHORN, 1988).

Devido aos efeitos do fluoreto na redução de cárie, a necessidade de cuidados odontológicos restauradores é menor nas comunidades que são fluoretadas. Estudo sobre o custo-efetividade da fluoretação, conduzido na Austrália, considerou os custos com o tratamento odontológico e anos de vida perdidos ajustados por incapacidade devido a cárie dentária e demonstrou que se a fluoretação fosse implementada geraria uma economia de cerca U$666 milhões para o estado de Queensland (CIKETIC; HAYATBAKHSH; DORAN, 2010).

Revisão sistemática incluindo dois estudos de custo-efetividade, quatro com informações relativas somente ao benefício e quatro com dados sobre custo e benefício, evidenciou que os custos odontológicos foram menores em comunidades com fluoretação da água. O custo anual da fluoretação *per capita* variou de U$0,11 a U$ 4,92 para comunidades com pelo menos mil habitantes e o benefício anual *per capita* variou de U$5,49 a U$93,19. Além disso, evidenciou que a relação custo-benefício diminui conforme aumenta o tamanho da população. Entretanto, os autores advertem que na revisão, os benefícios da intervenção em todos os estudos econômicos incluídos, foram estimados com base em suposições comparáveis de taxas de efetividade, e que estudos futuros deveriam se concentrar em dados de custo reais, desde que disponíveis. (RAN; CHATTOPADHYAY, 2016). Cabe acrescentar que diferenças decorrentes do grupo etário não foram consideradas.

Como o custo da fluoretação pode variar de acordo com cada comunidade, e cada país, algumas variáveis fundamentais devem ser consideradas para avaliação econômica da fluoretação da água. Essas variáveis estão relacionadas ao porte populacional dos sistemas de abastecimento, ao número de estações de tratamento, a quantidade e o tipo de equipamento e insumo utilizado para fluoretação, a condição bucal, a idade da população e o contexto socioeconômico do país em análise.

2 JUSTIFICATIVA

Diversos estudos sobre a efetividade da fluoretação foram realizados no mundo, entretanto, sobre sua avaliação econômica os mesmos concentram-se principalmente em países como Austrália, EUA, Canadá e Nova Zelândia (O'CONNELL et al., 2010; TCHOUAKET et al., 2013; WRIGHT et al., 2001; GRIFFIN et al., 2001; CIKETIC et al. 2010; COBIAC et al., 2012). A variabilidade dos resultados dos estudos de avaliação demonstra que o contexto socioeconômico da população de estudo é fundamental para determinação da viabilidade econômica da fluoretação em cada país.

No Brasil, poucos estudos analisam simultaneamente os custos, a efetividade e os benefícios da fluoretação da água de abastecimento público em diferentes contextos. Ademais, a produção de conhecimento sobre o tema é muito importante para as áreas de Saúde Pública/Coletiva; Odontologia e Saneamento Ambiental, podendo ainda subsidiar a tomada de decisão das autoridades sanitárias e dos gestores de empresas públicas e privadas do setor de saneamento, quanto à instalação ou interrupção de sistemas de fluoretação nas diferentes localidades brasileiras.

Cabe ressaltar que o custo do tratamento odontológico que poderia ser evitado é pago não só pelo indivíduo afetado, mas também pelo público em geral por meio de serviços prestados pelo Sistema Único de Saúde. Sendo o financiamento da saúde um tópico fundamental para a decisão sobre a utilização e a alocação dos recursos públicos (BRASIL, 2008), estudos que avaliem do ponto de vista econômico a política pública da fluoretação da água de abastecimento público, a despeito de sua complexidade, são imprescindíveis para informar os gestores das áreas da saúde e saneamento e subsidiar a ampliação, manutenção e/ou interrupção dessa estratégia de saúde pública.

3 OBJETIVO

3.1 OBJETIVO GERAL

Analisar potenciais fatores vinculados à qualidade da fluoretação da água de abastecimento público, seu custo-benefício e custo-efetividade em diferentes portes populacionais e grupos etários no Brasil.

3.2 OBJETIVOS ESPECÍFICOS

1) Analisar os fatores associados à qualidade da fluoretação da água de abastecimento público;

2) Estimar os custos totais associados à implementação e manutenção da fluoretação da água de abastecimento público, no período de 2012 a 2017 em diferentes portes populacionais;

3) Estimar a efetividade da fluoretação em diferentes áreas no contexto de múltiplas fontes de flúor;

4) Estimar o custo-benefício e o custo-efetividade da fluoretação da água de abastecimento público para diferentes portes populacionais.

4 MÉTODOS

Foi realizado um estudo de avaliação econômica, em que tanto consumo de recursos, quanto os benefícios em saúde foram medidos. A avaliação de custo-benefício e custo-efetividade foi conduzida na perspectiva da sociedade, por meio de metodologias aplicadas previamente (FYFE et al., 2015; CAMPAIN et al., 2010; KROON; VAN WYK, 2012a; VAN WYK, 2012b). Nas avaliações na perspectiva da sociedade, os custos são considerados de forma mais abrangente, uma vez que direta e indiretamente poderiam ser evitados, por exemplo, custos com transporte e deslocamento, perda de produtividade e com os procedimentos realizados (DRUMMOND et al., 2015). Para responder ao objetivo geral, o método foi organizado de acordo com os objetivos específicos.

4.1 FATORES ASSOCIADOS À QUALIDADE DA FLUORETAÇÃO

4.1.1 Tipo de estudo

Para avaliação dos fatores associados à qualidade da fluoretação foi realizado um estudo ecológico transversal abrangendo todos os 645 municípios do Estado de São Paulo.

4.1.2 Fonte de dados

Foram utilizados dados oficiais de concentração de flúor nos sistemas de abastecimento de água do Estado de São Paulo registrados no Sistema de Informação de Vigilância da Qualidade da Água para Consumo Humano (SISAGUA).

Para avaliação dos dados foi seguido um protocolo publicado em 2019 (Prado; Frazão, 2019) e, após a sua aplicação, 543 municípios foram incluídos no estudo. Os dados dos 102 municípios restantes foram extraídos da Pesquisa Estadual de Fluoretação da Água de Abastecimento Pública do Conselho Regional de Odontologia e desenvolvida pelo Centro Colaborador do Ministério da Saúde em Vigilância em Saúde Bucal da Universidade de São Paulo (CECOL/USP). Neste levantamento, as amostras de água foram coletadas de novembro de 2014 a outubro de 2015. Os pontos de coleta e o número de amostras em cada município foram determinados de acordo com o número de estação de tratamento de água e reservatório de água seguindo o Guia de

Amostragem para Vigilância da Concentração de Flúor em Serviços Públicos Água de Abastecimento (CECOL/USP). Nos municípios sem estação de tratamento de água em seu território, o reservatório foi escolhido como unidade de referência. Foram determinados quatro pontos de coleta por unidade de referência, dois no ponto mais próximo e dois no ponto mais distante da estação de tratamento de água.

4.1.3 Variáveis dependentes e independentes

A qualidade da fluoretação foi definida pelo percentual dos valores de concentração de flúor em cada município dentro da faixa do nível ótimo correspondente ao benefício máximo para a prevenção da cárie dentária e risco mínimo para a ocorrência de fluorose dentária, de acordo com documento de consenso técnico sobre Classificação de Águas de Abastecimento Público segundo o Teor de Flúor elaborado por pesquisadores e especialistas brasileiros (CECOL/USP 2011):

$$\text{Qualidade de fluoretação} = \frac{Nº\ of\ amostras\ adequadas\ (0.55 \leq T_{fluoreto} \leq\ 0.84)}{Nº\ total\ de\ amostras\ (n)}$$

Após o cálculo do percentual de amostras dentro da faixa de nível ótimo, a qualidade da fluoretação nos municípios foi classificada em cinco categorias: muito baixa (0,0 a 19,9%); baixa (20,0 a 39,9%); regular (40,0 a 59,9%); boa (60,0 a 79,9%); muito boa (80,0% ou mais). Para estimar a qualidade da fluoretação da água, a proporção de 80% ou mais de amostras foi definida como critério de conformidade (Pelletier, 2004). Com base nessa classificação, o desfecho foi determinado por meio de uma variável dicotômica, comparando municípios com qualidade de fluoretação “muito boa” em relação aos demais.

O Quadro 1 descreve as variáveis explicativas e respectivas categorias, ano e fonte de dados.

Quadro 1. Resumo das variáveis independentes incluídas no estudo

Variável	Descrição	Categorização	Ano	Fonte[a]
Tipo de serviço de saneamento	Tipo de administração das empresas públicas de abastecimento de água	1. Público Estatal 2. Público Municipal 3. Privado	2010	ANA
Tamanho populacional	Número de habitantes residentes nos municípios em análise	1. >100000 2. 20001 até 100000 3. 5001 até 20000 4. ≤ 5000	2010	IBGE
Renda familiar mensal *per capita*	Relação entre a soma dos rendimentos de todos os indivíduos que residem em domicílios particulares permanentes e o número total desses indivíduos	1. >1000 2. ≤1000	2010	IBGE
Taxa de população urbana*	Percentual de pessoas que residem em áreas urbanas	1. >94,93% 2. 88,46 até 94,93% 3. >78,71 até 88,45% 4. ≤78,71%	2010	IBGE
Índice de Desenvolvimento Urbano (IDH)*	A média geométrica dos índices normalizados em 3 dimensões: saúde (esperança de vida ao nascer), educação (média de anos de escolaridade para adultos, 25+ anos) e padrão de vida (renda nacional bruta *per capita*) transformada para uma escala de 0 (mais baixo) a 1 (mais alto).	1. >0,761 2. 0,739 até 0,761 3. 0,720 até 0,738 4. ≤0,719	2010	IBGE
Índice de Gini*	Indicador que avalia a desigualdade social. Aponta a diferença entre a renda dos mais pobres e dos mais ricos. Varia de zero (situação de igualdade) a um (situação de desigualdade máxima)	1. >0,48 2. 0,46 até 0,48 3. 0,42 até 0,45 4. ≤0,41	2010	IBGE
Produto Interno Bruto (PIB) *per capita**	Soma de todos os bens e serviços finais produzidos pelo município dividido pela população de cada município.	1. >32335,57 2.21986,70 até 32335,57 3.16065,25 até 21986,69 4. ≤16065,24	2015	IBGE
IPRS-Riqueza*	A dimensão riqueza do índice é composta por quatro indicadores: 1- PIB *per capita*; 2-remuneração dos empregados formais e benefícios previdenciários; 3-consumo residencial de energia elétrica; 4-Consumos de energia elétrica na agricultura, comércio e serviços. Varia de zero (pior situação) a cem (melhor situação).	1. >42 2. 38 até 42 3. 34 até 37 4. ≤33	2014	SEADE
Despesa *per capita* em saneamento e vigilância sanitária*	Média *per capita* em reais (R$) dos gastos municipais com saneamento e vigilância sanitária, de 2007 a 2011.	1. ≤2,86 2. 2,87 a 25,14 3. 26,15 a 147,57 4. >147,57	2007-2011	SNIS
Taxa de não conformidade da concentração de cloro **	Percentual de análises de cloro residual fora do padrão de qualidade esperado. É calculado dividindo o total de amostras não padronizadas pelo total de amostras analisadas para o parâmetro.	1. ≤0,82% 2. >0,82%	2015	SNIS

Nota: * Variáveis categorizadas por quartil; ** Variável categorizada de forma dicotômica considerando o terceiro quartil como referência; a-ANA (Agência Nacional de Águas); IBGE (Instituto Brasileiro de Geografia e Estatística); SEADE (Sistema Estadual de Análise de Dados); SNIS (Sistema Nacional de Informação Sanitária). IPRS-Riqueza é um índice referente à dimensão da riqueza em relação ao Índice de Responsabilidade Social de São Paulo.

4.1.4 Análise de dados

Como o interesse era determinar as características municipais dos sistemas de água que se beneficiariam com a melhoria da vigilância e das operações, a categoria de referência para o resultado foi qualidade de fluoretação "muito boa". Dada a prevalência do desfecho, foi realizada análise de regressão de Poisson com variância robusta para estimar as razões de prevalência (RPs) brutas e ajustadas e seus respectivos intervalos de confiança de 95% (ICs). A entrada das variáveis independentes no modelo foi realizada em três blocos, partindo da premissa de que as características dos municípios interagem entre si e certas características estão mais diretamente relacionadas ao resultado do que outras.

A hipótese testada foi baseada no arcabouço conceitual apresentado na Figura 1 e incluiu o PIB *per capita* anual e o índice de Gini no bloco 1, considerando que essas variáveis podem afetar as demais variáveis. O padrão de vida médio por domicílio é um fator importante para explicar o estado geral de saúde de uma população até determinado nível (WHO, 2017), e a desigualdade de renda tem sido associada ao baixo investimento em políticas públicas, principalmente educação e saúde (CELESTE; NADANOVSKY, 2010; PABAYO et al., 2019). Como os municípios paulistas apresentavam diferenças marcantes relacionadas ao PIB *per capita* anual e à distribuição de renda, esta última poderia estar levemente associada a uma renda mais alta, podendo-se esperar algum efeito sobre as políticas públicas, como fluoretação e tratamento da água.

A taxa de população urbana, o IDH, a dimensão da riqueza relativa do Índice de Responsabilidade Social de São Paulo (IPRS-Riqueza) e o gasto *per capita* com saneamento e vigilância sanitária foram incluídos no bloco 2. As duas primeiras variáveis têm uma clara correlação com as condições de saneamento (LIBÂNIO ET AL., 2005; ANAND; BHAYANKARAM, 2006), e alguns efeitos podem ser esperados na fluoretação da água. O IPRS-Riqueza é um indicador composto que busca captar, ao mesmo tempo, a produção de riqueza do município e das famílias por meio dos seguintes componentes: consumo de energia domiciliar, por conexão; consumo de energia dos setores de agricultura, comércio e serviços, por conexão; o rendimento médio dos empregados com carteira assinada nos setores privado e público; e valor agregado de impostos *per capita*.

Essas variáveis, em conjunto, permitem mensurar produção e renda, com a vantagem de uma disponibilidade mais rápida do que indicadores clássicos, como o PIB anual, que só é divulgado 2 anos depois. Além disso, dados do Sistema Estadual de Análise de Dados (SEADE) do estado de São Paulo mostraram que o consumo de energia é uma boa variável substituta para renda e produção. Durante a análise inicial dos dados, observou-se que o PIB anual e o IPRS-Riqueza tratam de dimensões distintas e independentes vinculadas aos municípios. Tais fatores podem estar associados a melhores condições de saneamento ou ao gasto *per capita* em saneamento e vigilância. Estudo mostrou que cidades com melhor IPRS apresentaram menores taxas de internação por diarreia, indicador associado à qualidade da água (VENANCIO et al., 2016).

Por fim, a renda familiar mensal *per capita*, a taxa de não conformidade na concentração do cloro residual livre, o tamanho da população e o tipo de serviço de saneamento foram adicionados no bloco 3, que deveriam ser as variáveis mais diretas relacionadas ao resultado. Esta última variável tem sido associada ao fornecimento de água fluoretada (SILVA; FRAZÃO, 2018). O número total da população apresentou forte correlação positiva com a qualidade da fluoretação (BELOTTI et al., 2018). A renda *per capita* está relacionada ao acesso a recursos materiais relevantes para a saúde na maioria das sociedades, incluindo água potável, instalações sanitárias, nutrição adequada e moradia. O cloro residual livre é a concentração de cloro que deve permanecer na água tratada após o processo de desinfecção para garantir a segurança microbiológica durante a distribuição. É um produto de baixo custo que pode inativar microrganismos em pouco tempo. (PALMEIRA et al., 2019). A taxa de não conformidade da concentração de cloro é um importante indicador da qualidade da água tratada (WHO, 2017), e pode-se esperar uma associação direta com a qualidade da fluoretação.

No modelo múltiplo final, apresentamos o efeito geral das variáveis do bloco 1 no resultado, o efeito das variáveis do bloco 2 ajustadas pelas variáveis do bloco 1 e os valores associados das variáveis do bloco 3 ajustados pelas variáveis dos blocos anteriores. As análises foram realizadas no programa Stata 14.1 (StataCorp), e o mapa temático foi construído no programa QGIS 3.4.1. QGIS Development Team, 2018).

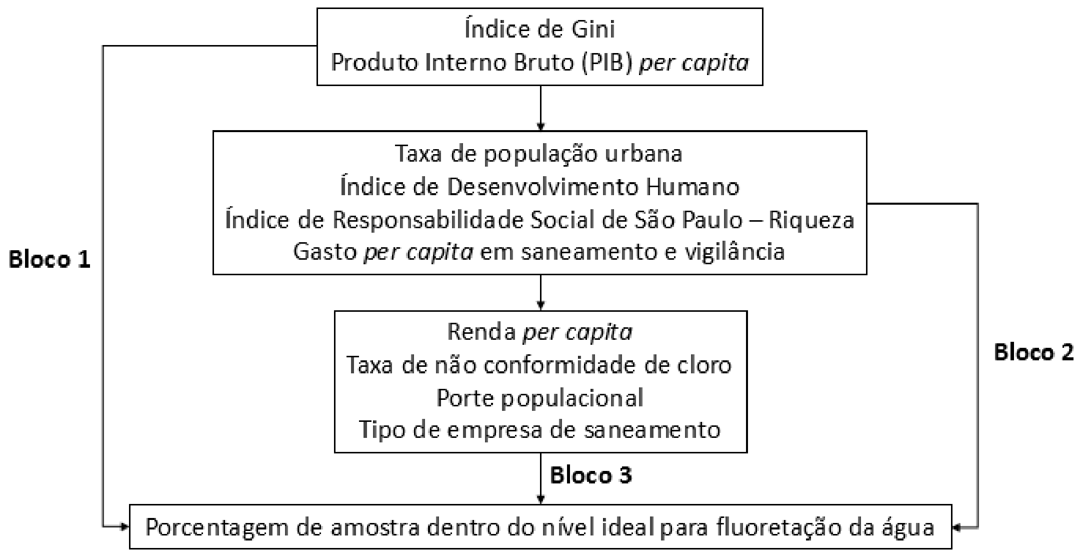

Figura 1. Modelo Teórico

4.2 CUSTOS ASSOCIADOS À FLUORETAÇÃO DA ÁGUA

4.2.1 Tipo de estudo

Foi realizado um estudo de série de casos sobre os custos da fluoretação em Estações de Tratamento de Água (ETA) envolvendo sete portes populacionais, durante 68 meses abrangendo o período de janeiro de 2012 a dezembro de 2017.

4.2.2 Fonte de dados

Todas as ETA eram operadas pela Companhia Espírito Santense de Saneamento (CESAN), responsável pelo abastecimento de 67% dos municípios do Espírito Santo (ES) e por cerca de 88 ETA distribuídas no território capixaba que produzem uma média de 7.000 l/s (litros por segundo). Trata-se de uma empresa de economia mista, na qual o Governo do Estado é acionista majoritário das ações da companhia. Segundo dados do Censo Demográfico 2010 para o Estado do Espírito Santo, 83,1% da população estava coberta por rede geral de abastecimento de água e 16,4% por poços ou nascentes dentro ou fora da propriedade. Foi selecionada uma ETA para cada porte populacional analisado neste estudo. Os casos descritos foram selecionados conforme o porte populacional da ETA e a disponibilidade de dados completos para o período selecionado.

4.2.3 Custo com o tratamento da água

Foi calculado o custo médio anual do tratamento da água considerando a disponibilidade de dados completos para o período de janeiro de 2014 a dezembro de 2018. Calculou-se o custo do metro cúbico (m³) produzido no município sede em que se localizava a estação de tratamento e o volume de água produzido no respectivo ano. Em seguida, esse custo do m³ total para o período foi multiplicado pelo volume produzido pela ETA em cada ano e dividido pela média da população abastecida pela ETA no período. No Quadro 2 foram listados os itens considerados para cálculo dos custos com tratamento de água.

Quadro 2. Composição dos custos do tratamento completo da água de abastecimento público.

Custos com recursos humanos	- Salários horas normais e extras -Férias, 13º salário, FGTS, licença (prêmio/maternidade/paternidade) - Vale transporte e alimentação -Assistência médica e social
Custos com material	- Material de expediente, uso e consumo - Material de operação e manutenção de sistemas - Material de tratamento - Material de laboratório - Material de segurança e proteção - Material de limpeza e higiene - Combustíveis e lubrificantes
Custos com serviços de terceiros	- Serviços de operação de sistemas - Serviços técnicos profissionais - Serviços de manutenção e limpeza - Serviços de vigilância - Aluguéis de imóveis, máquinas e carros - Energia elétrica - Serviços de comunicação (publicidade e propaganda) - Serviços de movimentação, carga e descarga de materiais - Serviços gráficos, cópias e encadernações
Custos com depreciações e amortizações	- Depreciações do imobilizado - Amortizações
Custos financeiros, tributários e fiscais	- Juros, multas e atualizações monetárias - Despesas bancárias - Remuneração do capital próprio - Contribuição sindical - IPTU, COFINS, PASEP, IOF, IPVA, CIDE - Provisões para processos tributários, cíveis, trabalhistas e ambientais
Outros custos	- Conduções, viagens e estadias - Doações - Exposições, congressos e eventos comemorativos - Indenizações trabalhistas e de terceiros - Perda no recebimento de tarifas - Despesas com incorporações

4.2.4 Custo da implementação e manutenção da fluoretação

Foi calculado o custo médio anual da fluoretação da água considerando a disponibilidade de dados completos para o período de janeiro de 2012 a dezembro de 2017. Foram levantadas junto a empresa de abastecimento informações referentes aos custos de instalação inicial, do produto químico, da operacionalização do sistema e do controle dos teores de flúor, conforme descrito por Frias et al. (2006). Não foram incluídos os custos para construção de novas instalações, uma vez que este capital já existe e não teria sido um custo a mais, independente do sistema ser fluoretado ou não. Portanto, os custos foram estimados da seguinte forma:

4.2.4.1 Custos de instalação (CI)

Neste item foram considerados: custos dos equipamentos (bomba dosadora, tanque de armazenamento e equipamento de controle da dosagem de fluoreto); custo de instalação que representa cerca de 85% do custo dos equipamentos (CDC, 1991); os custos de consultoria técnica representam 15% dos custos totais de capital de instalação.

Foi considerado o tempo de vida dos equipamentos, portanto, o capital de instalação foi estratificado por vinte anos. Este cálculo incluiu o capital inicial somado à consultoria técnica, dividido por 20 anos.

4.2.4.2 Custo do produto químico (CPQ)

Para o custo do produto químico utilizado em cada estação de tratamento foram considerados o consumo anual do ácido fluossilícico em quilogramas e multiplicado pelo custo do produto em cada ano analisado.

4.2.4.3 Custo de operação do sistema (COS) e Custo de controle dos teores de flúor (CCF)

Para estimar a operacionalização do sistema, foram considerados: custos com depreciação e manutenção de equipamentos, que representam cerca de 10% do capital inicial distribuídos ao longo da vida útil do equipamento; custos com recursos humanos, calculado por meio do custo médio anual dos salários, somados aos encargos trabalhistas, de um funcionário para cada ETA. Foram considerados neste item, os custos fixos para medição e controle dos teores de fluoreto pelo método colorimétrico SPADNS (2-parasulfofenilazo1,8 dihidróxi 3,6-naftaleno dissolufonato de sódio).

Portanto, para o cálculo dos custos da fluoretação *per capita*, foi considerada a Equação 1:

$$Custo\ da\ Fluoretação = \frac{CCII + CPQ + COS + CCF}{Porte\ populacional\ no\ ano}$$

(Equação 1)

Foi, também, realizado o cálculo para o controle de consumo do composto utilizado, de acordo com o Manual de fluoretação da água para consumo humano (BRASIL, 2012). Para tanto, inicialmente, conhecida a vazão da água da ETA (QETA), foi calculada a vazão de dosagem de ácido (Qácido), de acordo com a Equação 2:

$$Qácido = \frac{Q_{ETA}\ x\ teor\ de\ íon\ a\ ser\ aplicado\ x\ fator\ de\ proporcionalidade}{Concentração\ de\ ác.fluossilícico}$$

(Equação 2)

A concentração do ácido a 24% é de 291,3 g.L-1 e o fator de proporcionalidade (relação existente entre o peso molecular do ácido fluossilícico e a quantidade de íons fluoreto liberado pela sua molécula) representa 1,263. Após o cálculo da vazão do ácido, e conhecida a densidade de 1,2136 kg.L-1na concentração de 24% (BRASIL, 2012), foi calculado o consumo esperado, conforme a Equação 3:

$$Consumo_{ácido} = Q_{ácido}\ x\ densidade\ do\ ácido$$

(Equação 3)

O teor de íon a ser aplicado adotado para a composição da fórmula (1) foi o de 0,7 mg. L-1e foram consideradas variações em até 14% nos valores esperados, em função do intervalo de concentração ótima, entre 0,6 a 0,8 mg. L-1.

Calculou-se o custo *per capita* em dólar americano como referência, para permitir a comparação com estudos realizados internacionalmente (NIESSEN; DOUGLASS, 1984). Para tanto, considerou-se a variação média do real/dólar para o período de 2012 a 2017 e o período de 2014 a 2018, divulgada pelo Banco Central do Brasil. A variação média da moeda brasileira em relação do dólar americano (US$) foi de R$ 2,75 (R$1,95-3,19) por US$ 1,00 de 2012 a 2017, e R$3,20 (R$ 2,35-3,66) por

US$1,00 de 2014 a 2018.

Por fim, calculou-se a porcentagem representada pelo custo da fluoretação no custo total (custo da fluoretação mais custo do tratamento da água) a fim de estimar o seu peso em relação à totalidade das despesas.

4.3 EFETIVIDADE DA FLUORETAÇÃO

4.3.1 Tipo de estudo

Para avaliar a efetividade da fluoretação no Brasil, ou seja, o seu efeito em locais em que foi implementada quando comparado a locais sem a intervenção (PORTA, 2014; BRASIL, 2014), foi realizada uma revisão sistemática da literatura. O relato seguiu diretrizes e recomendações internacionais (PAGE et al., 2021). O protocolo foi registrado no Prospero (CRD42019142050).

4.3.2 Busca na literatura

A busca na literatura científica foi realizada nas seguintes bases de dados: MEDLINE/PubMed, LILACS, SciELO e SCOPUS. Além disso, foi examinada a lista de referências dos artigos selecionados com objetivo de incluir manualmente artigos não identificados na busca inicial. A busca teve três blocos de termos referentes a: 1-desfecho ("oral health" [All Fields] OR "dental caries" [All Fields] OR "caries" [All Fields] OR "decay" [All Fields] OR carious [All Fields]); 2-exposição ("fluoridation" [All Fields]); e 3-localização ("brazil" [All Fields]). Os termos foram combinados com o operador booleano "AND".

A triagem do título/resumo foi realizada de forma independente pelos autores. Foram revisados todos os registros e selecionou-se aqueles que preencheram os critérios de inclusão (Kappa = 0,82). Em seguida, os artigos foram lidos na íntegra e as discordâncias foram resolvidas por consenso.

4.3.3 Seleção dos estudos

Após os procedimentos de busca, foram incluídos estudos observacionais com grupos comparáveis, expostos e não expostos a fluoretação, que analisaram a experiência de cárie por meio do índice ceod/CPOD (dentes cariados, perdidos e obturados) ou pela prevalência de cárie (cárie vs livre de cárie). Ensaios controlados não foram encontrados e estudos ecológicos foram excluídos. Nenhuma restrição de idade ou idioma foi aplicada (Figura 2).

Como o objetivo foi analisar o efeito da medida em um cenário de amplo uso de dentifrícios fluoretados, os estudos publicados antes de 1995 foram excluídos considerando dois aspectos: o ano em que os dentifrícios fluoretados chegaram ao mercado em larga escala (CURY et al. 2004) e o tempo de produção de um efeito acumulado na redução da cárie dentária.

Os estudos foram classificados de acordo com a comparabilidade dos grupos populacionais expostos e não expostos para controlar possíveis vieses de confusão devido a diferenças sociais. As características consideradas foram se as áreas: (i) estavam localizadas no mesmo estado brasileiro e (ii) na mesma mesorregião; (iii) tinham tamanho populacional semelhante; e (iv) apresentavam a mesma categoria do Índice de Desenvolvimento Humano (IDH). Foram considerados o tamanho populacional e o IDH referente ao censo realizado no ano mais próximo dos dados. O cálculo assumiu a soma das características comparáveis em cada uma dessas quatro variáveis, e o escore variou de 0 (incomparável) a 4 (totalmente comparável). Estudos com valor dois ou mais foram considerados para inclusão nas meta-análises.

4.3.4 Extração de dados

As seguintes informações foram coletadas de cada estudo: autor, ano de publicação, número de áreas analisadas, idade dos indivíduos, tamanho da amostra, média ceo/CPO (desvio-padrão) e número e percentual de indivíduos com experiência de cárie. Sempre que necessário, mais informações foram solicitadas aos autores para obtenção de dados essenciais para a sumarização.

4.3.5 Análise estatística

O tamanho do efeito foi medido pela diferença média para ceod e CPOD±DP e *odds ratio* em uma escala logarítmica para prevalência de cárie (cárie *versus* livre de cárie). As análises estatísticas foram realizadas separadamente para cada dentição. Esse agrupamento não foi mutuamente exclusivo e, quando possível, os estudos foram incluídos em ambas as meta-análises.

Os artigos com pontuação 0 e 1 pelo índice de comparabilidade e sem valores de média e de variância foram excluídos da meta-análise, mas resumidos narrativamente. As meta-análises foram realizadas usando modelos de efeito aleatório. A heterogeneidade dos dados entre os estudos foi avaliada por meio do teste I-quadrado e foi considerada significativa quando >75% (HIGGINS et al., 2003). O viés de publicação foi representado graficamente por gráficos de funil e sua assimetria foi testada pelo teste de Egger (EGGER et al., 1997). As análises foram feitas no *software* Stata (Stata. Corporation, version 16.1, College Station, TX, USA).

4.3.6 Avaliação da qualidade dos estudos

A qualidade metodológica dos estudos incluídos nas meta-análises foi avaliada por meio da ferramenta *Critical Appraisal Checklist for Studies Reporting Prevalence*, desenvolvida pelo *Joanna Briggs Institute*. *Check list* específico para estudos de prevalência que inclui nove critérios críticos de avaliação adaptados para esse tipo de evidência (MUNN et al., 2015).

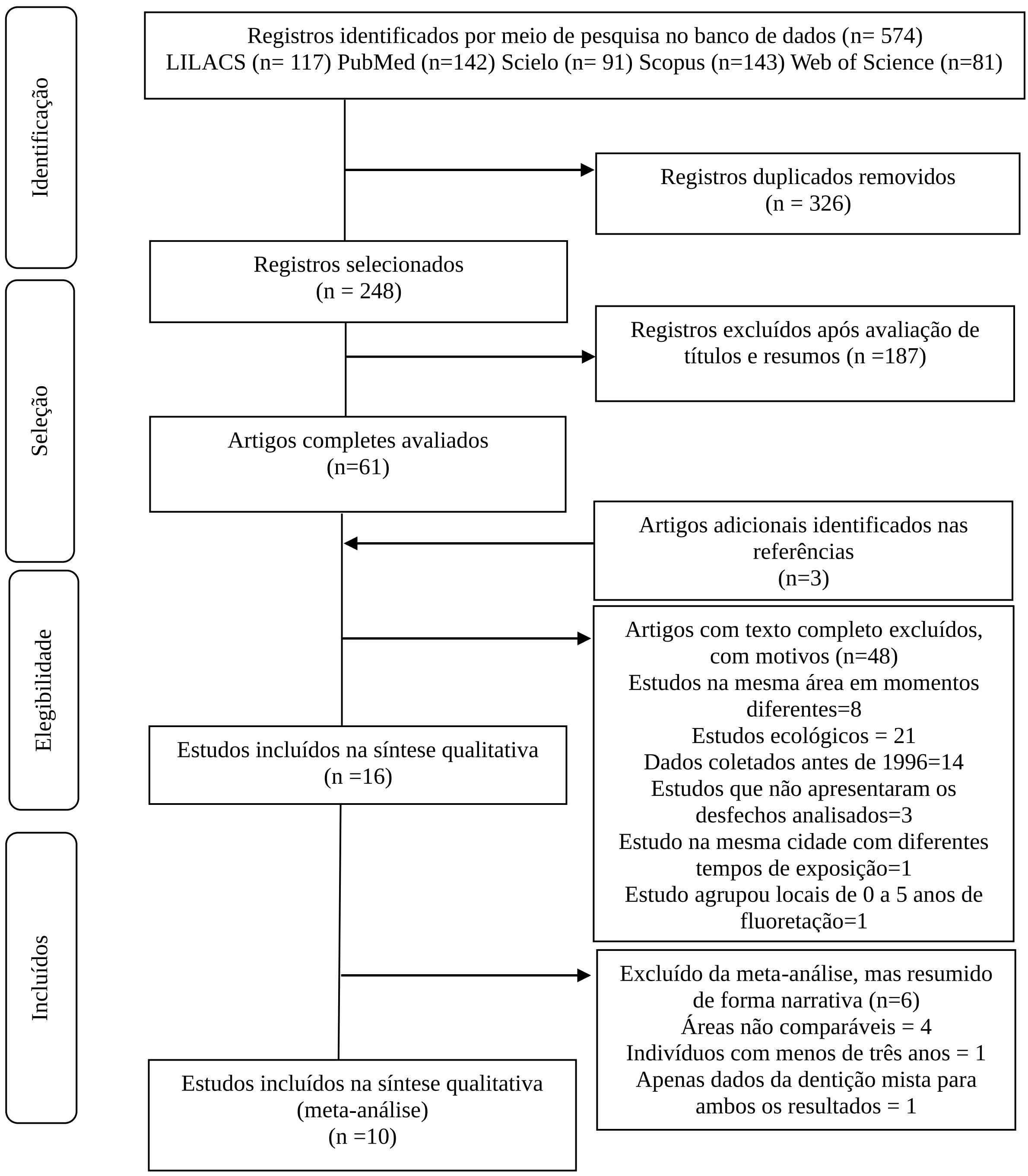

Figura 2. Fluxograma de seleção dos estudos

4.4 CUSTO-EFETIVIDADE E CUSTO-BENEFÍCIO DA FLUORETAÇÃO

As análises de custo-efetividade (CEA) e custo-benefício (CBA) foram realizadas a partir de uma perspectiva da sociedade, por meio de metodologias aplicadas em análises anteriores (FYFE et al., 2015; CAMPAIN et al., 2010; KROON; VAN WYK, 2012a; VAN WYK, 2012b). Essa perspectiva inclui os gastos do paciente e sua família, seja para acessar o serviço ou outros custos que possam ser considerados como consequência da intervenção, como custos por perda de produtividade e custos de transporte. O estudo seguiu as diretrizes do *Consolidated Health Economic Evaluation Reporting Standards* (HUSEREAU et al., 2013).

4.4.1 Custos com a fluoretação

As estimativas de custo com a fluoretação foram baseadas em dados relatados em um estudo publicado que incluiu custos para sete tamanhos de população brasileira, variando de menos de 2.000 a mais de 500.000, entre 2012 e 2017 (BELOTTI, FRAZÃO, 2021). Os custos totais foram estimados pelas seguintes variáveis: custo de capital de instalação inicial, custos de produtos químicos, custo operacional do sistema e de monitoramento do fluoreto. Dentro do custo de instalação inicial foram considerados os custos de equipamentos, custos de instalação (85% dos custos de equipamentos) (CDC, 2001) e custos de consultoria técnica (15% do custo de instalação inicial). Os custos operacionais incluíram os custos de depreciação e manutenção dos equipamentos, que representam cerca de 10% do capital inicial, e os custos de recursos humanos de um funcionário para cada estação de tratamento de água, calculados com base no custo médio anual dos salários, acrescidos dos encargos trabalhistas. A partir dos dados disponíveis, os custos de capital anuais da instalação inicial foram calculados a uma taxa básica de desconto de 3,5% e uma vida útil básica para equipamentos de capital de 20 anos (FRIAS et al., 2006; MOORE et al., 2017).

4.4.2 Cárie evitada

As estimativas anuais de cárie evitada foram extraídas da revisão sistemática realizada sobre o efeito da fluoretação no contexto do amplo uso de dentifrícios fluoretados, com base em estudos com grupos populacionais brasileiros (BELOTTI; FRAZÃO, 2021). A evidência foi derivada de estudos observacionais com controles simultâneos e dados para um ponto no tempo. Para controlar o viés de confusão devido às diferenças sociais entre as áreas, foram acessados dados sociodemográficos e socioeconômicos das áreas investigadas e os artigos foram classificados de acordo com sua comparabilidade. A meta-análise incluiu dez estudos comparáveis publicados entre 1998 e 2018. A diferença de ceod médio entre áreas fluoretadas e não fluoretadas foi obtida de crianças de 5 a 8 anos e de 3 a 12 anos e a diferença na média do CPOD foi feita de crianças de 7 a 12 anos.

4.4.3 Custos do tratamento da cárie dentária

O custo total do tratamento odontológico foi estimado incluindo os custos diretos e indiretos. Os custos diretos referem-se a um exame completo e restauração de duas superfícies dentárias, de acordo com a Classificação Brasileira de Procedimentos Odontológicos em 2019 (CBHPO). Os custos indiretos incluíram despesas de transporte e perda de produtividade estimada de três horas gastas com o deslocamento e a consulta odontológica (CAMPAIN et al., 2010; FYFE et al., 2015), ambos com base no salário-hora médio em 2019. Esses custos foram em relação a uma visita e quatro passagens de transporte público, pois em todos os cenários o paciente precisava estar acompanhado por um adulto. A tarifa média do transporte público foi de US$ 1,01 em 2019, segundo a Pesquisa Nacional de Mobilidade Urbana (BRASIL, 2019).

Em consonância com estudos anteriores, foram feitas as seguintes suposições: (a) o custo dos efeitos colaterais adversos (fluorose dentária) foi considerado insignificante e não foi atribuído um valor (CAMPAIN et al., 2010; COBIAC; VOS, 2012; WRIGHT et al., 2011); (b) todas as superfícies cariadas seriam tratadas e o tratamento consistiria em uma restauração de amálgama dental de duas superfícies por ceod/CPOD (FYFE et al. 2015). O custo do tratamento odontológico foi dividido pela vida útil das restaurações de amálgama igual a 12,8 anos (VAN NIEUWENHUYSEN et al., 2003). Para determinar o custo anual evitado foi aplicada uma taxa de desconto de 3,5%.

Os resultados foram apresentados em dólares dos EUA (USD) com base na taxa de câmbio média entre o real brasileiro (BRA) e o dólar entre 1º de janeiro de 2019 e 31 de dezembro de 2019 (BRA 1 = USD 0,2535) (INSTITUTE FOR APPLIED ECONOMIC RESEARCH, 2019).

4.4.4 Custo-efetividade e custo-benefício da fluoretação

A relação custo-efetividade foi estimada dividindo-se o custo líquido *per capita* anual da fluoretação pela diferença da média ceod/CPOD entre locais fluoretados e não fluoretados (FYFE et al., 2015). O custo líquido foi calculado subtraindo os custos associados com a fluoretação e os custos anuais evitados (GRIFFIN; JONES; TOMAR, 2001). O custo-benefício foi estimado de acordo com Kroon e Van Wyk (2012), em que o custo da implantação da fluoretação da água foi dividido pelos custos anuais evitados. Um programa deve ser considerado para implementação e manutenção se o custo-benefício for <1 (KROON; VAN WYK, 2012a, 2012b).

4.4.5 Análise de sensibilidade

A análise de sensibilidade unidirecional foi realizada para testar a robustez dos resultados de acordo com os valores dos parâmetros medidos e fornecer uma variedade plausível de economia que poderia ser obtida com a fluoretação da água (DRUMMOND et al., 2015). Portanto, os parâmetros analisados foram: (1) preenchimento à base de amálgama em apenas uma superfície; (2) preenchimento à base de resina em duas superfícies, considerando a vida útil de 7,8 anos (VAN NIEUWENHUYSEN et al., 2003); (3) níveis superiores e inferiores da efetividade estimada da fluoretação; (4) taxas de desconto de 0% e 7%.

5 RESULTADOS

5.1 Municipality-level characteristics associated with very-low-to-good quality of water fluoridation in São Paulo state, Brazil, at 2015

Original Report: Epidemiologic Research

Municipality-Level Characteristics Associated with Very Low to Good Quality of Water Fluoridation in São Paulo State, Brazil, in 2015

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Abstract: *Introduction: Community water fluoridation (CWF) is a measure of recognized importance due to its effectiveness in preventing tooth decay at the population level. However, for the maximum benefit to be achieved, the high-quality standard of CWF must be maintained over time.*

Objective: To analyze the municipality-level characteristics associated with quality of water fluoridation in São Paulo state, Brazil.

Methods: An ecological study was performed using official data sources on fluoride concentration surveillance in 2015. The outcome was municipalities that have not met the quality standard, identified as those with less than 80% of water samples within the optimal level for caries prevention. The independent variables were municipality-level indicators related to demographics, economics, and sanitation characteristics. Crude and adjusted prevalence ratios were estimated using Poisson regression with robust variance.

Results: In total, 43.4% municipalities exhibited the outcome. Adjusted by Gini index, the prevalence ratio was 32% higher in municipalities with lower annual gross domestic product per capita. Adjusted by social responsibility index and earlier variables, the prevalence was higher in the municipalities with higher per capita expenditure on sanitation and health surveillance, where the urban population rate was lower, and with a human development index ≤0.761. Adjusted by earlier variables, the prevalence ratio was twice and 3.5 times higher for municipalities, respectively, with per capita income less than or equal to US$574 and where the type of sanitation utility was municipal and private; 50% higher in those with less than 100,000 habitants; and 20% higher in those with a chlorine concentration nonconformity rate above 0.82%.

Conclusions: To ensure high quality of CWF, additional management measures should be implemented in municipalities with less than 100,000 habitants, a higher chlorine concentration nonconformity rate, a lower per capita income, and where the type of sanitation utility was municipal or private.

Knowledge Transfer Statement: *The study showed that the quality of fluoridation was associated with municipality-level characteristics. The findings can be used by policy makers to identify and support municipalities that will need to improve fluoridation quality if they are to reach oral health goals.*

Keywords: water supply, oral health, public health, multivariate analysis, public policy, public health surveillance

Introduction

Community water fluoridation (CWF) is a public health strategy that

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refers to the adjusting of the fluoride concentration in drinking water for dental caries prevention at the population level. Besides its low cost relative to its high social benefit, CWF reduces social inequality in the access to fluoride favoring across all strata of the population served by the public water supply (Kumar 2008). Despite being a measure of recognized importance, inequalities in local distribution are still found among the geographic entities of the countries that provide water fluoridation, resulting in an uneven coverage among the state/territories of Canada, the United States, Australia, and Brazil. For the maximum benefit of water fluoridation to be achieved, an optimum concentration of fluoride that is effective in preventing tooth decay must be maintained over time. Ability to maintain this level is considered high-quality CWF (Narvai 2000; Pelletier 2004).

Income inequality (Celeste et al. 2009), low human development, and economic indicators, such as annual gross domestic product (GDP) per capita (Baker et al. 2018), have been associated with dental caries and could be linked with the quality of CWF. A healthy population is important for economic growth, but it does not follow that economic growth necessarily improves general health or reduces health inequities. Richer and larger cities have better structural conditions to provide better public policies (Aguiar et al. 2018). While a strong economy can contribute to health, it is well documented that this correlation becomes weaker once annual GDP per capita increases over a threshold of US$5,000 (World Health Organization 2017).

Some studies have assessed the provision of the CWF in Brazilian municipalities according to population size and human development index (HDI) (Frazão and Narvai 2017). The association of the HDI with aspects such as the availability of public utilities water supply and the oral health conditions of the population has been found (Ardenghi et al. 2013). Populations living in cities with the worst socioeconomic conditions are those that do not benefit from CWF (Gabardo et al. 2008). Furthermore, the adoption of such preventive measures has been delayed in cities with worse socioeconomic and demographic indicators, such as HDI, Gini index, and annual GDP per capita (Peres et al. 2004).

While there is evidence supporting an association between public policy implementation and features of the territories, currently, the information on the relationship between maintaining an optimal level of fluoride over time and municipality-level characteristics related to sanitation, health, and economic and income inequality variables is scarce (Belotti et al. 2018).

High variation in fluoride concentration was reported in the recent past (Buzalaf et al. 2002) but can still be found today (Moore et al. 2020). As surveillance is an important strategy for ensuring water quality (World Health Organization 2017), it can be assumed that fluoridation quality depends on the surveillance framework (Frazão et al. 2018). The implementation of such a framework depends on several determinants, among which include an integrated regulatory system composed of different organizations (each one with a specific purpose within the chain involved from catchment to tap) directed to check that water safety plans are working (Reiter and Rouse 2016). In countries in which the governmental structures and political processes are based on federalist systems, the integration of the organizations with duties on water quality depends, to a large extent, on subnational units, whether at the state or municipal level.

In Brazil, the use of water fluoridation technology expanded in the 1980s. This resulted from the implementation of a government program that provided credit and technical support to public water treatment companies. Following this expansion, there were reports of localities in which fluoridation was not maintained consistent with the standard. These reports gave rise to external control-based surveillance systems focusing on the adequacy of fluoride content based on water samples at different points of the supply network (Narvai 2000). Such systems received an important boost in 2000, when the municipal health authorities became responsible for carrying out surveillance actions and implementing their own sampling plan for water collection (Frazão et al. 2018).

Given these aspects, the objective was to investigate the factors associated with the quality of fluoridation in water supply systems in the state of São Paulo, Brazil, in 2015.

Methods

A cross-sectional ecological study based on official data was carried out covering all 645 municipalities in the state of São Paulo. The writing of this study is consistent with GATHER (Guidelines for Accurate and Transparent Health Estimates Reporting).

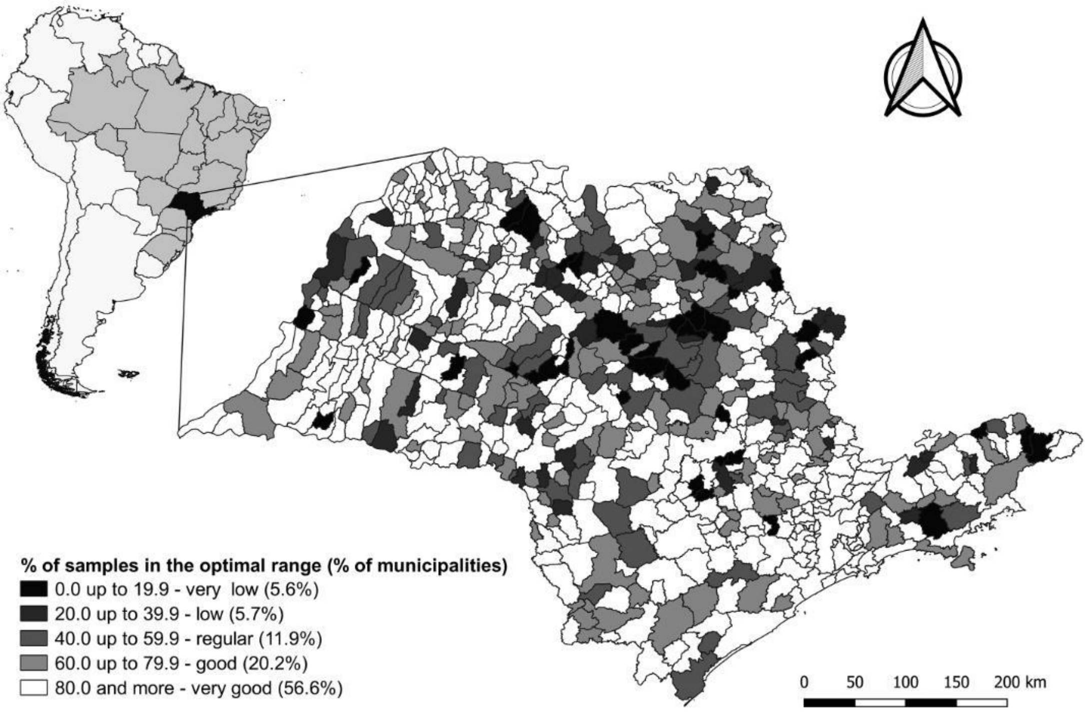
Study Area

São Paulo accounts for 32.4% of the national GDP and is the most populated and developed state in Brazil. In 2015, around 43 million inhabitants were distributed in its 645 municipalities. In 2010, the public water supply reached 97.9% of urban households. The state and municipal levels of government must accomplish the Annex XX of Consolidation Ordinance No. 5/2017 from the Brazilian Ministry of Health, which establishes the standards for safety and drinking water quality as well as the responsibilities regarding water surveillance. Moreover, the Health Department of São Paulo State set the Resolution SS-65/02 on April 12, 2005, which approved water with 0.6 to 0.8 mgF/L. Therefore, all of the water offered to the population, distributed by systems or alternative supplying solutions, must comply with the physical, chemical, and microbiological requirements defined by the standing legislation, so it will not expose risks to the users.

Data Source

We used official data on fluoride concentration in the water supply

Figure 1. Spatial distribution of the quality level of fluoridation in municipalities in the state of São Paulo, Brazil, 2015.



systems of the state of São Paulo registered in the Information System for Monitoring the Quality of Water for Human Consumption for the year 2015.

The verification procedures followed a protocol for data assessment (Prado and Frazão 2019). After applying the protocol, 543 municipalities were included in the study. The data for the remaining 102 municipalities were extracted from the State Survey on Fluoridation of Public Water Supply sponsored by the Regional Council of Dentistry and developed by the Collaborating Center of the Ministry of Health in Oral Health Surveillance at University of São Paulo (CECOL/USP). In this survey, water samples were collected between November 2014 and October 2015. The collection points and the number of samples in each municipality were determined according to the number of water treatment plants and water reservoirs following the Sampling Guide for Surveillance of Fluoride Concentration in Public Supply Water (CECOL/USP). In municipalities without a water treatment plant within their territory, the reservoir was chosen as the reference unit. Four collection points were determined per reference unit, 2 at their nearest point and 2 at the most distant reach from the water treatment plant.

Dependent and Independent Variables

The fluoridation quality was defined by the percentage of fluoride concentration values in each municipality within the range of the optimal level corresponding to the maximum benefit for preventing dental caries and minimum risk for the occurrence of dental fluorosis, according to the Technical Consensus on Classification of Public Water Supply in Relation to Fluoride Content promoted by CECOL/USP:

$$\text{Fluoridation quality} = \frac{\text{No. of suitable samples} \left(0.55 \leq T_{\text{fluoride}} \leq 0.84\right)}{\text{Total number of samples}\left(n\right)} \quad (1)$$

After calculating the percentage of samples within the optimal level range, the quality of fluoridation in the municipalities was classified into 5 categories (Fig. 1). To estimate the quality of water fluoridation, the proportion of 80% or more samples was defined as a compliance criterion (Pelletier 2004). Based on this classification, the outcome was determined using a dichotomous variable, comparing municipalities with “very good” fluoridation quality in relation to the others.

Table 1 describes the explanatory variables and respective categories, year, and data source.

Data Analysis

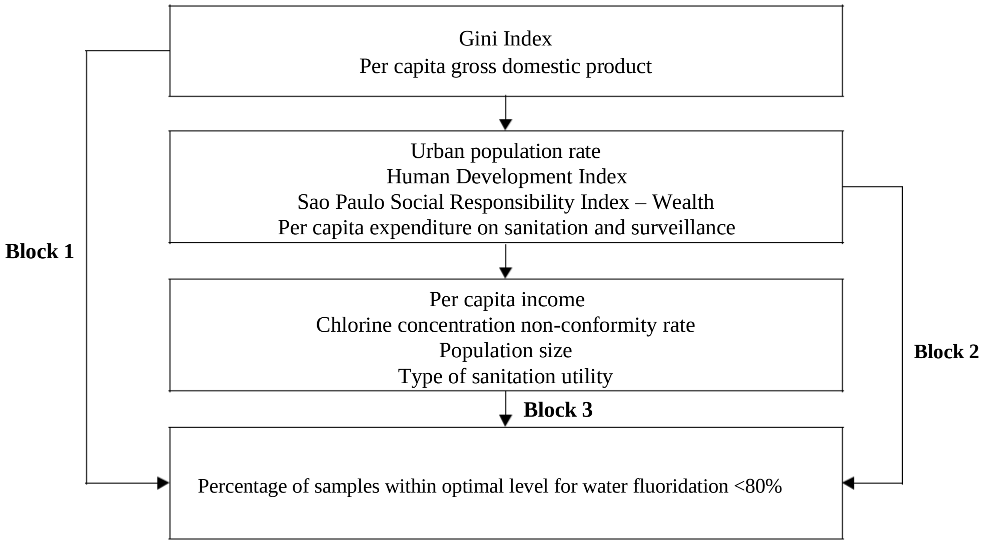
As the interest was to determine the municipal characteristics of water systems that would benefit from improved surveillance and operations, those less likely to provide an optimal level of fluoride, the reference category for the outcome was “very good” quality of fluoridation. Given the prevalence of the outcome, Poisson regression analysis with robust variance was performed to estimate the crude and adjusted prevalence ratios (PRs) and

Table 1.
Summary of the Independent Variables Included in the Study.

Variable	Description	Categorization	Year	Source[a]
Type of sanitation utility	Type of administration of public water supply companies.	1. State-owned Public 2. Municipal-owned Public 3. Private	2010	ANA
Population size	Number of inhabitants residing in the municipalities under analysis	1. >100000 2. 20001 up to 100000 3. 5001 up to 20000 4. ≤ 5000	2010	IBGE
Per capita income (in Brazilian reais R$)	Monthly ratio between the sum of income of all individuals residing in permanent private households and the total number of these individuals	1. >1000 2. ≤1000	2010	IBGE
Urban population rate*	Percentage of individuals residing in urban areas	1. >94.93% 2. >88.45 up to 94.93% 3. >78.71 up to 88.45% 4. ≤78.71%	2010	IBGE
Human Development Index*	The geometric mean of normalized indices on 3 dimensions: health (life expectancy at birth), education (mean years of schooling for adults, 25+ y), and standard of living (gross national income per capita) transformed to a scale from 0 (lowest) to 1 (highest).	1. >0.761 2. 0.739 up to 0.761 3. 0.720 up to 0.738 4. ≤0.719	2010	IBGE
Gini Index*	Indicator that assess social inequality. It points out the difference between the income of the poorest and the richest. Varies from zero (equal situation) to one (maximum inequality situation)	1. >0.48 2. >0.45 up to 0.48 3. >0.41 up to 0.45 4. ≤0.41	2010	IBGE
Per capita GDP*	Sum of all final goods and services produced by the municipality divided by the population of each municipality.	1. >32335.57 2. >21986.69 up to 32335.57 3. >16065.24 up to 21986.69 4. ≤16065.24	2015	IBGE
IPRS-Wealth*	The wealth dimension of the index is composed of four indicators: 1- Per capita GDP; 2-remuneration of formal employees and social security benefits; 3-residential consumption of electric energy; 4-consumption of electricity in agriculture, commerce and services. It ranges from zero (worst situation) to one hundred (best situation).	1. >42 2. >37 up to 42 3. >33 up to 37 4. ≤33	2014	SEADE
Per capita expenditure on sanitation and health surveillance *	Average per capita in reais (R$) of municipal expenditure on sanitation and sanitary surveillance, from 2007 to 2011.	1. ≤2.86 2. >2.86 up to 25.14 3. >25.14 up to 147.57 4. >147.57	2007-2011	SNIS
Chlorine concentration nonconformity rate**	Percentage of residual chlorine analyzes outside the expected quality standard. It is calculated by dividing the total of non-standard samples by the total of samples analyzed for the parameter.	1. ≤0.82% 2. >0.82%	2015	SNIS

IPRS-Wealth is an index referring to wealth dimension relative to the São Paulo Social Responsibility Index. *Variables categorized by quartile. **Variable categorized dichotomously considering the third quartile as a reference. ANA, Brazilian National Water Agency; GDP, Gross domestic product; IBGE, Brazilian Institute of Geography and Statistics; SEADE, Statewise System for Data Analysis; SNIS, National Sanitation Information System.

Figure 2. Theoretical model.



their respective 95% confidence intervals (CIs). Values of goodness-of-fit criteria (Akaike information criterion and Bayesian information criterion) were more favorable for Poisson than logistic regression.

The entry of independent variables in the model was carried out in 3 blocks, based on the premise that municipal characteristics interact with each other and certain characteristics are more directly related to the outcome than others. The tested hypothesis was based on the conceptual framework shown in Figure 2 and included the annual GDP per capita and the Gini index in block 1, considering these variables could affect the remaining variables. The average standard of living per household is an important factor to explain the general health status of a population until a determined level (World Health Organization 2017), and income inequality has been associated with underinvestment in public policy, particularly education and health care (Celeste and Nadanovsky 2010; Pabayo et al. 2019). As the municipalities in São Paulo state had marked differences related to annual GDP per capita and income distribution, the last could be lightly associated with higher income, and some effect on public policy, such as water fluoridation and treatment, could be expected.

The urban population rate, the HDI, the wealth dimension relative to the São Paulo Social Responsibility Index (IPRS-Wealth), and the per capita expenditure on sanitation and health surveillance were included in block 2. The first 2 variables have a clear correlation with sanitation conditions (Libânio et al. 2005; Anand and Bhayankaram 2006), and some effects could be expected on water fluoridation. The IPRS-Wealth is a composite indicator that seeks to capture, at the same time, the production of wealth in the municipality and families through the following components: household energy consumption, per connection; agriculture, commerce, and services sectors energy consumption, by connection; the average income of employees with a formal contract in the private and public sectors; and tax-added value per capita. These variables together allow measurement of production and income, with the advantage of faster availability than classic indicators, such as annual GDP, which is only released 2 y later. Also, data from the Statewise System for Data Analysis (SEADE) of São Paulo state have shown that energy consumption is a good proxy for income and production. During the initial data analysis, it was observed that annual GDP and IPRS-Wealth deal with distinct and independent dimensions linked to the municipalities.

Such factors could be associated with better sanitation conditions or with the per capita expenditure on sanitation and surveillance. Study showed that cities with better IPRS had lower hospitalization rates due to diarrhea, an indicator associated with water quality (Venancio et al. 2016).

Finally, the per capita monthly household income, the rate of nonconformity in the concentration of the parameter-free residual chlorine, the population size, and the type of sanitation utility were added in block 3, which were supposed to be the most direct variables related to the outcome. The latter variable has been associated with the provision of water fluoridation (Silva and Frazão 2018). The total population showed a strong positive correlation with fluoridation quality (Belotti et al. 2018). Per capita income is related to access to material resources relevant to health in most societies, including clean water, sanitation facilities, adequate nutrition, and housing. Free residual chlorine is the chlorine concentration that must remain in the treated water after the disinfection process has taken place for ensuring microbiological safety during distribution. It is a low cost product that can inactivate microorganisms in a short time. (Palmeira et al. 2019). The chlorine concentration nonconformity rate is an important indicator of treated water quality (World Health Organization 2017), and a direct association with fluoridation quality could be expected. In the final multiple model, we presented the overall effect of the variables in block 1 on the outcome, the effect of block 2's variables adjusted by the variables in block 1, and the associated values of the variables in block 3 adjusted by the variables in previous blocks.

The analyses were performed using the Stata 14.1 program (StataCorp), and the thematic map was built using the QGIS 3.4.1 program (QGIS Development Team, 2018).

Results

All 645 municipalities in the state of São Paulo were analyzed. Of these, 56.6% had "very good" fluoridation quality, and 43.4% exhibited fluoridation at the other levels, with less than 80% of samples within the optimal level range (Fig. 2).

Table 2 shows the percentage distribution of the categories of the independent variables according to the outcome. Fluoridation quality considered "very good" was more frequent in cities with a Gini index greater than 0.48, with a higher annual GDP per capita, with less per capita spending on sanitation and health surveillance (first quartile), with a greater population in an urban area, and with an HDI greater than 0.761. Furthermore, in municipalities with IPRS-Wealth in the highest quartile, with per capita income higher than R$1,000 (1,000 reais), and with a lower rate of noncompliance with the parameter-free residual chlorine (≤0.82%), a higher prevalence of "very good" quality of fluoridation also was observed, achieving values of 64.3%, 81.8%, and 59.3%, respectively. Approximately 80% of the municipalities with a population size greater than 100,000 inhabitants had "very good" quality, as well as 78.1% of the municipalities where the treatment of public water supply was operated by a state-owned public company.

Table 3 shows the association values with the outcome defined by the percentage of samples in the range of the optimal level of less than 80%. The values of the variables in block 2 were adjusted by the variables in block 1, and the values of those in block 3 were adjusted by the variables in blocks 1 and 2. Several municipality-level characteristics showed categories significantly associated with the outcome.

In block 1, the outcome had a 50% higher prevalence (95% CI, 1.17–1.94) in municipalities with a 0.42 to 0.45 Gini index and a 32% higher prevalence (95% CI, 1.02–1.70) in those with first-quartile annual GDP per capita.

In block 2, the prevalence of the outcome was higher in the municipalities with the highest per capita expenditure on sanitation and health surveillance and in those where the percentage of the urban population was lower. Municipalities with HDI between 0.720 and 0.761 and with IPRS-Wealth in the third quartile had a significantly higher prevalence for the outcome. It is worth noting that the adjusted value of the prevalence ratio relative to the first quartile of HDI changed from 1.15 (P = 0.318) to 1.33 (P = 0.072) in a clear trend of the outcome association with lower values.

In block 3, the prevalence of the out-come was 1.5 times higher in municipal-ities with less than 100,00 inhabitants, more than twice as high for those with per capita monthly household income less than or equal to R$1,000 (1,000 reais) (PR = 2.17; 95% CI, 1.19–3.97), more than 3.5 times higher where oper-ators were municipal (PR = 4.05; 95% CI, 2.73–6.01) or private (PR = 3.58; 95% CI, 2.30–5.59), and higher in those with the highest rate of nonconformity in the con-centration of the parameter-free residual chlorine (PR = 1.21; 95% CI, 1.02–1.43).

Discussion

Just under half of the municipalities did not reach the measure of very good quality, a proportion (80% or more) of samples with fluoride concentrations within the optimal level. Very good quality of CWF was higher in municipalities with a population size greater than 100,000 inhabitants, with a water treatment service operated by a state-owned enterprise, lower rate of noncompliance of the parameter-free residual chlorine, lower per capita expenditure on sanitation and health surveillance, per capita monthly household income greater than R$1,000 (US$574), HDI greater than 0.761, a greater concentration of the population in urban areas, higher annual GDP per capita, and Gini index greater than 0.48.

As an important focus was to provide information for managers of the water supply systems, the outcome was very low to good quality of water fluoridation. The main contribution was to show that municipality-level characteristics interacted with each other, and some of them were more directly related to the outcome than others. Adjusted by the remaining variables, cities with less than 100,000 habitats, increased rate of noncompliance of the parameter-free residual chlorine, reduced per capita monthly household income, and water treatment service operated by private and municipal-owned utilities were associated with lack of fluoridation quality. One study showed a strong positive correlation between population size and CWF quality (Belotti et al. 2018). It is recognized that the benefits derived from modern technology occur much more quickly in large urban centers and metropolitan regions, where the highest levels of income and the greatest technical and business training are concentrated (Tucci et al. 2000). Earlier studies showed that better-off towns tended to present a higher coverage by the water supply network and were more inclined to add fluoride (Peres et al. 2004; Gabardo et al. 2008; Frazão and Narvai 2017). However, no study had found an association between the rate of noncompliance with the parameter-free residual chlorine and reduced per capita monthly household income with the CWF quality.

Table 2.
Percentage Distribution of Municipalities According to the Quality of Fluoridation and Independent Variables, State of São Paulo, Brazil, 2015.

Variable	Category	Fluoridation, *n* (%)		Total No.	*P* Value[a]
		Very Good	Other Categories		
Gini index	>0.48	106 (65.8)	55 (34.2)	161	0.006
	>0.45–0.48	61 (57.5)	45 (42.5)	106	
	>0.41–0.45	92 (47.4)	102 (57.6)	194	
	≤0.41	106 (57.6)	78 (42.4)	184	
Per capita gross domestic product (quartiles)	Fourth	103 (64.0)	58 (36.0)	161	0.102
	Third	93 (57.8)	68 (47.2)	161	
	Second	86 (53.4)	75 (46.6)	161	
	First	83 (51.2)	79 (48.8)	162	
Per capita expenditure on sanitation and surveillance (quartiles)	First	125 (77.2)	37 (22.8)	162	<0.001
	Second	118 (73.3)	43 (26.7)	161	
	Third	70 (43.5)	91 (56.5)	161	
	Fourth	52 (32.5)	109 (67.7)	161	
Urban population rate	>94.93%	107 (66.5)	54 (33.5)	161	0.016
	>88.45–94.93%	81 (50.3)	80 (49.7)	161	
	>78.71–88.45%	84 (52.2)	77 (47.8)	161	
	≤78.71%	93 (57.4)	69 (42.6)	162	
Human development index	>0.761	103 (64.8)	56 (35.2)	159	0.027
	0.739–0.761	80 (49.7)	81 (50.3)	161	
	0.720–0.738	81 (52.3)	74 (47.7)	155	
	≤0.719	101 (59.4)	69 (40.6)	170	
IPRS-Wealth[b] (quartiles)	Fourth	90 (64.3)	50 (35.7)	140	0.003
	Third	76 (44.7)	94 (55.3)	170	
	Second	95 (58.6)	67 (41.4)	162	
	First	104 (60.1)	69 (39.9)	173	
Per capita income (in Brazilian reais R$)	>1,000	36 (81.8)	8 (18.2)	44	<0.001
	≤1,000	329 (54.7)	272 (45.3)	601	
Type of sanitation utility	State-owned public	286 (78.1)	80 (21.9)	366	<0.001
	Municipal-owned public	75 (28.0)	193 (72.0)	268	
	Private	4 (36.4)	7 (63.4)	11	
Population size	>100,000	61 (80.3)	15 (19.7)	76	<0.001
	20,001–100,000	97 (54.8)	80 (45.2)	177	
	5,001–20,000	118 (48.4)	126 (51.6)	244	
	≤5,000	89 (60.1)	59 (39.9)	148	
Chlorine concentration nonconformity rate	≤0.82%	289 (59.3)	198 (40.7)	487	0.013
	>0.82%	76 (48.1)	82 (51.9)	158	

[a]Chi-square test.
[b]IPRS-Wealth is the wealth dimension relative to the São Paulo Social Responsibility Index.

Table 3.
Crude and Adjusted Analysis of Municipal Characteristics Associated with the Percentage of Fluoride Samples in the Optimal Level Range for Prevention of Dental Caries Less Than 80%, State of São Paulo, Brazil, 2015.

Variable	Category	Crude Values			Adjusted Values		
		PR	95% CI	*P* Value	PR	95% CI	*P* Value
Block 1[a]							
Gini index	>0.48	1.00	—	—	1.00	—	—
	>0.45–0.48	1.24	0.91–1.69	0.168	1.23	0.90–1.67	0.191
	>0.41–0.45	1.54	1.19–1.98	0.001	1.50	1.17–1.94	0.002
	≤0.41	1.24	0.94–1.63	0.121	1.23	0.93–1.61	0.144
Per capita gross domestic product (quartiles)	Fourth	1.00	—	—	1.00	—	—
	Third	1.17	0.89–1.54	0.255	1.17	0.89–1.54	0.269
	Second	1.29	0.99–1.68	0.057	1.25	0.96–1.62	0.095
	First	1.35	1.04–1.75	0.022	1.32	1.02–1.70	0.037
Block 2[b]							
Per capita expenditure on sanitation and surveillance (quartiles)	First	1.00	—	—	1.00	—	—
	Second	1.17	0.80–1.71	0.422	1.23	0.85–1.79	0.278
	Third	2.47	1.80–3.39	0.000	2.59	1.89–3.53	0.000
	Fourth	2.96	2.19–4.01	0.000	3.40	2.50–4.63	0.000
Urban population rate	>94.93%	1.00	—	—	1.00	—	—
	>88.45%–94.93%	1.48	1.13–1.94	0.004	1.32	1.03–1.69	0.029
	>78.71%–88.45%	1.43	1.09–1.87	0.010	1.34	1.02–1.76	0.034
	≤78.71%	1.27	0.96–1.68	0.096	1.42	1.06–1.89	0.019
Human development index	>0.761	1.00	—	—	1.00	—	—
	0.739–0.761	1.43	1.10–1.85	0.007	1.33	1.03–1.72	0.030
	0.720–0.738	1.36	1.04–1.77	0.026	1.32	1.01–1.73	0.044
	≤0.719	1.15	0.87–1.52	0.318	1.33	0.98–1.81	0.072
IPRS-Wealth[c] (quartiles)	Fourth	1.00	—	—	1.00	—	—
	Third	1.55	1.19–2.01	0.001	1.44	1.12–1.85	0.004
	Second	1.16	0.87–1.54	0.319	1.10	0.84–1.46	0.487
	First	1.12	0.84–1.49	0.452	1.23	0.92–1.66	0.158
Block 3[d]							
Per capita income (in Brazilian reais R$)	>1,000	1.00	—	—	1.00	—	—
	≤1,000	2.49	1.32–4.69	0.005	2.17	1.19–3.97	0.012
Type of sanitation utility	State-owned public	1.00	—	—	1.00	—	—
	Municipal-owned public	3.29	2.68–4.05	0.000	4.05	2.73–6.01	0.000
	Private	2.91	1.79–4.74	0.000	3.58	2.30–5.59	0.000

(continued)

Table 3.
(continued)

Variable	Category	Crude Values			Adjusted Values		
		PR	95% CI	*P* Value	PR	95% CI	*P* Value
Population size	>100,000	1.00	—	—	1.00	—	—
	20,001–100,000	2.29	1.41–3.71	0.001	1.58	1.02–2.43	0.040
	5,001–20,000	2.61	1.64–4.19	0.000	1.81	1.15–2.86	0.010
	≤5,000	2.01	1.23–3.31	0.005	1.96	1.20–3.20	0.007
Chlorine concentration nonconformity rate	≤0.82%	1.00	—	—	1.00	—	—
	>0.82%	1.28	1.06–1.54	0.010	1.21	1.02–1.43	0.031

PR, prevalence ratio; —, reference category. Bold indicates significance on the 95% confidence limit.
[a]Adjusted between annual gross domestic product per capita and Gini index.
[b]Adjusted by block 1.
[c]IPRS-Wealth is the wealth dimension relative to the São Paulo Social Responsibility Index.
[d]Adjusted by previous blocks.

In an investigation comprising 38 cities in São Paulo state, researchers detected a relationship between positive total coliform water samples and lower levels of free residual chlorine and higher values of turbidity and nitrate, but no correlation was reported on fluoride concentration (Palmeira et al. 2019). In a survey covering 1,023 households in 64 Spanish cities, the level of free residual chlorine in the user's tap was inversely related to his or her satisfaction. The authors corroborated the notion that users with higher household income are likely to be more demanding of better water quality (García-Rubio et al. 2016), which helps to explain why richer cities have better structural conditions to provide better public policies (Aguiar et al. 2018). In the current study, the lack of CWF quality was more than twice as high for cities with below-median per capita monthly household income.

Moreover, the findings indicated that to provide access to chlorinated and fluoridated water of very good quality, it seems not to be sufficient for the company to be public but to be state owned. The better the control of chlorine in the public water supply, the better the CWF quality. The scale on which the sanitation company operated had implications for the quality of services provided, since the company with this characteristic, analyzed in this study, operated in 366 of the 645 municipalities in the state of São Paulo, serving about 26 million inhabitants. The results suggest that companies that operate on a local scale only, whether publicly owned by the city or that are under the administration of private companies, have greater difficulties in providing fluoridated water classified as "very good" quality. The trajectory of the Brazilian sanitation sector reveals that state-owned companies concentrated greater investment capacity, technical expertise, and historical experience due to public policies put into practice in the last 25 y of the 20th century (Sabbioni 2008). Study on the insourcing and outsourcing dynamics of public service delivery among US municipalities from 2002 to 2007 found that water distribution and treatment had one of the highest rates of stable public delivery (Warner and Hefetz 2012).

On the role of the state, Pontes and Schramm (2004) argue that, from the point of view of protection bioethics, a state that claims to be legitimate must ensure universal access to water drinking as a right. To them, the state must assume responsibility for the provision of sanitation services, in particular the provision of very good-quality water, and privatization policies that might generate situations of social injustice, which endanger the health of the population, are not advisable.

Some unprecedented findings stand out. Adjusted by the Gini index and annual GDP per capita, municipalities with higher per capita expenditure on sanitation and health surveillance and lower HDI were associated with a lack of CWF quality. One possible explanation for the association between the outcome and higher per capita expenditure on sanitation and health surveillance is that cities with a higher expense would have a sanitation system in structural expansion, therefore requiring a greater investment by local management in the sector. Another explanation is that the smaller the demographic size of the municipality, the greater its per capita expenditure on the sector and the possibility of the service to be operated on a local scale under the administration of private companies or owned by the town. These points would clarify the lack of CWF quality. Earlier studies had found an association between CWF provision and HDI (Peres et al.

Table 3.
(continued)

Variable	Category	Crude Values			Adjusted Values		
		PR	95% CI	*P* Value	PR	95% CI	*P* Value
Population size	>100,000	1.00	—	—	1.00	—	—
	20,001–100,000	2.29	1.41–3.71	0.001	1.58	1.02–2.43	0.040
	5,001–20,000	2.61	1.64–4.19	0.000	1.81	1.15–2.86	0.010
	≤5,000	2.01	1.23–3.31	0.005	1.96	1.20–3.20	0.007
Chlorine concentration nonconformity rate	≤0.82%	1.00	—	—	1.00	—	—
	>0.82%	1.28	1.06–1.54	0.010	1.21	1.02–1.43	0.031

PR, prevalence ratio; —, reference category. Bold indicates significance on the 95% confidence limit.
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2004; Gabardo et al. 2008). In the same adjusting, associations were observed with a demographic variable expressed by a lowered urban population and an economic variable related to municipal wealth. However, such variables were less important than population size and per capita monthly household income, which were shown to be more directly linked with the outcome.

Determining categories of income inequality and annual GDP per capita associated with the lack of CWF quality, however, their effect lost importance in the presence of other municipal characteristics and appeared to be relevant for adjusting the included variables in block 2.

Persistent poverty, inequitable access to water supply and sanitation services, inadequate financing, and deficient information about the state of water resources, their use, and management impose further constraints on water resources management and the ability to achieve the sustainable development objectives of the Water Development Report released by the United Nations in 2015. The findings on CWF quality showed the relevance of population size, per capita monthly household income, type of sanitation company, and the rate of noncompliance of the parameter-free residual chlorine.

As the results reported in this study were based on data from all cities of São Paulo state, bias due to convenience samples was prevented. One important limitation refers to the lack of variables related to an intermediate level in which the operations of water treatment have been undertaken by sanitation companies and the operations of water surveillance have been carried out by the local health systems. In an integrated regulatory system directed to ensure safe water for health, the characteristics related to this organizational level could be very relevant. Some studies have described significant variation in the fluoridation knowledge level of water plant operators (Lalumandier et al. 2001) and of water surveillance workers (Belotti et al. 2019) that might reflect weak levels of structuring and institutionality of certain practices within the scope of local organizations. Despite this, the study showed characteristics connected to the municipality, a strategic entity for building an integrated regulatory system directed to ensure safe drinking water.

In conclusion, the quality of fluoridation was associated with municipality-level characteristics. To ensure high quality of water fluoridation, additional management measures should be implemented in municipalities with fewer than 100,000 inhabitants, with high chlorine concentration nonconformity rate, with low per capita income, and where the type of sanitation utility was municipal owned or private.

Author Contributions

L. Belotti, contributed to conception, design, data analysis, and interpretation, drafted and critically revised the manuscript; C. Zilbovicius, C.C.d.S. Soares, P.C. Narvai, contributed to data acquisition, analysis, and interpretation, critically revised the manuscript; P. Frazão, contributed to conception, design, data acquisition, analysis, and interpretation, drafted and critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work.

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5.2 Intervening factors on the costs of fluoridation in water supply systems: a case study in seven population sizes

Technical Article

Intervening factors in the costs of fluoridation in water supply systems: a case study in seven population sizes

Fatores intervenientes nos custos da fluoretação em sistemas de abastecimento de água: estudo de caso em sete portes populacionais

Lorrayne Belotti[1]*, Paulo Frazão[1]

ABSTRACT

The aim of this study was to analyze the costs of fluoridation in water supply systems of different population sizes. A case study was carried out comprising cities in the state of Espírito Santo, Brazil. The costs of initial installation, the chemical product, the operation of the system, and the control of fluoride levels between the years 2012 and 2017 were considered. The annual *per capita* cost of the treatment was calculated to estimate the fluoridation weight concerning the total expenses. The fluoridation annual *per capita* cost ranged from R$ 20.14 (US$ 7.23) in towns with less than two thousand inhabitants to R$ 0.39 (US$ 0.14) in cities with a population of approximately 520 thousand inhabitants. In systems that supply up to 30 thousand inhabitants, the running cost was responsible for most of the expenses, ranging from 98.2 to 84%. For cities with 520 thousand inhabitants, the costs with the chemical product corresponded to 74.7% of the expenses. Compared with the total treatment cost, the water fluoridation cost ranged from 0.2 to 0.6% for population sizes of 30 thousand inhabitants or more and varied from 1.3 to 7.3% for towns with less than 10 thousand inhabitants. Considering that the decision-making process is complex in the field of public policies, and decision-makers suffer multiple influences as for different policy alternatives, knowing the implications of population size for costs is essential for informed decision-making.

Keywords: fluoridation; cost analysis; water supply.

RESUMO

O objetivo foi analisar os custos da fluoretação em sistemas de abastecimento de água de diferentes portes populacionais. Realizou-se estudo de caso em municípios do estado do Espírito Santo, Brasil. Foram considerados dados referentes aos custos de instalação inicial, do produto químico, da operacionalização do sistema e do controle dos teores de flúor nos anos de 2012 a 2017. Foi calculado o custo *per capita* anual do tratamento da água a fim de estimar o peso do custo da fluoretação na totalidade das despesas. O custo *per capita* anual da fluoretação variou de R$ 20,14 (US$ 7,32) para o porte com menos de 2 mil habitantes a R$ 0,39 (US$ 0,14) para o porte com cerca de 520 mil habitantes. Nos sistemas que servem até 30 mil habitantes, o custo de operacionalização foi responsável por maior parte dos gastos, variando de 98,2 a 84%. No porte de 520 mil habitantes, os custos com o produto químico corresponderam a 74,7% dos gastos. O custo da fluoretação da água em relação ao custo total variou de 0,2 a 0,6% nos portes populacionais de 30 mil habitantes ou mais e de 1,3 a 7,3% nos portes abaixo de 10 mil habitantes. Como o processo de tomada de decisão no campo das políticas públicas é complexo e os tomadores de decisão sofrem múltiplas influências em torno de diferentes alternativas de políticas, conhecer a implicação do porte populacional nos custos é essencial para uma tomada de decisão informada.

Palavras-chave: fluoretação da água; análise de custos; abastecimento de água.

INTRODUCTION

The Community Water Fluoridation (CWF) is a public health intervention technology defined by adjusting the fluoride concentration in drinking water, acknowledged as safe (BEAL; LENNON, 2017) and effective to reduce dental caries in the population (MCDONAGH *et al*., 2000; WHELTON *et al*., 2019). Its effectiveness occurs even in populations that use fluoride toothpaste. Depending on the extent of the water supply system, it can reduce social inequality in access to fluoride and benefit the entire population, especially the most vulnerable ones (KUMAR, 2008; NARVAI *et al*., 2014; SANDERS *et al*., 2019). The availability of CWF can be considered a public policy due to the multiplicity of associated interests, the complexity of the decisions involved, and the administrative and management requirements related to its implementation (FRAZÃO; NARVAI, 2017).

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One reason claimed by sanitation companies to prevent the expansion of fluoridation coverage is related to the installation cost of the concentration adjustment system and the costs of the chemical product and professional updating and training (FRIAS *et al*., 2006; RAMOS; VALENTIM, 2012). Although studies in different countries have demonstrated that fluoridation costs are low compared with the savings resulting from averted treatment (GRIFFIN; JONES; TOMAR, 2001; KROON; VAN WYK, 2012; MARIÑO, 2013), few studies have described the intervening factors in the cost of implementing this public policy.

The average cost per inhabitant/year for 2003 was R$ 0.08 (US$ 0.03) in the city of São Paulo, Brazil. The accumulated cost for 18 years of implementation and maintenance of the fluoridation system was R$ 1.44 (US$ 0.97) *per capita* (FRIAS *et al*., 2006). In the city of Sorocaba (state of São Paulo), the *per capita* cost was R$ 1.43 (US$ 0.72) in 2009, and from 1989 to 2008 the estimated *per capita* cost ranged from R$ 1.19 to R$ 1.43 (US$ 0.59 to 0.72) (MARTINEZ *et al*., 2013). However, both Brazilian studies refer to large cities, with more than 500 thousand (Sorocaba) and 10 million (São Paulo) inhabitants, and have no detailed information about the intervening factors in the costs.

The feasible factors that influence the cost composition in the different population sizes may be related to the types of equipment that vary according to the system flow, employed technology, monitoring devices, and the need for metering pumps and storage tanks. It is estimated that the cost of chemical product is the second-largest expense in the operation of water treatment plants, representing 26% of the total cost. The first expense is related to human resources, materials, and services (FRANCISCO; ARICA, 2018). Operational and management aspects of water treatment plants located in small communities, occasionally distant from large urban centers, must also be taken into account.

Furthermore, health researches on costs have achieved an important role as a decision and analysis instrument to determine programs and public policies. This is because the integration among different areas of knowledge, such as economics, administration, and health, provides a better comprehension of the efficiency, efficacy, and effectiveness of health services, actions, and policies. Therefore, considering that scientific information on fluoridation cost can provide subsidies for incorporating this technology and supporting its maintenance in areas that have this benefit, the objective was to analyze the cost of fluoridation of water supply systems in seven population sizes.

METHOD

A case study was carried out on the costs of fluoridation in Water Treatment Plants (WTP), considering seven population sizes during 68 months in the period from January 2012 to December 2017. The WTP were managed by Espírito Santo Sanitation Company responsible for supplying 67% of the municipalities in the state of Espírito Santo (ES) and also for approximately 88 WTP in the territory, which has produced on average seven thousand liters per second of treated water. It is a mixed-capital corporation, in which the State Government is the majority shareholder. In 2010, according to Brazilian Demographic Census, 83.1% of the ES population was covered by water supply systems and 16.4% by wells or springs inside or outside their property. For each population size analyzed, a WTP was selected. The size of the population and the availability of complete data were considered for the selection of cases.

Costs of water treatment

The average annual cost of water treatment was calculated considering the availability of complete data for the period from January 2014 to December 2018. The cost of the m³ produced in the municipality where the WTP was located and the volume of water produced in the respective year were estimated. Then, the cost for the period was multiplied by the volume produced in each year and divided by the population supplied by WTP in the period. The items considered for calculating water treatment costs are listed in Chart 1.

Costs of fluoridation

The average annual cost of water fluoridation was calculated from January 2012 to December 2017, considering the availability of complete data. Information was collected from the supply company regarding costs of initial installation, the chemical product, the operation of the system, and the control of fluoride levels, as described by Frias *et al*. (2006). Costs for the construction of new plants were not included, as this capital already exists and would not have been an additional cost, regardless of the fluoridation status. Therefore, the costs were estimated as follows:

Chart 1 - Composition of the costs of the complete treatment of public water supply.

Human Resources	– Normal and overtime wages – Layoff, 13th salary, Brazilian Government Severance Indemnity Fund for Employees, leave of absence (premium/ maternity/paternity) – Transport and food benefits – Medical and social insurance
Materials	– Expedient material, use and consumption – System operation and maintenance material – Treatment material – Laboratory material – Safety and protection material – Cleaning and hygiene material – Fuels and lubricants
Outsourced services	– System operation services – Professional technical services – Maintenance and cleaning services – Surveillance services – Real estate, machinery and car rentals – Electricity – Communication services (publicity and advertising) – Material handling, loading and unloading services – Printing, copying and binding services
Depreciation and amortization	– Depreciation and amortization of property, plant and equipment
Financial, tax and fiscal-related costs	– Interest, fines and monetary updates – Bank expenses – Compensation of own capital – Union contribution – Urban real estate tax, Social Security Financing Contribution, Social Integration Program, Tax on financial transactions, Tax on vehicles, and Contribution for Intervention in the Economic Domain – Provisions for tax, civil, labor, and environmental proceedings
Other costs	– Driving, travel and accommodation – Donations – Exhibitions, congresses and commemorative events – Labor indemnities – Loss of receipt of tariffs – Expenses on incorporations

Source: prepared by the authors.

- Costs of initial installation (CII) – the following items were considered: equipment costs (metering pump, storage tank, and fluoride dosage control equipment); installation costs, which represent about 85% of the equipment cost (CDC, 1991); and technical consultancy costs, corresponding to 15% of total costs related to installation capital. The lifetime of the equipment was considered; therefore, the installation capital was stratified for 20 years. This calculation included the initial capital plus technical consultancy, divided over 20 years;
- Costs of the chemical product (CCP) – the annual consumption of fluorosilicic acid in kilograms in each WTP was considered and then multiplied by its cost in the respective year;
- Costs of the system operation (CSO) and of fluoride level control (CFC) – to estimate the system operation costs, depreciation and maintenance of equipment costs were considered, which represent approximately 10% of the initial capital distributed over its lifetime, and human resource costs of one employee per WTP, calculated considering the average annual cost of wages plus labor charges. Furthermore, in this section, fixed costs for measuring and controlling fluoride levels by the SPADNS (2-(parasulfophenylazo)-1,8-dihydroxy-3,6-naphthalene-disulfonate) colorimetric method were estimated.

Therefore, to calculate the *per capita* costs of fluoridation, Equation 1 was applied:

$$\text{Costs of fluoridation} = \frac{CCII + CCP + CSO + CFC}{\text{covered population by year}} \quad (1)$$

The fluoride consumption was calculated according to the Fluoridated Water for Human Consumption Manual (BRASIL, 2012). Considering that flow rate data of water from WTP (QWTP) were informed by the company, the flow rate of acid dosage (Qacid) was calculated, as reported by Equation 2:

$$Qacid = \frac{Q_{WTP} \text{ x ion content to be applied x proportionality factor}}{\text{Concentration of fluorosilicic acid}} \quad (2)$$

The concentration of fluorosilicic acid is 291.3 g.L-1 (24%) and the proportionality factor (relationship between its molecular weight and the amount of fluoride ions released by its molecule) represents 1.263. Subsequently, the expected consumption was determined considering the density of 1.2136 kg.L-1 at a concentration of 24% (BRASIL, 2012) according to Equation 3:

$$\text{Expected consumption}_{acid} = Q_{acid} \text{ x acid density} \quad (3)$$

The ion content to be applied used in Equation 1 was 0.7 mg.L^{-1} and variations of up to 14% in the expected consumption were accepted, as the optimal concentration ranged between 0.6 and 0.8 mg. L^{-1}.

The results were presented in reais, the Brazilian monetary unit (BRL), and also in United States Dollars (USD) to allow comparison with international studies (NIESSEN; DOUGLASS, 1984). The average variations of the real-dollar for the period from 2012 to 2017 (USD 1 = BRL 2.75 [1.95 – 3.19]) and for the period from 2014 to 2018 (USD 1 = BRL 3.20 [2.35 – 3.66]), released by the Central Bank of Brazil, were considered.

Finally, the percentage represented by the cost of fluoridation in the total cost (cost of fluoridation plus cost of water treatment) was determined to estimate its weight concerning the total expenses.

RESULTS

The chemical product applied to all WTP was the fluorosilicic acid (H2SiF6), in a concentration of 24%. The range of the acid costs is shown in Table 1. Values varied from R$ 0.39/kg in 2012 to 1.23/kg in 2017, increasing 315%. In the WTP that supplied less than two thousand inhabitants, the total cost ranged from R$ 194.22 (2012) to R$ 339.48 (2017), and in the one that supplied 520 thou- sand inhabitants, it ranged from R$ 96,984.03 to R$ 236,473.08. This expense included the product transport cost from the supplier to the WTP (Table 1).

Data on WTP that supplied different population sizes in the state of Espírito Santo were used. In addition to differences in the population size and active

Table 1 - Cost of fluorosilicic acid, according to the year and population size.

Year	Fluorosilicic acid	Population size (in thousand inhabitants)						
		< 2	6	9	30	70	160	520
2012	Cost (R$/Kg)	0.39	0.39	0.39	0.39	0.39	0.39	0.39
	Total cost (R$)	194.22	398.93	877.97	2,831.40	11,673.09	33,545.15	96,984.03
2013	Cost (R$/Kg)	0.48	0.48	0.48	0.48	0.48	0.48	0.48
	Total cost (R$)	174.24	528.14	1,253.95	3,518.59	14,457.60	39,673.44	111,951.84
2014	Cost (R$/Kg)	0.67	0.67	0.67	0.67	0.67	0.67	0.67
	Total cost (R$)	286.22	864.41	1,916.74	5,589.02	21,141.85	55,420.39	154,530.32
2015	Cost (R$/Kg)	0.83	0.83	0.83	0.83	0.83	0.83	0.83
	Total cost (R$)	310.75	1,000.06	2,085.46	5,812.66	27,121.08	53,953.32	169,683.62
2016	Cost (R$/Kg)	1.10	1.10	1.10	1.10	1.10	1.10	1.10
	Total cost (R$)	302.28	1,199.62	2,412.96	8,118.73	34,946.25	64,714.44	223,124.74
2017	Cost (R$/Kg)	1.23	1.23	1.23	1.23	1.23	1.23	1.23
	Total cost (R$)	339.48	1,190.64	3,337.76	8,484.28	38,979.84	63,990.75	236,473.08

Source: prepared by the authors.

connections of water, WTP also differed in volume of produced water and its flow rate, varying respectively from 9,302.76 to 4,709,286.39 (m^3 per month), and from 25.19 to 6,480.45 (m^3.h-1).

The initial capital cost for each WTP included the common metering pump (by impulse), the storage tank, and the fluoride dosage control equipment (SPANDS), plus the installation (85% of the total equipment costs) and technical consultancy cost (15% of the installation costs). For WTP with a population size less than or equal to 30 thousand inhabitants, the total costs were R$ 5,896.24; when stratified for 20 years, such costs were R$ 294.91 per year. According to the sanitation company, for WTP larger than 50 thousand inhabitants, two metering pumps, a high-volume storage tank, and one fluoride control equipment (SPANDS) are used. Installation and technical consultancy costs, therefore, amounted to R$ 9,196.24; when stratified for 20 years, such costs were R$ 459.81 per year.

In terms of system operation, to estimate human resources costs, the earnings of one operational technical employee per WTP were considered. The average monthly wage of operators working in WTP located in the countryside of the state (≤ 30 thousand inhabitants), from 2012 to 2017, was R$ 2,059.44. For WTP located in urban centers, the average monthly wage was R$ 3,620.19. The 13th salary, labor charges, and 1/3 vacation per year were also considered. From these values, the average for the period was calculated, totaling R$ 31,647.03/year and R$ 55,630.68/year of human resources costs per WTP, located in rural areas and urban centers, respectively.

Depreciation and maintenance costs of the equipment were also considered into system operation, which represent 10% of the initial capital costs of installation, therefore R$ 29.48 for WTP with less than 10 thousand inhabitants and R$ 45.98 for larger WTP. The costs of the fluoride concentration control method (laboratory glassware and reagents), used in all WTP, were included in the initial capital.

The annual *per capita* cost varied according to the population size; therefore, the cost was: R$ 20.14 (US$ 7.32) for the population size of less than two thousand inhabitants; R$ 5.60 (US$ 2.04) for six thousand inhabitants; R$ 3.96 (US$ 1.44) for nine thousand inhabitants; R$ 1.20 (US$ 0.44) for 30 thousand inhabitants; R$ 1.16 (US$ 0.42) for 70 thousand inhabitants; and R$ 0.70 (US$ 0.26) and R$ 0.39 (US$ 0.14) for 160 and 520 thousand inhabitants, respectively (Table 2).

The percentage composition of expenses was also different according to the size of the population. In systems that supplied up to 30 thousand inhabitants, the cost of operation had high participation in the composition of expenses, varying from 98.2% in the area with less than two thousand inhabitants to 84.03% in the area with 30 thousand inhabitants. These costs decreased about 15% in the size of 70 thousand inhabitants compared with the 30 thousand inhabitants. There was a balance in the participation of the items in the total cost in the population size of 160 thousand inhabitants. For 520 thousand inhabitants, the chemical product was the largest expense corresponding to 74.7% of the costs (Table 2).

In areas with two and six thousand inhabitants, the consumption of fluorosilicic acid was less than expected, with a variation of -96.0% and -19.4%, respectively. In other sizes, the percentage of variation was within the expected values: ± 14% (Table 2).

The annual costs of water treatment ranged from approximately R$ 418 thousand, for the smallest population size, to R$ 90 million for the largest area. In systems that supplied up to 30 thousand inhabitants, costs on human resources were responsible for the highest percentage in the composition of total costs, varying from 58.4% in the area with less than two thousand inhabitants to 41.8% in the area with 30 thousand inhabitants. The costs of outsourced services were responsible for over 30% of the total composition of costs in sizes larger than

Table 2 - Annual estimates of performance indicators of Water Treatment Plants, composition of costs and consumption of fluorosilicic acid, for the period from 2012 to 2017, according to population sizes.

Performance indicators of Water Treatment Plants	Population size (in thousand inhabitants)						
	< 2	6	9	30	70	160	520
Active connections (mean)	595.90	2,031.90	3,106.99	10,886.65	22,841.13	30,006.63	121,135.64
Produced volume (m^3 per month)	9,302.76	30,204.49	58,352.69	192,073.32	749,235.46	1,487,214.98	4,709,286.39
Produced flow rate ($m^3.h^{-1}$)	25.19	42.72	82.49	267.12	1,029.90	2,048.91	6,480.45
Operating time (hours/-month)	402.57	708.51	707.55	719.34	727.69	725.97	726.82
Composition of costs							
Cost of initial capital for installation* (R$)	294.81	294.81	294.81	294.81	459.81	459.81	459.81
% of costs	0.91	0.90	0.87	0.78	0.57	0.43	0.21
Cost of chemical (R$)	297.87	863.63	1,980.81	5,725.78	24,719.95	51,882.91	165,457.94
% of costs	0.9	2.6	5.8	15.19	30.57	48.0	74.7
Costs of the system operation (R$)	31,676.52	31,676.52	31,676.52	31,676.52	55,676.66	55,676.66	55,676.66
% of costs	98.2	96.5	93.3	84.03	68.86	51.5	25.1
Per capita cost (R$)	20.14	5.60	3.96	1.20	1.16	0.70	0.39
Per capita cost (US$)	7.32	2.04	1.44	0.44	0.42	0.26	0.14
Consumption of fluorosilicic acid							
Registered (kg)	368.90	1,112.80	2,524.04	7,368.98	31,290.38	71,207.25	218,680.93
Expected (kg)	723.03	1,328.10	2,564.42	8,304.28	32,018.25	63,697.68	201,467.92
% variation	-96.0	-19.4	-1.6	-12.69	-2.33	+10.55	+7.87

*Fractional cost over 20 years considering the life span of the equipment. Source: prepared by the authors.

70 thousand inhabitants. The cost of m³ produced decreased as the population size increased, ranging from R$ 4.08 to R$ 1.98 (Table 3).

The cost of water fluoridation compared with the total cost varied from 0.7 to 0.2% in the population sizes of 30 thousand inhabitants or more, and from 1.3 to 7.3% in the three smallest population sizes (Table 4).

DISCUSSION

The CWF cost changed in line with the size of treatment plant coverage, i.e., the smaller the population size covered, the higher the cost per person. Operationalization and chemical costs were the factors mainly responsible for the total cost composition, in both small and large population sizes, respectively. In the smallest size, the fluoridation cost nearly corresponded to 7% of the total water treatment, whereas in the size of 520 thousand inhabitants this fraction represented only 0.2% of the total cost.

This is the first Brazilian study comparing intervening factors in the costs of CWF and the water treatment in seven different population sizes. Francisco and Arica (2018) presented an analysis model considering only chemical costs of water treatment in Campos dos Goytacazes city, in the state of Rio de Janeiro. Other studies have estimated the annual *per capita* cost of water fluoridation in large municipalities without providing detailed information on the intervening factors (FRIAS *et al*., 2006; MARTINEZ *et al*., 2013).

In the present study, the annual *per capita* cost was R$ 20.14 (US$ 7.32) for less than two thousand inhabitants and R$ 0.39 (US$ 0.14) for the size of 520 thousand inhabitants. Differences in fluoridation costs according to population size have also been observed in Australia. In communities with less than

Table 3 - Composition of the annual costs of water treatment (in thousands of reais), for the period from 2014 to 2018.

	Population size (in thousand inhabitants)						
	< 2	6	9	30	70*	160*	520
Human Resources	248.40	768.13	1,407.93	2,863.01	24,588.96	24,588.96	22,440.71
% of costs	59.4	62.1	52.7	41.8	28.3	28.3	24.7
Materials	10.82	28.43	73.29	259.88	3,618.44	3,618.44	2,393.43
% of costs	2.6	2.3	2.7	3.8	4.2	4.2	2.6
Outsourced services	92.41	216.73	602.54	2,032.93	31,490.70	31,490.70	29,888.50
% of costs	22.1	17.5	22.5	29.7	36.3	36.3	32.9
Depreciation and amortization	15.22	49.96	200.08	762.66	6,426.46	6,426.46	6,059.21
% of costs	3.6	4.0	7.5	11.1	7.4	7.4	6.7
Financial, tax and fiscal-related costs	35.09	124.38	297.47	730.61	11,930.21	11,930.21	14,014.07
% of costs	8.4	10.1	11.1	10.7	13.8	13.8	15.4
Other costs	16.12	49.43	91.04	194.24	8,698.18	8,698.18	16,047.34
% of costs	3.9	4.0	3.4	2.8	10.0	10.0	17.7
Total	418.06	1,237.07	2,672.35	6,843.32	86,752.96	86,752.96	90,843.26
Costs of m³ (in reais)	4.08	3.43	4.00	2.97	1.98	1.98	2.15

*Water Treatment Plants located in the same municipality. Source: prepared by the authors.

Table 4 - Comparison of the annual *per capita* costs of water treatment with the costs of fluoridation. Mean value and standard deviation.

	Population size (in thousand inhabitants)						
	< 2	6	9	30	70	160	520
Average cost of water treatment (R$)	254.63	240.70	304.69	214.45	239.24	231.07	203.03
Standard deviation	33.28	24.36	38.92	23.14	14.68	37.49	5.72
Average cost of water treatment (US$)	79.57	75.22	95.22	67.02	74.76	72.21	63.45
Standard deviation	10.40	7.61	12.16	7.23	4.59	11.71	1.79
Average cost of Community Water Fluoridation (R$)	20.14	5.61	3.96	1.20	1.16	0.70	0.39
Standard deviation	2.52	0.79	0.55	0.19	0.19	0.24	0.10
Average cost of Community Water Fluoridation (US$)	7.32	2.04	1.44	0.44	0.42	0.25	0.14
Standard deviation	0.92	0.29	0.20	0.07	0.07	0.09	0.04
Percentage of fluoridation cost in the total cost (in reais)	7.3	2.3	1.3	0.6	0.5	0.3	0.2
Percentage of fluoridation cost in the total cost (in dollar)	8.3	2.6	1.5	0.7	0.6	0.3	0.2

Source: prepared by the authors.

five thousand inhabitants, the *per capita* cost was A$ 4.38, whereas in those with more than 50 thousand inhabitants, it was A$ 0.53 (FYFE *et al*., 2015).

In the state of Florida, United States of America, a study carried out on 44 communities with different population sizes, between 1981 and 1989, showed that the cost of fluoridated public water supply is highly dependent on the organizational structure of the supply system and population size. Thus, the annual *per capita* cost was US$ 2.12 for communities with less than 10 thousand inhabitants, US$ 0.68 for population sizes between 10 and 50 thousand inhabitants, and US$ 0.31 for 50 thousand inhabitants or more (RINGELBERG; ALLEN; BROWN, 1992).

Costs for installing fluoridation varied from five to nine thousandreais, depending on the studied population size. These costs were lower than those estimated for the municipality of São Paulo (FRIAS *et al*., 2006) due to the greater number of WTP and equipment required in that municipality.

In addition, there are differences related to the technology employed among supply companies. The company reported in this study used the colorimetric method to analyze fluoride concentration in all population sizes. This method, although more prone to reading errors due to the presence of interfering ions in the water (SILVA *et al*., 2007), is cheaper compared with the electrometric method (MOTTER *et al*., 2011), a fact that can influence the decision-making for using the colorimetric technique by supply companies.

For WTP with the largest population size (and also the highest water flow rate), chemical costs accounted for about 74% of the total cost. Moreover, it was observed that the cost of fluorosilicic acid per kilogram significantly increased over the analyzed years: approximately 315%. This increase may be related to market interests in the product, as fluorosilicic acid is a secondary product of the fertilizer industry and, according to the authors' experience in this field of study, for many years it was distributed to sanitation companies at no cost.

Personnel costs linked to the operationalization of the system increased in smaller population sizes. In six of the seven population sizes, this portion represented, from the total fluoridation costs, half of it or more, whereas for treatment, three of the seven population sizes analyzed had higher expense on human resources in the total composition of costs. These costs are part of the operating costs that are proportional to the amount of treated water (BHOJWANI *et al*., 2019). In contrast to the expense on chemicals, which increases according to the quantity of produced water, personnel expenses are fixed and their weight in the total operating cost tends to decrease as the amount of produced water increases.

Another important aspect of the study concerns the chemical consumption used to adjust the fluoride concentration. The results showed higher variation of expected consumption in smaller population sizes. A previous study on 40 municipalities in the state of São Paulo described a higher percentage of samples within the standard regarding the concentration of fluoride in larger systems, where the frequency of monitoring water quality is generally greater (DARÉ; DALL'AGLIO SOBRINHO; LIBÂNIO, 2009).

This study compared the fluoridation cost with the total cost involving the treatment and the fluoridation of water. In population sizes of 30 thousand inhabitants or more, this weight was the smallest regarding all the involved costs. Conversely, in population sizes smaller than 10 thousand inhabitants, this value represents between 1.3 and 7.3% of the total cost. Those in management, regulation, and operation of sanitation services must be responsible for creating alternatives related to public policies that ensure suitable conditions for the rational use of natural resources, the economic and financial balance, and the universal access to treated and fluoridated water in the WTP serving small population sizes.

A limitation of the present study was the difficulty in generalizing the obtained results, considering that it is a case study involving seven population sizes. However, this type of study design allowed the investigation and in-depth analysis of factors involved in the fluoridation costs. It is worth mentioning that about 70% of Brazilian municipalities have a population size up to 20 thousand inhabitants (IBGE, 2011), in such a way that the information produced in this study may assist managers of public and private companies and other decision-makers serving different population contexts in the sanitation sector. In addition, it is necessary to consider that there are myriads of options and methods for managing water supply and treatment systems due to the wide variety of water sources, treatment methods, and recycling options (BHOJWANI *et al*., 2019). With the advancement of remote communication and monitoring resources, the operating costs estimated in this study for population sizes smaller than 10 thousand inhabitants could be significantly reduced.

CONCLUSIONS

Regarding the findings, the authors conclude that the cost of fluoridation over the total cost of the operation (treatment and fluoridation) varied from 0.2 to 0.6% in the population sizes of 30 thousand inhabitants or more, and from 1.3 to 7.3% of the total cost in population sizes smaller than 10 thousand inhabitants.

AUTHORS' CONTRIBUTIONS

Belotti, L.: Conceptualization, Data Curation, Formal Analysis, Methodology, Writing – original draft. Frazão, P.: Conceptualization, Data Curation, Methodology, Supervision, Writing – original draft.

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5.3 Effectiveness of water fluoridation in an upper-middle-income country: A systematic review and meta-analysis

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SYSTEMATIC REVIEW

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Effectiveness of water fluoridation in an upper-middle-income country: A systematic review and meta-analysis

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Abstract

Aim: To summarize the information on the effectiveness of community water fluoridation (CWF) on the reduction of dental caries in the context of the wide use of fluoridated toothpaste in Brazil.

Design: A systematic review was conducted regarding the effect of CWF based on studies with Brazilian population groups using the following electronic databases: MEDLINE/PubMed, LILACS, SciELO, and SCOPUS. The literature search was conducted up to August 2019. Studies that compared caries experience in at least two areas, one fluoridated and the other non-fluoridated, by mean dmft/DMFT (decayed, missing, and filled teeth) index or caries prevalence (caries vs. caries-free) were included. Considering the beginning of widespread use of fluoride dentifrice and the time for producing dental caries decline, studies published before 1995 were excluded. Descriptive analysis and meta-analyses were carried out. The effect size was measured by mean difference for dmft and DMFT ± SD and odds ratios on a logarithmic scale for caries prevalence.

Results: Of the 574 studies retrieved, 16 and 10 were included in the qualitative and quantitative analysis, respectively. Fluoridated areas exhibited lower mean dmft/DMFT than non-fluoridated areas did. The mean difference in the dmft between non-fluoridated and fluoridated areas was −2.28 (95% CI −3.26; −1.30) for children aged 5–8 years and −1.12 (95% CI −1.93; −0.32) for those aged 3–12 years; the mean difference in the DMFT was −0.61 (95% CI −0.80; −0.42) for the children aged between 7 and 12 years. The caries prevalence was 1.4 times and 57% lower, respectively, at primary and permanent dentition in fluoridated areas. Heterogeneity was observed in all age groups, ranging from 77.6% to 98.2%.

Conclusion: Community water fluoridation remains effective in preventing dental caries in children younger than 13 years, even with the widespread use of fluoridated toothpaste.

KEYWORDS
dental caries, fluoridation, meta-analysis, systematic review, water supply

1 | INTRODUCTION

Dental caries is the most common worldwide oral disease.[1] Despite its prevalence and severity declining in the most developed areas, social inequalities persist and the lower socioeconomic groups are the most affected.[1] The reduction recorded in many countries has been attributed to the widespread use of fluoride. In the past, community water fluoridation (CWF) had a more prominent role because it was the only significant source of fluoride, which provided substantial lifelong caries prevention to a considerable number of people worldwide with safety and at a low cost.[2] Currently, other fluoride sources are available. The preventive effect attributable to the CWF with the widespread use of fluoridated toothpaste is expected to be lower, and it can vary in each territory according to population exposure to other dental caries determinants such as access to sugar intake and provision of school dental health programs.

A recent Cochrane systematic review reported that CWF is effective at reducing the caries levels in both primary and permanent dentitions in children. The available data, however, were derived predominantly from studies conducted prior to 1975, demanding contemporary evidence.[3] Furthermore, owing to the restrictive criteria used to include studies in the review, such as inclusion of only prospective studies with a concurrent control, comparing at least two populations, one receiving fluoridated water and the other non-fluoridated water, and with at least two points in time evaluated, important public health questions could not be answered.[4]

Since knowledge regarding dental caries prevention byfluoridated toothpaste use has been consolidated, the topicon the need to continue the CWF has been open to debate.[5,6]Moreover, the reduction by more than two-thirds in theprevalence of dental caries, observed in pioneering commu-nity trials, is no longer achieved. Although CWF remainseffective,[2,3,7] it is important to review studies analyzing itseffects on populations exposed to multiple fluoride sources.In 1974, water fluoridation in water treatment plants became mandatory in Brazil. Between 1970 and 1990,urban water supply coverage increased from 54% to 90%and fluoridation coverage increased from 3% to 42%.[8] Sincethen, the coverage of CWF has been increasing in Brazil,and approximately 144 million Brazilians or 76.3% of thepopulation had access to fluoridated water in 2008.[9] Themost recent study on fluoridation coverage revealed that78.6% of the population had access to adjusted water forfluoride at 0.7 mg/L in municipalities with 50 thousand inhabitants or more in 2015.[10] Its coverage is as large as the main countries that have CWF, such as the United States (63.4%)[11] and Australia (88.5%)[12]; however, the gross domestic product is lower, placing it among the upper-middle-income countries,[13] and the Human Development Index value at 2018 was 0.761, positioning it at 79 of 189 countries and territories.[14] Public policies such as taxation, advertising restrictions, and education to lower free sugar consumption are not adopted in the country. Given the extent and historical aspects of the CWF in Brazil, investigating its effectiveness in an upper-middle-income country with widespread use of fluoridated toothpaste[15] is relevant for the advancement of scientific knowledge about its effects in different sociodemographic and cultural contexts. Besides, while many studies of fluoridation in Brazil have been conducted, no meta-analysis has been published.

Despite accumulated scientific knowledge on its safety and efficacy, CWF has faced the growing spread of false information over the Internet and social networks.[16] As this phenomenon can affect the community's continued support and maintenance of public policy, studies updating evidence in the context of multiple fluoride sources are important. Therefore, the objective was to summarize the information on the effectiveness of CWF on the re- duction of dental caries with the widespread use of fluori-dated toothpaste in Brazil.

Why this paper is important to paediatric dentists

- Although there is a reduction in the prevalence and severity of dental caries globally, the lower socioeconomic countries are the most affected by this disease.
- The community water fluoridation (CWF) effect was greater at the primary dentition than at the permanent dentition.
- CWF is still effective at reducing caries levels in Brazilian children, even with the widespread use of other fluoride sources.

2 | MATERIALS AND METHODS

The protocol was registered in Prospero (CRD42019142050), and this review was written following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines.[17]

2.1 | Literature search

The literature search was performed up to August 2019 in the following databases: MEDLINE/PubMed, LILACS, SciELO, and SCOPUS. Additionally, we examined the list of references to include articles not identified in the initial search. The search had three blocks of terms regarding the following: (1) the outcome ("oral health" [All Fields] OR "dental caries" [All Fields] OR "caries" [All Fields] OR "decay" [All Fields] OR carious [All Fields]); (2) the exposure ("fluoridation" [All Fields]); and (3) the location ("brazil" [All Fields]). The terms were combined with the Boolean operator "AND."

The title/abstract screening was performed independently by the authors (LB and PF). They reviewed all registers and selected those fulfilling the inclusion criteria (kappa statistic = .82). They scrutinized all full-text papers to ensure required data regarding caries in fluoridated and non-fluoridated areas, and the disagreements were resolved by consensus. PF graduated in dentistry with PhD in public health and, as a full professor in Public Health School at the University of Sao Paulo, has large research experience in Dental Public Health. LB is a PhD candidate at the same university and, since graduation in dentistry, is involved in public health and paediatric dentistry researches.

1.1 | Study selection

After the searching procedures, observational studies with comparable groups exposed and non-exposed to CWF, comparing caries experience by mean dmft/DMFT (decayed, missing, and filled teeth) index or by caries prevalence (caries vs. caries-free), were included. Controlled trials were not found, and ecologic studies were excluded. No age or language restrictions were applied.

As the objective was to analyze the CWF effect with the widespread use of fluoridated toothpaste, studies published before 1995 were excluded considering the year (1989) when fluoride dentifrices reached the market on a large-scale basis[15] and the time for producing an accumulated effect on reducing dental caries at index ages of 5 and 12 years. (Appendix S4).

The studies were classified according to the comparability of exposed and non-exposed population groups for controlling potential confounding bias due to area-based social differences. The considered characteristics were

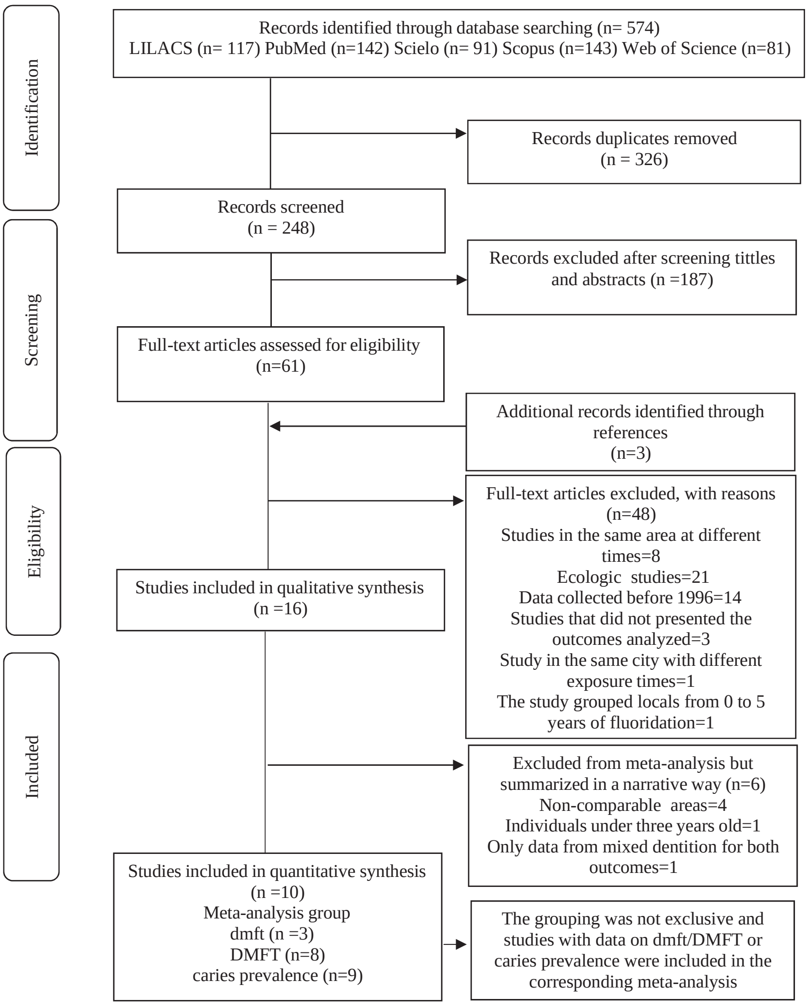

FIGURE 1 Flowchart of study selection

TABLE 1 Summary characteristics of included studies on the effect of water fluoridation measured in different areas, Brazil, 1998–2018

			Permanent dentition					
			Fluoridated areas				Non-fluoridated areas	
Author (year)	Number of areas	Age (years)	*N*	% of caries	DMFT	SD	*N*	% of caries
Cardoso et al. (2003)[24]	2	12	231	55.0	2.29	2.56	223	57.8
Cruz et al. (2018)[25]	2	11–12	184	58.2	1.76	1.92	128	65.7
Cypriano et al. (2003)[23 a,b]	7	5	337	60.3	0.1	0.9	38	84.3
Cypriano et al. (2003)[23 a,b]	7	6	348	67.5	0.1	0.0	51	88.2
Cypriano et al. (2003)[23 a,b]	7	7	390	77.4	0.5	1.0	65	86.2
Cypriano et al. (2003)[23 a,b]	7	8	415	78.8	0.8	1.0	83	92.8
Cypriano et al. (2003)[23 a,b]	7	9	438	83.4	1.2	2.1	88	96.5
Cypriano et al. (2003)[23 a,b]	7	10	417	80.2	1.6	1.0	85	83.6
Cypriano et al. (2003)[23 a,b]	7	11	453	70.5	1.9	2.2	74	79.7
Cypriano et al. (2003)[23 a,b]	7	12	393	68.8	2.5	3.0	56	83.8
Dini et al. (1998) [a][26 c]	2	7–8	195	21.0	0.5	1.1	182	44.0
Dini et al. (1998) [a][26 c]	2	9–10	250	49.0	1.3	1.6	150	58.0
Dini et al. (1998) [a][26 c]	2	11–12	203	69.0	2.3	2.2	157	79.0
Dini et al. (1998) [a][26 c]	2	7–8	98	23.0	0.5	1.0	182	44.0
Dini et al. (1998) [a][26 c]	2	9–10	111	65.0	1.6	1.6	150	58.0
Dini et al. (1998) [a][26 c]	2	11–12	90	71.0	2.3	2.1	157	79.0
Dini et al. (1998) [b][27 c]	3	3–4						
Dini et al. (1998) [b][27 c]	3	5–6						
Dini et al. (2000)[28]	2	9–10	287	46.7	1.08	1.42	210	63.3
Franzolin et al. (2010)[29 c]	2	12	120	80.0	2.94	2.29	120	91.7
Guerra et al. (2010)[21]	2	12	1002	NR	1.32	1.92	119	NR
Gushi et al. (2005)[30 b]	35	15–19	1393	89.5	6.43	4.68	432	93.6
Parisotto et al. (2010)[22 c,d]	2	5–7						
Rando-Meireles (2016)[31 b]	2	5						
Rando-Meireles (2016)[31 b]	2	12	233	47.6	1.41	2.6	148	67.8
Rando-Meireles (2016)[31 b]	2	15–19	183	74.3	4.21	7.3	146	82.0
Rando-Meireles (2016)[31 b]	2	35–44	373	99.5	15.87	8.0	229	100.0
Rando-Meireles (2016)[31 b]	2	65–74	255	99.6	25.09	7.4	181	100.0
Rihs et al. (2009)[32 b]	29	35–44	708	98.2	20.8	7.2	451	98.2
Sales-Peres et al. (2002)[33 e]	2	12	75	78.7	2.92	NR	88	78.3
Sales-Peres et al. (2002)[33 e]	2	12	95	94.7	7.06	NR	82	92.7
Sales-Peres et al. (2002)[33 e]	4	12	48	93.8	3.08	NR	97	100.0
Sampaio et al. (2000)[34 f]	13	12	98	79.6	2.5	2.1	96	88.5
Tagliaferro et al. (2004)[35 g]	Large	7–12	2451	49.0	1.5	2.0	591	58.0
Tagliaferro et al. (2004)[35 g]	Medium	7–12	2404	57.0	1.8	2.1	1575	71.0
Tagliaferro et al. (2004)[35 g]	Small	7–12	3551	65.0	2.2	2.5	2908	66.0
Tiano et al. (2009)[36]	2	<3						

Abbreviation: NR, not reported.

[a]The prevalence value refers to mixed dentition.

[b]Study areas were not considered comparable for meta-analyses.

[c]Fluoridated and non-fluoridated areas of the same city were analyzed.

[d]The mean value without distinction between dmft and DMFT and the prevalence value refer to mixed dentition.

[e]Eight municipalities were analyzed and grouped according to population size.

[f]The areas had fluoride naturally occurring in drinking water with adequate level for the prevention of caries.

[g]Twenty-nine municipalities were analyzed and grouped according to population size.

		Primary dentition							
		Fluoridated areas				Non-fluoridated areas			
DMFT	SD	*N*	% of caries	dmft	SD	*N*	% of caries	dmft	SD
2.95	2.97								
2.6	3.38								
0	0.0	337		2.8	3.7	38		5.5	4.7
0.4	1.1	348		3.2	3.8	51		4.3	4.0
0.6	1.2	390		3.6	3.0	65		4.5	3.7
0.8	1.4	415		3.1	2.1	83		4.2	2.8
1.3	1.4	438		2.5	3.2	88		2.8	2.4
1.5	1.4	417		1.4	2.1	85		1.4	1.9
2.1	2.6	453		0.6	1.1	74		0.6	0.9
3.1	2.7	393		0.2	1.0	56		0.7	0.4
0.9	1.2	195	73.0	3.1	2.9	182	92.0	4.9	3.1
1.4	1.6								
2.8	2.4								
0.9	1.2	98	70.0	2.8	2.5	182	92.0	4.9	3.1
1.4	1.6								
2.8	2.4								
		441	32.4	1.1	2.2	45	57.8	2.4	3.3
		462	56.9	2.5	3.3	118	89.0	5.3	4.1
1.82	1.81								
4.02	2.61								
2.33	2.59								
6.45	4.32								
		19	42.0	1.6	2.4	27	81.0	5.2	4.7
		224	41.1	1.93	3.4	204	67.0	2.75	3.4
2.37	3.5								
4.98	4.2								
19.65	7.1								
28.07	5.5								
21.3	7.7								
3.45	NR								
6.47	NR								
4.82	NR								
3.9	3.7								
2.0	2.5	2451	NR	1.8	2.5	591	NR	2.1	2.8
2.6	2.6	2404	NR	2.0	2.6	1575	NR	2.7	3.0
2.4	2.6	3551	NR	2.3	2.8	2908	NR	2.4	2.8
		38	10.0	0.57	1.91	30	23.7	0.68	1.83

whether the areas (i) were located in the same Brazilian state and (ii) in the same mesoregion; (iii) had similar population size; and (iv) showed the same category of the Human Development Index (HDI). The population size and the HDI related to the census conducted in the year closest to the data were considered. The calculation assumed the sum of comparable characteristics in each of these four variables, and the score varied from 0 (incomparable) to 4 (completely comparable; Appendix S1). Studies with values of two or more were considered for inclusion in the meta-analyses.

1.1 | Data extraction

The following information was collected from each study: author, publication year, number of areas analyzed, age of individuals, sample size, mean dmft/DMFT (SD), and the number and percentage of individuals with caries experience. Whenever necessary, more information was requested from the authors to obtain essential data for summarization.

1.2 | Statistical analysis

The effect size was measured by mean difference for dmft and DMFT ± SD and odds ratios on a logarithmic scale for caries prevalence (caries vs. caries-free). The statisti- cal analyses were performed separately for each dentition.This grouping was not mutually exclusive, and when pos-sible, studies were included in both meta-analyses.

Articles scored 0 and 1 by comparability index and with no mean-variance values were excluded from the meta-analysis but summarized narratively. The meta-analyses were performed using random-effect models. Data heterogeneity among the studies was assessed using *I*-squared tests and was considered significant when >75%.[18] Publication bias was graphically represented by funnel plots, and their asymmetry was tested by Egger's test.[19] The analyses were performed using Stata software (Stata Corporation, version 16.1).

1.3 | Quality assessment

The methodological quality of the individual studies, which were included in meta-analyses after applying the comparability index, was evaluated using the *Critical Appraisal Checklist for Studies Reporting Prevalence* tool, developed by the Joanna Briggs Institute. It is specific to prevalence studies and includes nine critical assessment criteria adapted for this type of evidence[20] (Appendix S2).

2 | RESULTS

The online search strategy listed 574 articles, of which 326 were duplicates. Only 61 papers fulfilled the inclusion criteria and were selected for full-text reading. Three further studies were included based on reference lists. Of the 16 articles included in qualitative synthesis, only 10 were included in the quantitative synthesis (Figure 1).

All were population-based studies. Fifteen evaluated both the mean dmft/DMFT and the caries prevalence,and one, the continuous outcome.[21] Nine studies as- sessed just the mean DMFT, two assessed only the mean dmft, four evaluated both measures, and one evaluatedthe mean with no distinction between dmft and DMFT.[22] Of 15 articles that analyzed caries prevalence, eight as- sessed only permanent dentition, two assessed only pri- mary dentition, three evaluated both dentitions, and two assessed caries prevalence only at mixed dentition.[22,23] The studies were published from 1998 to 2018, and the sample size ranged from 19 to 3551 participants in each group. The participants' age varied from 5 to 74 years (Table 1).

Three articles compared areas with more than 30 years of fluoridation to a recently fluoridated area. As the recently fluoridated areas had not been supplied for long enough to impact caries prevalence, the studies were included.[26–28] Two studies[26,27] estimated the outcomes inthe same population, separating them into two age groups(3–4 and 5–6 years), and then, the age groups with the lowest number of participants were excluded. Moreover, Dini et al.[26] analyzed three areas (two fluoridated and one non-fluoridated). To avoid repetition of the control group,the fluoridated area with more individuals was includedin the meta-analysis.

Sampaio et al.[34] evaluated 13 rural villages in which six had naturally fluoridated drinking water with adequate levels for the prevention of caries (0.7–1.0 ppm F). One study analyzed eight municipalities and classified the outcomes according to the population size.[33] Similarly, one study assessed 29 cities and organized the results according to the population size (large, medium, and small) but did not report the number of cities in each group.[35]

According to the comparability score, six studies analyzed areas fully comparable. Four of them explored different areas (fluoridated and non-fluoridated) in the same municipality,[22,26,27,29] and two assessed municipalities with similar social and demographic characteristics.[25,36] Four studies scored 2,[21,24,28,35] and two obtained 3 points.[33,34] On the contrary, four studies were excluded from the meta-analysis because the compared areas had significant social and demographic differences.[23,30–32] Although the study of Sales-Peres and Bastos[33] scored 3 points, it was not included in the meta-analysis because it

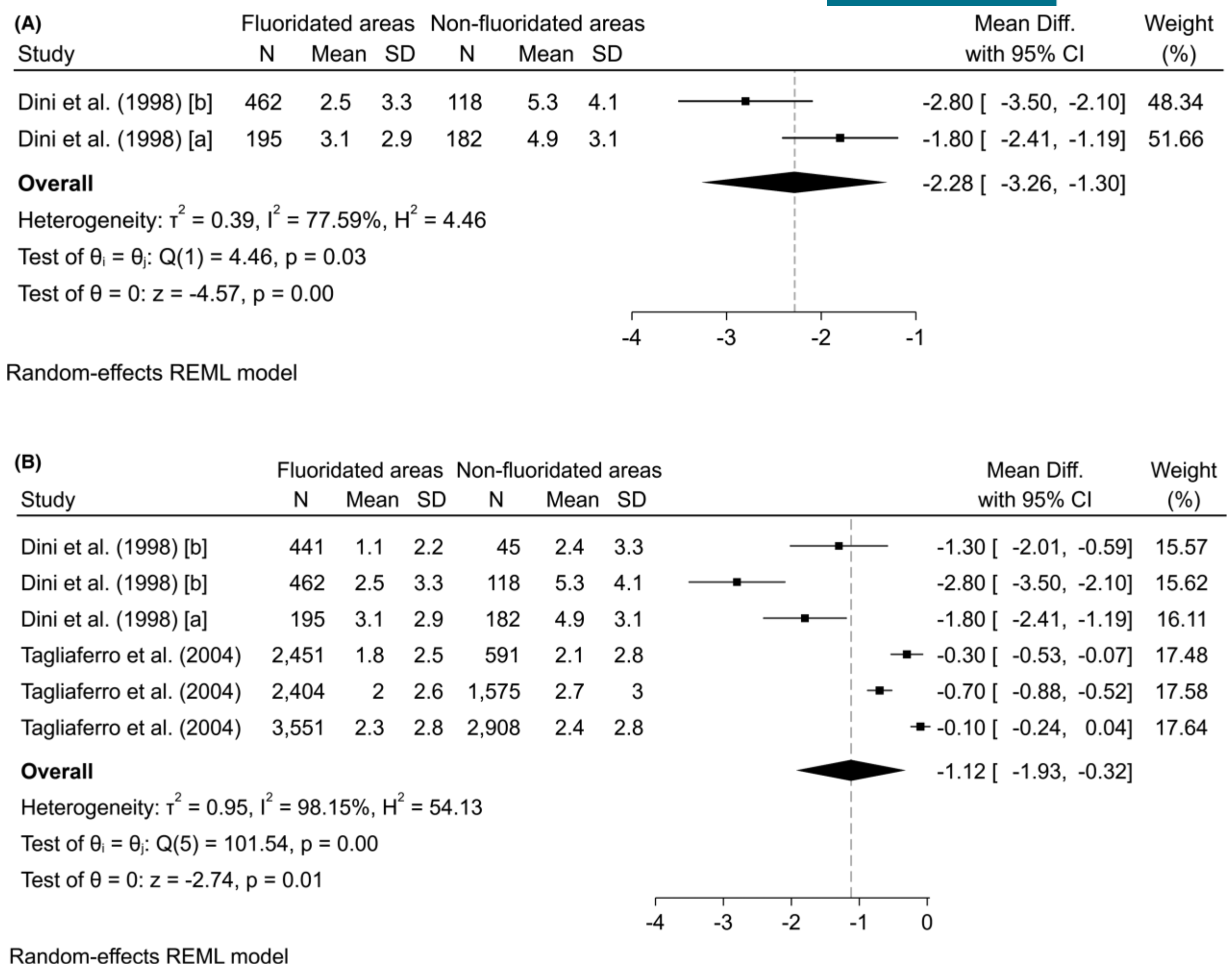

FIGURE 2 Forest plots for mean dmft index in the age groups of 5–8 (A) and 3–12 (B) years for studies on the effect of water fluoridation in different areas using the random-effect model, Brazil, 1998–2010

did not provide data on the variance of the mean DMFT (Appendix S1).

Quality assessment criteria were fulfilled by most papers included in the meta-analysis. The reporting and methodological weakness referred to statistical analysis since the methods section was not detailed enough. Some studies did not show the confidence intervals or the numerator and denominator outcomes (Appendix S2).

The *meta-analysis for the mean dmft* included data extracted from three studies[26,27,35]: Two studies could not be included because one did not separate the dmft and the DMFT,[22] and the other included participants younger than three years[36]; and one study included schoolchildren at ages in which the risk of caries attack is reduced.[35] As the final mean difference of dmft could be affected, two pooled mean dmft were carried out for children aged5–8 years and for those aged 3–12 years. The mean difference in the dmft between non-fluoridated and fluoridated areas was −2.28 (95% CI −3.26; −1.30) for children aged 5–8 years and −1.12 (95% CI −1.93; −0.32) for children aged 3–12 years (Figure 2). A high level of heterogeneity was observed in both age groups, 3–12 years (I^2 = 98.15%; P < .001) and 5–8 years (I^2 = 77.59%; P = .03). For the group of studies that analyzed the dmft, it was not possible to estimate the effect of small studies due to the needed minimum number to perform the test.

After exclusion, the *meta-analysis on the mean DMFT* included data obtained from eight studies[21,24–26,28,29,34,35] and was carried out for children aged 7–12 years. The mean difference in the DMFT between groups exposed and non-exposed to CWF was −0.61 (95% CI −0.80; −0.42) (Figure 3). A high level of heterogeneity was observed (I^2 = 82.44%; P < .001). Asymmetry in the funnel plot, possibly related to publication bias, was observed and confirmed by Egger's test (P = .0344; Appendix S3).

The *meta-analysis for caries prevalence* included nine papers. One assessed only mixed dentition and could not be included in study.[22] The caries prevalence was 1.4

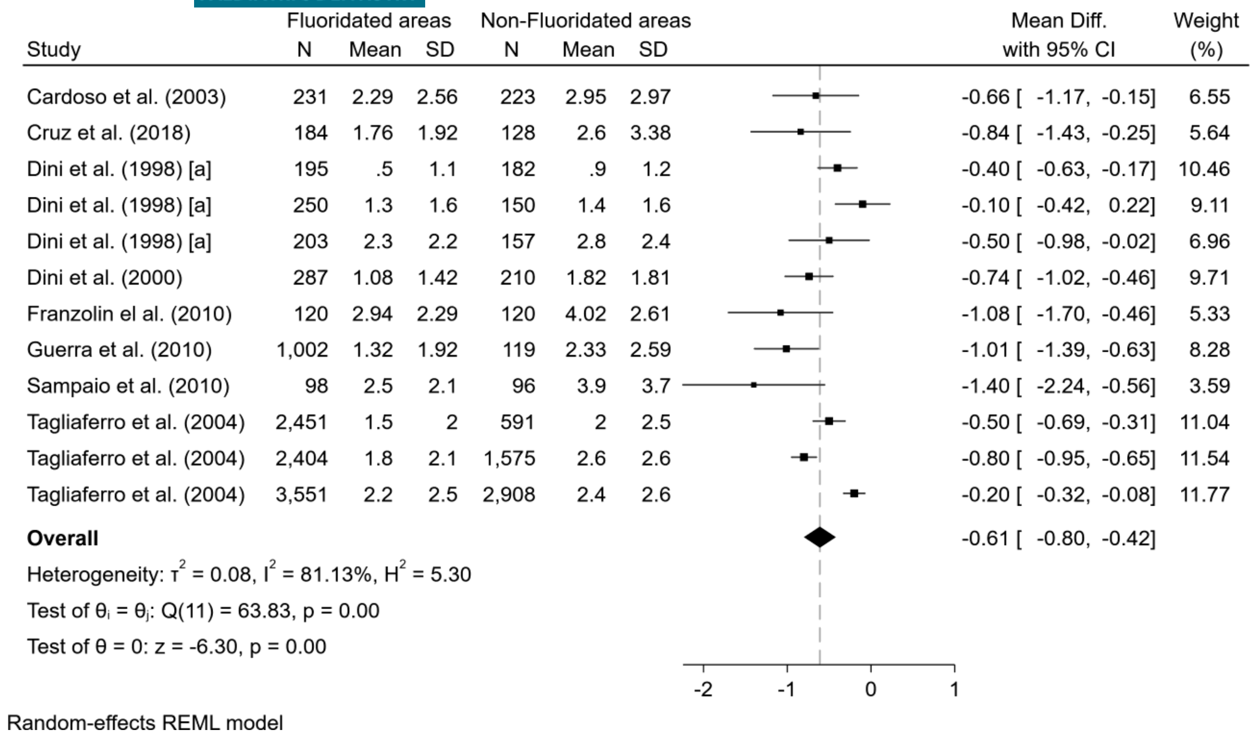

FIGURE 3 Forest plots for mean DMFT index in the age group of 7–12 years for studies on the effect of water fluoridation in different areas using the random-effect model, Brazil, 1998–2018

times lower (ln[OR] −1.42 95% CI −1.86; −0.99) at primary dentition (from 3 to 8 years) and 57% lower (ln[OR] −0.43 95% CI −0.60; −0.24) at permanent dentition (from 7 to 12 years) (Figure 4). The visual inspection of the funnel graph revealed asymmetry in the distribution of the studies; however, it was not confirmed by the Egger's test (*P* = .1334; Appendix S3).

4 | DISCUSSION

This systematic review assessed the severity and prevalence of caries among individuals living in fluoridated and non-fluoridated areas in Brazil. In the meta-analysis, fluoridated areas exhibited lower mean dmft/DMFT than non-fluoridated areas. The caries prevalence was also lower, and the CWF effect was greater at the primary dentition than at the permanent dentition. The effect was observed in an upper-middle-income country in which public policies such as taxation, advertising restrictions, and education to lower free sugar consumption are not adopted, but the use of fluoridated toothpaste is widespread.

The evidence was derived from observational studies with concurrent controls and data for one point in time; hence, it is necessary to assume that the caries levels of the compared areas were similar before the intervention and that the differences observed through a single measure over time correspond to the effect resulting from the intervention in only one of the areas. Such studies are unable to evaluate the changes in dental caries levels over time, and the main risk of bias is related to the mentioned prem-ise. Despite this, the included studies had a good methodological quality, and the results must be interpreted as the best available evidence resulting from contemporary and population-based studies in the country.

Although randomized controlled trials are widely used to measure the effectiveness of medicine and clinical interventions, they are often inadequate for evaluating public preventive programs. In the case of water fluoridation, it is usually impractical to randomly assign individuals to fluoridated and non-fluoridated water supplies,[4] and observational studies, quasi-experimental designs, and time-series analyses with comparison groups are the most appropriate study designs.[37] The summarization, herein presented through observational studies with concurrent controls, confirmed that differences between those exposed and non-exposed to CWF still exist and are in the expected direction.[38] Consistency has been identified as an essential and valuable criterion for evaluating and grading evidence in public health, and the results are consistent with the notion that water fluoridation remains effective.[38]

The high level of heterogeneity detected in the meta-analysis could be explained by the observational de- sign of the included studies and diversity of the studied

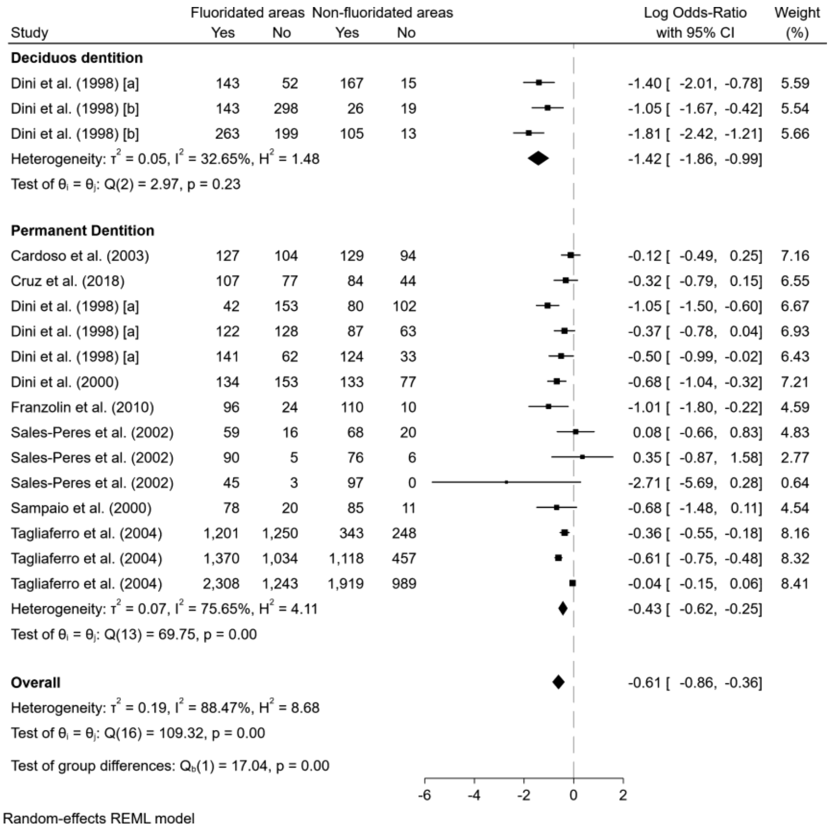

FIGURE 4 Forest plots for caries prevalence (yes or no) at primary (from 3 to 8 years) and permanent dentition (from 7 to 12 years) for studies on the effect of water fluoridation in different areas using the random-effect model, Brazil, 1998–2018

populations. To address the high heterogeneity, we used a random-effect model that considers the differences among studies as a process of random sampling.[39] Other possible sources of heterogeneity could not be explored owing to limitations of available data in each study.

To control the confounding bias owing to area-based social differences, we gathered demographic and socio-economic data and excluded articles that compared areas exposed and non-exposed to CWF with social differences that could influence the pooled results. It is important that confounders are considered using conceptual models of caries determinants for adjusting estimates of the fluoridation effect. Moreover, greater attention should be given to contamination, observer bias, and control of exposure and outcome measurements.[38]

Two major meta-analyses included only prospective studies with concurrent controls, comparing at least two populations, in which fluoride was introduced or withdrawn at the beginning of the study.[3,40] In the first meta-analysis,[40] the median value of mean change in dmft/DMFT was 2.25 teeth. In the Cochrane review,[3] the mean dmft/DMFT in the CWF areas was 1.81 lower in primary teeth and 1.16 lower in permanent teeth. In this meta-analysis, the mean differences in dmft/DMFT between non-fluoridated and fluoridated areas were −2.22 in primary teeth (for children aged 5–8 years) and −0.54 in permanent teeth (for children aged 7–12 years). Similar to the Cochrane review,[3] the results confirmed that water fluoridation was more effective in primary denti- tion than in permanent dentition. Analysis involving 59 cross-sectional studies published between 1990 and 2010, some of them adjusting for confounders, showed 30%– 59% lower dmft and 40%–49% lower DMFT in fluoridated areas.[41]

Improving social factors and increasing access to fluoridated water and toothpaste have been invoked as the principal determinants of the current oral health transition of the Brazilian population.[42] Despite these achievements, two-thirds of the towns had medium and low levels of human development in Brazil, and efforts to increase the opportunities for income and education improvement of the population should be continued. Approximately one-fourth and 15.0% of the population remain, respectively, deprived of fluoridated water and water treated at least by filtration and disinfection. Fiscal austerity and weakness in the regulatory mechanisms in the Brazilian sanitation sector pose a challenge to public health leaders for the maintenance and expansion of the CWF.[43]

It was not possible to assess the fluoridation effect on the prevention of dental caries in the adult population owing to the limited data. Some Brazilian studies, however, have reported that CWF is also effective in the adult population.[32,44,45] In spite of the mentioned points, the results of this study provide relevant information on the current effectiveness of CWF with the widespread use of fluoridated toothpaste. The lack of evidence from prospective studies should not be confused with, or taken to imply, an absence of effect. A consensus has been reached among investigators and health authorities that a combinationof scientific evidence and values, resources, and context should be considered in decision-making. The key components of evidence-based public health include making decisions using the best available research evidence, and systematic reviews are the most objective among the different forms of evidence.[37]

The available evidence from good-quality population-based studies with concurrent controls and data for one point in time showed that CWF remains effective in the prevention of dental caries in Brazil, even though the use of fluoridated toothpaste is widespread. Prospective studies adjusting for confounders are also warranted.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

L.B. and P.F. contributed to conception, design, analysis, and interpretation of the data; drafted the article and revised it critically for important intellectual content; and gave final approval of the version to be published.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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5.4 Economic evaluation of community water fluoridation in an upper-middle income country

ABSTRACT

OBJETIVE: To estimate the cost-effectiveness and cost-benefit of Community Water Fluoridation (CWF) for schoolchildren according to different sizes of population served in Brazil. **METHOD:** The economic evaluation was conducted from a societal perspective. The total costs were estimated by four variables in different population sizes: capital cost of initial installation, chemical product costs, system's operational cost, and costs of monitoring. The effect of CWF was analyzed in the context of the wide use of fluoridated toothpaste, based on studies with Brazilian population groups. The total cost of dental treatment was estimated including direct and indirect cost with a discount rate of 3.5%. One-way sensitivity analysis was conducted to test the robustness of the results according to measured parameter values. **RESULTS:** The costs averted resulting from CWF were US$174.40 and US$85.67 for children aged 5-8 and 3-12 years, respectively, and US$46.66 for those aged of 7-12 years, according to the average effectiveness of the CWF for each group age. The cost-effectiveness, cost-benefit ratio results were favorable in all scenarios where size of population served was 6,000 or more inhabitants. Scenarios unfavorable to CWF were observed only in size up to 2,000 inhabitants. **CONCLUSIONS**: The economic evaluation of CWF in an upper-middle income country showed to be a cost-effective oral health intervention and more economically advantageous mainly in larger areas at both deciduous and permanent dentition.

Key-words: Fluoridation; water supply; cost-effectiveness; cost-benefit; health economics.

INTRODUCTION

Despite being largely preventable, oral diseases remain the most common noncommunicable diseases worldwide. The clinical, aesthetic, functional, emotional and social implications are substantial, and the annual economic impact is high being 64% directly attributable to treatment costs, with the remaining 36% relating to productivity losses due to absenteeism from school and work (RIGHOLT et al., 2018). Although the reduction in the prevalence and severity of dental caries nowadays, mainly in the most developed areas, it is still the most common global oral disease. The social inequalities in dental health persist and the lower socio-economic groups are the most affected. (PERES et al., 2019). Income inequality (CELESTE et al., 2009), low human development, and economic indicators, such as annual Gross Domestic Product *per capita* (GDP) (BAKER et al., 2018), have been associated with its higher prevalence.

In this context, the Community Water Fluoridation (CWF) is an important public health strategy for dental caries prevention at the population level. Besides its low-cost relative to its high social benefit, CWF reduces social inequality in the access to fluoride favoring across all strata of the population served by the public water supply (KUMAR, 2008). A recent Cochrane systematic review reported that water fluoridation is effective at reducing the caries levels in both deciduous and permanent dentition in children (IHEOZOR-EJIOFOR et al., 2015).

In Brazil, the use of water fluoridation technology started in 1953 and water fluoridation in water treatment plants became mandatory in 1974. Between 1970 and 1990, urban water supply coverage increased from 54% to 90% and fluoridation coverage increased from 3% to 42% (SILVA; FRAZÃO, 2018). In 2008, about 144 million Brazilians or 76.3% of the population had access to fluoridated water (FRAZÃO; NARVAI, 2017). The most recent study on fluoridation coverage revealed that 78.6% of the population had access to adjusted water for fluoride at 0.7 mg/L in municipalities with 50 thousand inhabitants or more in 2015 (RONCALLI et al., 2019).

Despite the high coverage of CWF in Brazil, as in countries like the USA (63.4%) (CDC, 2018) and Australia (88.5%) (STORMON; LALLOO, 2020), studies that simultaneously analyze its costs, effectiveness and benefit in contexts of different population sizes are scarce. A study conducted in both fluoridated and non-fluoridated USA communities with observed caries reductions concluded that water fluoridation was still cost saving except for communities with less than 5,000 residents (GRIFFIN; JONES; TOMAR, 2001). Similarly, a New Zealand study exhibited that CWF remained cost effective for communities over 5,000 under all scenarios when sensitivity analysis was conducted (FYFE et al., 2015). A scoping review comprising 24 studies of economic evaluation of CWF for dental caries prevention published after 1973 showed that few studies produced estimates according to the size of the community (MARIÑO; ZAROR, 2020).

The economic evaluation of CWF is relevant for the advancement of scientific knowledge in different sociodemographic and cultural contexts and populations exposed to widespread use of fluoridated dentifrice (WHELTON et al., 2019). Besides, it can support decision-making by health authorities and managers of public and private companies in the sanitation sector, regarding the installation or interruption of fluoridation systems in different locations.

Given these aspects, the objective of this study was to estimate the cost-effectiveness and cost-benefit of fluoridation of public water supply for schoolchildren according to different sizes of population served in Brazil.

METHODS

The cost-effectiveness (CEA) and cost-benefit analyses (CBA) were conducted from a societal perspective, by methodologies applied in previous analyses (FYFE et al., 2015; CAMPAIN et al., 2010; KROON; VAN WYK, 2012a; VAN WYK, 2012b). This perspective includes the expenses incurred by the patient and his/her family, either to access the service or other costs that can be considered as a consequence of the intervention such as costs for lost productivity and transportation costs to and from the dental office. The study's reporting adhered to international standards (HUSEREAU et al., 2014).

Costs associated with CWF

CWF cost estimates were based on data reported in a published study that included costs for seven Brazilian population sizes, ranging from less than 2,000 to more than 500,000, between 2012 and 2017 (BELOTTI, FRAZÃO, 2021). The total costs were estimated by four variables: capital cost of initial installation, chemical product costs, system's operational cost, and costs of monitoring. Within the cost of initial installation, the equipment costs, installation costs (85% of the equipment costs) (CDC, 2001), and costs of technical consultancy (15% of the cost of initial installation) were considered. The operational costs included depreciation and maintenance costs of equipment, which represent about 10% of the initial capital, and the human resource costs of one employee for each water treatment plant, calculated using the average annual cost of wages, plus labor charges. From the available data, annual capital costs of initial installation were calculated at a base discount rate of 3.5% and a base lifespan for capital equipment of 20 years (FRIAS et al., 2006; MOORE et al., 2017).

Caries averted

The annual estimates of caries averted were taken from a systematic review conducted regarding the effect of community water fluoridation (CWF) in the context of the wide use of fluoridated toothpaste, based on studies with Brazilian population groups (Belotti, Frazão, 2022). The evidence was derived from observational studies with concurrent controls and data for one point in time. To control the confounding bias owning to the social differences among the areas, sociodemographic and socioeconomic data from the areas investigated were accessed and the papers were classified according to their comparability. The meta-analysis included ten comparable studies published between 1998 and 2018. The difference in mean dmft between fluoridated and non-fluoridated areas was obtained from children with 5-8 and with 3-12 years-old and the difference in mean DMFT was taken from children with 7-12 years-old. More details can be obtained elsewhere (BELOTTI; FRAZÃO, 2022).

Costs of treatment for dental caries

The total cost of dental treatment was estimated including direct and indirect costs. Direct costs referred to a complete examination and filling of two dental surfaces, with amalgam, according to the Brazilian Classification of Dental Procedures in 2019 (CBHPO). Indirect costs included transportation expenses and estimated productivity loss of three hours spent with the commute and the dental appointment (CAMPAIN et al., 2010; FYFE et al., 2015), both based on the average hourly wage rate in 2019. These costs were regarding one visit and four public transportation tickets since in all scenarios the patient needed to be accompanied by an adult. The average public transportation fare was US$1.01 in 2019, according to the National Urban Mobility Survey (BRASIL, 2019) (Table 1).

Table 1. Description of fees for treatment in societal perspective.

Description	Quantification	Value	Source
Societal perspective			
1. Direct Costs			
a- Complete examination	1	US$ 27.10	CBHPO[1]
b- Filling on 2 surfaces, amalgam	1	US$ 41.89	CBHPO[1]
2. Indirect Costs			
a- Loss of productivity	180 min	US$ 3.45	Decree nº 9661[2]
b- Transportation	4	US$ 4.06	BRASIL, 2019[3]

In 2019, US$1 = R$3.95
1.Brazilian Classification of Dental Procedures in 2019 (CBHPO), available in <https://cbhpo.com.br/>
2.Decree nº 9661 - Regulates Law No. 13,152, of July 29, 2015, which provides for the value of the minimum wage and its long-term valuation policy. Avaiable in: <http://www.planalto.gov.br/ccivil_03/_ato2019-2022/2019/decreto/D9661.htm>
3.BRASIL. National Urban Mobility Survey, 2019. Avaiable in: <https://www.gov.br/mdr/pt-br/assuntos/mobilidade-e-servicos-urbanos/pesquisa-nacional-de-mobilidade-urbana-2019>

In line with previous studies, the following assumptions were made: (a) cost of adverse side effects (dental fluorosis) were assumed to be negligible and not attributed a value (CAMPAIN et al., 2010; COBIAC; VOS, 2012; WRIGHT et al., 2001); (b) all carious surfaces would be treated and treatment would comprise of a two-surface dental amalgam restoration per dmft/DMFT (FYFE et al. 2015). The cost of dental treatment was divided by the lifespan of the amalgam restorations equal to 12.8 years (VAN NIEUWENHUYSEN et al., 2003). To determine annual cost averted was applied to a discount rate of 3.5%.

The results are presented in United States Dollars (USD) based on the average exchange rate between the Brazilian Real (BRA) and USD between January 1, 2019 and December 31, 2019 (BRA 1 = USD 0.2535) (INSTITUTE FOR APPLIED ECONOMIC RESEARCH, 2019).

Costs-Effectiveness and cost-benefit of CWF

The cost-effectiveness was estimated by dividing the annually *per capita* net cost of the CWF with the difference in mean dmft/DMFT resulting from CWF (FYFE et al., 2015). The net cost was calculated by subtracting costs associated with CWF from annual costs averted (GRIFFIN; JONES; TOMAR, 2001). The cost-benefit was estimated according to Kroon and Van Wyk (2012), in which the cost of the implementation of water fluoridation was divided by the annual costs averted. A program should be considered for implementation and maintenance if cost-benefit is <1 (KROON; VAN WYK, 2012a, 2012b).

Sensitivity Analysis

One-way sensitivity analysis was conducted to test the robustness of the results according to measured parameter values (DRUMMOND et al., 2015). It provided one plausible variety of savings that could be obtained from CWF. Therefore, sensitivity analysis for the societal perspective was conducted on: (1) filling on one amalgam-based surface; (2) filling on two resin-based surfaces considering the lifespan of 7.8 years (VAN NIEUWENHUYSEN et al., 2003); (3) upper and lower levels of estimated effectiveness of CWF; (4) discount rates at 0% and 7%.

RESULTS

The mean annual *per capita* cost of CWF varied according to the population size; therefore, the cost was: US$ 7.35 for the size with less than 2 thousand inhabitants, US$ 2.05 for 6 thousand, US$ 1.45 for 9 thousand, US$ 0.44 for 30 thou inhabitants, US$ 0.42 for the population size of 70 thousand, and US$ 0.26 and US$ 0.14 for 160 and 520 thousand inhabitants, respectively (Table 2).

Table 2. Annual CWF costs *per capita*, from 2012 to 2017 (base discount rate of 3.5% and a base lifespan for capital equipment of 20 years).

Size of population served	Mean Annual *per capita* of CWF with 95% CI
Small 1 (< 2000)	US$ 7.35 (6.62, 8.08)
Small 2 (6000)	US$ 2.05 (1.82, 2.28)
Small 3 (9000)	US$ 1.45 (1.29, 1.61)
Medium 1 (30000)	US$ 0.44 (0.38, 0.49)
Medium 2 (70000)	US$ 0.42 (0.37, 0.48)
Large 1 (160000)	US$ 0.26 (0.19, 0.33)
Large 2 (520000)	US$ 0.14 (0.12, 0.17)

The mean difference between non-fluoridated and fluoridated areas in the dmft was -2.28 (95%CI -3.26; -1.30) for children aged 5-8 years and -1.12 (95% CI -1.93; -0.32) for children aged 3-12 years. Whereas the difference in the DMFT was -0.61

(95%IC -0.80; -0.42) for children aged 7-12 years (Table 3).

Table 3. Difference in mean dmft/DMFT between fluoridated and non-fluoridated areas

Age	Outcomes	Mean difference with 95% CI
5 to 8	dmft	-2.28 (-3.26, -1.30)
3 to 12	dmft	-1.12 (-1.93, -0.32)
7 to 12	DMFT	-0.61 (-0.80, -0.42)

From the societal perspective, the total cost of a two-surface dental amalgam restoration, including direct and indirect costs, was US$76.50. The costs averted resulting from CWF were US$174.40 and US$85.67 for children aged 5-8 and 3-12 years, respectively, and US$46.66 for those aged of 7-12 years, according to the average effectiveness of the CWF for each group age.

The cost-effectiveness ratio in sizes with 6 thousand inhabitants or more, varied from -7.46 to -4.16 for all aged groups. CWF represented a negative net cost (cost saving) in almost all scenarios, except in the population size up to 2,000 inhabitants for the age from 7 to 12 years old. Similar to cost-effectiveness, cost-benefit ratio results were favorable in all scenarios where size of population served was 6,000 or more inhabitants. For every dollar spent with CWF provision the *per capita* saved amount varied at deciduous dentition from US$ 8,3 to 100 in 5-8 years-old schoolchildren and from US$ 4,1 to 50 in 3-12 y.o. schoolchildren and at permanent dentition from US$ 2,2 to 33,3 in 7-12 y.o. schoolchildren (Table 4). The result was unfavorable for the CWF in only a scenario: size small 1 for the age from 7 to 12 years old.

When the variables were adjusted for sensitivity analysis, cost-effectiveness and cost-benefit remained favorable to CWF for all ages in areas with 6,000 inhabitants or more. The negative variation of cost-effectiveness increased from 3.3 points (-4.2 to -7.5) to 12.0 points (-1.1 to -13.1) according to parameters applied. The main factors were the effectiveness of CWF and the kind of treatment offered. While decreased effectiveness compromised the cost-effectiveness, treatment based on two-surface resin filling became CWF even more cost-effective. The results were similar to cost-benefit. Scenarios unfavorable to CWF were observed only in size up to 2,000 inhabitants.

Table 4. Cost Effectiveness and Cost Benefit by population size (societal perspective).

Size of population served	Cost-Effectiveness			Cost-Benefit		
	dmft		DMFT	dmft		DMFT
	5 to 8	3 to 12	7 to 12	5 to 8	3 to 12	7 to 12
Small 1 (< 2000)	-4.29	-0.95	4.53	0.43	0.87	1.60
Small 2 (6000)	-6.62	-5.69	-4.16	0.12	0.24	0.45
Small 3 (9000)	-6.88	-6.22	-5.14	0.08	0.17	0.32
Medium 1 (30000)	-7.32	-7.12	-6.80	0.03	0.05	0.10
Medium 2 (70000)	-7.33	-7.14	-6.83	0.02	0.05	0.09
Large 1 (160000)	-7.40	-7.28	-7.09	0.02	0.03	0.06
Large 2 (520000)	-7.46	-7.39	-7.29	0.01	0.02	0.03

DISCUSSION

The economic evaluation of CWF in an upper-middle income country showed to be a cost-effective oral health intervention and more economically advantageous mainly in larger areas at both deciduous and permanent dentition. The findings are extremely important seeing that the use of fluoridated dentifrice is wide in the study area (CURY et al., 2004). According to the sensitivity analysis, the most important factors for both cost-effectiveness and cost-benefit were the effectiveness of CWF and the type of restorative dental treatment.

The annual *per capita* cost of community water fluoridation ranged from US$ 0.14 to US$ 7.35, also showing a strong relationship between community size and cost-effectiveness/benefit. In the state of Florida, United States of America, a study carried out on 44 communities with different population sizes, between 1981 and 1989, showed that the cost of fluoridated public water supply is highly dependent on the organizational structure of the supply system and population size (RINGELBERG; ALLEN; BROWN, 1992).

Because annual program costs varied by population size, net savings did as well. Differences in cost effectiveness according to population size have also been observed in Australia. In communities with less than five thousand inhabitants, the cost effectiveness in a children population was -2.23, whereas in those with more than 50 thousand inhabitants, it was – 6.09 (FYFE et al., 2015). In the United States, net savings for communities with 20,000 or more people represented a greater percentage of total net savings than those for communities with smaller populations, due to lower *per capita* fluoridation costs and greater numbers of people served (O'CONNEL et al., 2016).

The systematic review conduced in 2014 that included studies from the U.S, Australia, Canada, and New Zealand reported that the benefit of CWF exceeding cost proposes a positive rate of return for investment in CWF interventions, which indicated that CWF saved money from a societal perspective and also reduced caries. However, for small communities with less than 1,000 inhabitants indicated that *per capita* annual cost exceeded *per capita* annual benefit (RAN; CHATTOPADHYAY, 2016).

Tchouaket et al. (2013) analyzed the cost-effectiveness of CWF by simulating several scenarios of reductions in dental caries attribute to the intervention, ranging from 1% to 50%. Even though the different methodological approach, results go in the same direction of this study and sensitivity analyzes showed that if the CWF reduced tooth decay by 1%, one dollar invested in the fluoridation program would save $7.32 to $8.53 in dental care costs per inhabitant in 2010 in Quebec.

The levels of effectiveness used in this study were based on adjusted mean differences in dmft/DMFT between fluoridated and non-fluoridated communities. As the CWF effect was greater at the deciduous dentition than at the permanent dentition the values of both cost-effectiveness ratio and cost-benefit ratio were more favorable at the deciduous dentition. Meanwhile the observed results showed advantageous savings provided by CWF at permanent dentition. It is worth noting that this difference in favor of public health intervention could be lower if the dental treatment was simpler and based on new approaches as minimally invasive dentistry. However, even so CWF would be cost-effective because the cost related to dental team accounts for most of the dental treatment expenses (MACEDO et al., 2016).

The effectiveness and the type of restorative dental treatment were the factors with more influence in the sensitivity analyses, mainly in small scenarios. In larger sizes of population served, even when the worst-case analysis was conducted the CWF remained cost-effective. In analyses reported by other studies the cost-effectiveness/benefit of CWF were also sensitive to the following factors: discount rate, effectiveness of CWF, caries increment, the type and lifespan of the restoration

(CAMPAIN et al., 2010; FYFE et al., 2015).

The model presented in this article allowed to estimate the cost and confirmed the advantages of CWF even in a context of wide use of fluoridated dentifrice. However, the cost of public health intervention can vary among countries according diverse factors such as system design, the availability of and the type of chemical used, equipment, adjustment of natural fluoride levels, the number of fluoride injection points, access to health care, age distribution and population size.

It is important to underline that some benefits of CWF could not to be included in the adopted model, such as social acceptability due to retention of teeth, avoidance of extractions and dental implants and less pain and discomfort with a resulting reduction in loss of time from school or work. Moreover, the savings would be higher in Midwest, Northeast and North macro-regions of the country where oral health data from 2003 and 2010, the two largest and earliest national surveys, showed higher values of dental caries for 12-year-old children (FREIRE et al., 2013) and adults (FRAZÃO, BOUSQUAT, ANTUNES, 2013). One could argue that the costs of treatment for fluorosis were also not considered. However fluorosis prevalence data have showed low values in South and Southeast macro-regions in which more municipalities have CWF provision and better socioeconomic conditions (SILVA, ANTUNES, FRAZÃO, 2021) and a significant proportion of cases of fluorosis that require treatment have been observed only in naturally occurring areas with values above those recommended for caries prevention (BARROS, TOMITA, 2010). In addition, confounding factors, such as oral hygiene habits, exposure to other fluoride sources and diet, were not controlled for.

In conclusion, CWF represented a negative net cost (cost saving) in all scenarios, excepting in the population size up to 2,000 inhabitants for the age from 7 to 12 years old. For every dollar spent with CWF provision the *per capita* saved amount varied according to type of dentition; age group and population size. At permanent dentition, the cost savings reached up to US$ 33,3 per each schoolchild.

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Supplementary Table 1. Sensitivity Analysis Range for CWF (societal perspective) by population size.

	Cost-Effectiveness			Cost-Benefit		
	dmft		DMFT	dmft		DMFT
	5 to 8	3 to 12	7 to 12	5 to 8	3 to 12	7 to 12
Small 1 (< 2000)						
1- Resin (two faces)	-9.98	-6.64	-1.16	0.24	0.50	0.91
2- Amalgam (one face)	-3.72	-0.38	5.10	0.46	0.94	1.73
3- Lower effectiveness	-1.86	15.45	9.98	0.75	3.06	2.33
4- Higher effectiveness	-5.26	-3.71	1.67	0.30	0.51	1.22
5- Lower discount rate	-2.75	0.59	6.07	0.54	1.10	2.02
6- Higher discount rate	-6.02	-2.68	2.81	0.35	0.71	1.30
Small 2 (6000)						
1- Resin (two faces)	-12.31	-11.38	-9.85	0.07	0.14	0.25
2- Amalgam (one face)	-6.05	-5.12	-3.59	0.13	0.26	0.48
3- Lower effectiveness	-5.94	-1.11	-2.64	0.21	0.85	0.65
4- Higher effectiveness	-6.89	-6.45	-4.95	0.08	0.14	0.34
5- Lower discount rate	-5.08	-4.15	-2.62	0.15	0.31	0.56
6- Higher discount rate	-8.34	-7.41	-5.88	0.10	0.20	0.36
Small 3 (9000)						
1- Resin (two faces)	-12.57	-11.91	-10.83	0.05	0.10	0.18
2- Amalgam (one face)	-6.31	-5.65	-4.57	0.13	0.26	0.48
3- Lower effectiveness	-6.40	-2.99	-4.06	0.15	0.60	0.46
4- Higher effectiveness	-7.07	-6.77	-5.70	0.06	0.10	0.24
5- Lower discount rate	-5.34	-4.68	-3.60	0.11	0.22	0.40
6- Higher discount rate	-8.61	-7.95	-6.86	0.07	0.14	0.26
Medium 1 (30000)						
1- Resin (two faces)	-13.01	-12.81	-12.48	0.01	0.03	0.05
2- Amalgam (one face)	-6.75	-6.55	-6.23	0.03	0.06	0.10
3- Lower effectiveness	-7.18	-6.14	-6.47	0.05	0.18	0.14
4- Higher effectiveness	-7.38	-7.29	-6.97	0.02	0.03	0.07
5- Lower discount rate	-5.78	-5.58	-5.25	0.03	0.07	0.12
6- Higher discount rate	-9.05	-8.85	-8.52	0.02	0.04	0.08
Medium 2 (70000)						
1- Resin (two faces)	-13.02	-12.83	-12.52	0.01	0.03	0.05
2- Amalgam (one face)	-6.76	-6.57	-6.26	0.03	0.05	0.10
3- Lower effectiveness	-7.19	-6.20	-6.52	0.04	0.17	0.13
4- Higher effectiveness	-7.39	-7.30	-6.99	0.02	0.03	0.07
5- Lower discount rate	-5.79	-5.60	-5.29	0.03	0.06	0.12
6- Higher discount rate	-9.06	-8.87	-8.55	0.02	0.04	0.07
Large 1(160000)						
1- Resin (two faces)	-13.09	-12.97	-12.78	0.01	0.02	0.03
2- Amalgam (one face)	-6.83	-6.72	-6.52	0.02	0.03	0.06
3- Lower effectiveness	-7.32	-6.70	-6.90	0.03	0.11	0.08
4- Higher effectiveness	-7.44	-7.38	-7.19	0.01	0.02	0.04
5- Lower discount rate	-5.86	-5.74	-5.55	0.02	0.04	0.07
6- Higher discount rate	-9.13	-9.01	-8.82	0.01	0.03	0.05
Large 2 (520000)						
1- Resin (two faces)	-13.14	-13.08	-12.98	0.00	0.01	0.02
2- Amalgam (one face)	-6.89	-6.82	-6.72	0.01	0.02	0.03
3- Lower effectiveness	-7.41	-7.08	-7.18	0.01	0.06	0.04
4- Higher effectiveness	-7.47	-7.44	-7.34	0.01	0.01	0.02
5- Lower discount rate	-5.91	-5.85	-5.75	0.01	0.02	0.04
6- Higher discount rate	-9.18	-9.12	-9.01	0.01	0.01	0.02

6 LIMITAÇÕES

É importante ressaltar que alguns benefícios da fluoretação da água de abastecimento público não foram incluídos no modelo adotado, como a aceitação social pela manutenção dos dentes, melhora da autoestima, extrações e implantes dentários evitados, e menos dor e desconforto com consequente redução da perda de tempo de escola ou trabalho. Além disso, fatores de confusão, como hábitos de higiene bucal, exposição a outras fontes de flúor e dieta, não foram controlados.

Outra limitação é decorrente da utilização de dados secundários para as informações de efetividade da fluoretação, uma vez que, foram utilizados estudos já publicados sobre a condição de saúde bucal da população que recebe a intervenção. Não foi possível avaliar o efeito da fluoretação na prevenção da cárie dentária na população adulta devido aos dados limitados. Além disso, cabe ressaltar a importância que os fatores de confusão sejam considerados em estudos que avaliem a efetividade de fluoretação, usando modelos conceituais de determinantes de cárie para ajustar as estimativas do efeito da fluoretação. Apesar disso, os estudos incluídos apresentaram boa qualidade metodológica, e os resultados devem ser interpretados como a melhor evidência disponível resultante de estudos contemporâneos e de base populacional no país.

7 CONSIDERAÇÕES FINAIS

Como o processo de tomada de decisão no campo das políticas públicas é complexo e os tomadores de decisão sofrem múltiplas influências em torno de diferentes alternativas de políticas, conhecer os fatores relacionados a qualidade da fluoretação, seus custos e sua efetividade é essencial para uma tomada de decisão informada.

O estudo demonstrou que para garantir a alta qualidade da fluoretação, medidas adicionais de gestão devem ser implementadas em municípios com menos de 100.000 habitantes, que apresentam maior índice de não conformidade de concentração de cloro, com menor renda *per capita* e onde o tipo de serviço de saneamento seja municipal ou privado.

A fluoretação mantem-se como uma medida de baixo custo per capita, variando de acordo com o porte populacional das estações de tratamento; quanto menor o porte, maior o custo per capita da medida. Os custos de operacionalização e do produto químico foram os maiores responsáveis na composição total dos custos, em portes menores e maiores, respectivamente. Por esse motivo, caberá aos responsáveis pela gestão e regulação do setor e aos operadores dos serviços, a criação de alternativas de políticas públicas que assegurem as ETA de pequeno porte condições adequadas para o uso racional de recursos naturais em busca do equilíbrio econômico-financeiro e a universalização do acesso à água tratada e fluoretada..

Reafirma-se que a fluoretação é uma das variáveis importantes para mudança do perfil epidemiológico da cárie, uma vez que beneficia todos os estratos da população que tem acesso a água tratada e fluoretada. Em locais em que esse acesso ainda é limitado, é necessário que os tomadores de decisão lancem mão de outras medidas para que a população tenha acesso ao benefício preventivo do fluoreto.

Ademais, apesar das diferenças de custos entre os portes populacionais, no que se refere a efetividade da medida, as evidências disponíveis de estudos populacionais com controles simultâneos e dados para um ponto no tempo mostraram que a fluoretação continua eficaz na prevenção da cárie dentária no Brasil, mesmo no contexto do uso generalizado de dentifrício fluoretado. Portanto, a fluoretação da água de abastecimento público mostrou ser uma intervenção de saúde bucal custo-efetiva e economicamente mais vantajosa principalmente, principalmente em áreas com maior porte populacional, tanto na dentição decídua quanto na permanente.

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9. APÊNDICES

Artigo: Effectiveness of water fluoridation in Brazil: systematic review and meta-analysis

Appendix 1: Classification according to the comparability of the areas investigated.

Estudos	**(i)**	**(ii)**	**(iii)**	**(iv)**	**Sum**
Cardoso et al. (2003)					2
Cruz et al. (2018)					4
Cypriano et al. (2003)					1
Dini et al. (1998) [a]*					4
Dini et al. (1998) [b]*					4
Dini et al. (2000)					2
Franzolin el al. (2010)*					4
Guerra et al. (2010)					2
Gushi et al. (2005)					1
Parisoto et al. (2010)*					4
Rando-Meirelles (2016)					1
Rihs et al. (2009)					1
Sales-Peres et al. (2002)					3
Sampaio et al. (2000)**					3
Tiano et al. (2009)					4
Tagliaferro et al. 2004					2

(i)- Areas located in the same state of Brazil
(ii)- Areas located in the same mesoregion
(iii)- Areas had similar population size (less than 10,000; 10,000 up to 50,000; more than 50,000);
(iv)- Areas had the same category of the Human Development Index
* Regions (fluoridated and non-fluoridated) from the same city were analyzed
** Different rural villages of Paraíba, Brazil with same presumed human development level

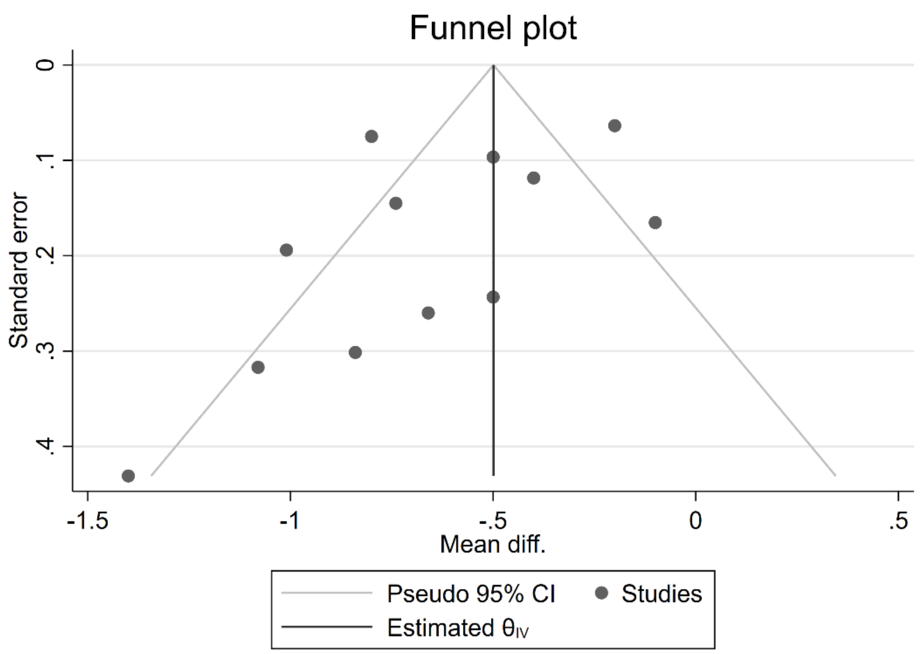
Appendix 2: Quality assessment
JBI Critical Appraisal Checklist for Studies Reporting Dental Caries Prevalence and Severity Data

Study	1	2	3	4	5	6	7	8	9
Cardoso et al. (2003)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Cruz et al. (2018)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Dini et al. (1998) [a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dini et al. (1998) [b]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dini et al. (2000)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Franzolin el al. (2010)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Guerra et al. (2010)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sales-Peres et al. (2002)	Yes	Yes	Unclear	Yes	No	Yes	Unclear	No	Yes
Sampaio et al. (2000)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Tagliaferro et al. (2004)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

1.Was the sample frame appropriate to address the target population?
2. Were study participants sampled in an appropriate way?
3. Was the sample size adequate?
4. Were the study subjects and the setting described in detail?
5.Was the data analysis conducted with sufficient coverage of the identified sample?
6. Were valid methods used for the identification of the condition?
7. Was the condition measured in a standard, reliable way for all participants?
8. Was there appropriate statistical analysis?
9. Was the response rate adequate?

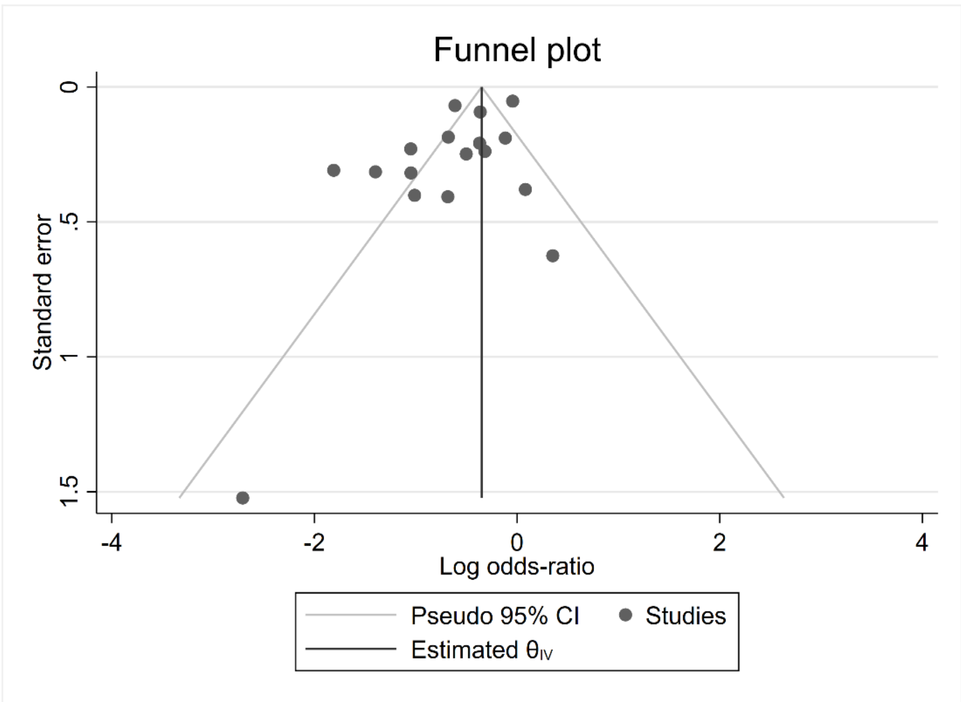
Appendix 3: Funnel plots for studies on the effect of water fluoridation

(A) DMFT studies (7 to 12 years old)



*Egger's regression intercept: -2.04; SE: 0.964; p: 0.0344

(B) caries prevalence (caries vs caries-free) studies



*Egger's regression intercept: -1.12; SE: 0.748; p:0.1334

Appendix 4: Excluded articles

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year-old children in Brazil, 1980-2005. Int Dent J. 2012;62(6):308-314. 18. Lucas SD, Portela MC, Mendonça LL. Variations in tooth decay rates among children 5 and 12 years old in Minas Gerais, Brazil. Cad Saude Publica. 2005;21(1):55-63. 19. Mello TRD, Antunes JLF, Waldman EA. Prevalence of untreated caries in deciduous teeth in urban and rural areas in the state of Sao Paulo, Brazil. Rev Panam Salud Publica-Pan Am J Public Heal. 2008;23(2):78-84 20. Moimaz SAS, Costa ACO, Silva LP, Saliba O, Garbin CAS, Araújo KS. A comparative analysis of caries and fluorosis among cities with and without public water supply fluoridation in São Paulo State, Brazil. Rev Odonto Ciência. 2010;25(1):15-19. 21. Peres MA, Antunes JLF, Peres KG. Is water fluoridation effective in reducing inequalities in dental caries distribution in developing countries? Recent findings from Brazil. Soz Praventivmed. 2006;51(5):302-310.	
1. Peres MA, Peres KG, Barbato PR, Höfelmann DA. Access to Fluoridated Water and Adult Dental Caries. J Dent Res. 2016;95(8):868-874.	Study in the same city with different exposure times *(n=1)*
1. Aguiar VR, Pattussi MP, Celeste RK. The role of municipal public policies in oral health socioeconomic inequalities in Brazil: A multilevel study. Community Dent Oral Epidemiol. 2018;46(3):245-250. 2. Barbato PR, Peres MA. Tooth loss and associated factors in adolescents: a Brazilian population-based oral health survey. Rev Saude Publica. 2009;43(1):13-25. 3. Barbato PR, Peres MA, Hofelmann DA, Peres KG. Contextual and individual indicators associated with the presence of teeth in adults. Rev Saude Publica. 2015;49:27.	Studies that did not presented the outcomes analyzed *(n=3)*
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1. Rigo L, Abegg C, Bassani DG. Dental caries in schoolchildren living in cities of Rio Grande do Sul, Brazil, with and without water fluoridation. RSBO. 2010;7(1):57-65.	The study grouped locals from 0 to 5 years of fluoridation *(n=1)*

Artigo: Economic evaluation of community water fluoridation in an upper-middle income country

1- **Cost *per capita* of CWF (CCWF):**

$$CCWF = \frac{cci + ccp + cso + cm}{n}$$

Where:
cii= capital cost of initial installation
ccp=costs of chemical product
cso= system's operational cost
cm= costs of monitoring fluoride levels
n= supplied population

2- **Costs averted resulting from CWF (CA):**

$$CA = (dc + ic) \times dif(\mu dmft/DMFT)$$

Where:
dc = direct cost (of a two-surface filling)
ic = indirect cost (productivity loss)
dif(µdmft/DMFT) = the difference in mean dmft/DMFT resulting from CWF

3- **Annual costs per dmft/DMFT averted resulting from CWF (ACA):**

$$ACA = \frac{CA \times dr}{1 - (1 + dr)^{-t}}$$

Where:
CA = costs averted resulting from CWF
dr = Discount rate (3.5%)
t = lifespan of the treatment (12.8 years for amalgam restorations and 7.8 years for resin restorations)

4- **Cost-effectiveness**

$$CE = \frac{(CCWF - ACA)}{(dif(dmft/DMFT)}$$

Where:
CCWF–ACA = net cost of CWF
dif(µDMFT) = difference in mean dmft and DMFT resulting from CWF

5- **Cost-Benefit**

$$CB = \frac{CCWF}{ACA}$$

Where:
CCWF=Cost *per capita* of CWF
ACA = Annual costs per dmft/DMFT averted resulting from CWF

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Título: A Utilização de Diaminofluoreto de Prata na Clinica de Odontopediatria da Universidade Federal do Espirito Santo.
Orientador: Ana Maria Martins Gomes.

Endereço para acessar este CV: http://lattes.cnpq.br/0336022787699316

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

Currículo Lattes

Dados gerais | Formação | Atuação | Projetos | Produções | Inovação | Educação e Popularização de C & T | Eventos | Orientações | Bancas | Citações | +

Paulo Frazão

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Última atualização do currículo em 15/07/2022

Paulo Frazão é Professor Titular do Departamento de Política, Gestão e Saúde da Faculdade de Saúde Pública da USP. Concluiu o doutorado em Saúde Pública pela Universidade de São Paulo em 1999. Obteve título de Livre Docente pela USP em 2009. Foi consultor do Ministério da Saúde. Foi Vice-Coordenador do Programa de Pós-Graduação em Saúde Coletiva da Universidade Católica de Santos entre 2006 e 2008, Vice-Chefe do Departamento de Política, Gestão e Saúde da FSP-USP entre 2016 e 2017, e Chefe do Departamento de Política, Gestão e Saúde da FSP-USP entre 2018 e 2021. Atualmente é Coordenador do DINTER em Saúde Pública entre a USP e Universidade Estadual de Ciências da Saúde de Alagoas. Publicou 129 artigos em periódicos especializados e apresentou 159 trabalhos em eventos técnico-científicos. Possui 38 capítulos de livros e 4 livros publicados e 2 organizados e dois pre/posfácio. Participou de 6 eventos no exterior e 152 no Brasil. Orientou 22 dissertações de mestrado e 10 teses de doutorado, e supervisionou 8 monografias de especialização e 8 trabalhos de iniciação científica nas áreas de Saúde Coletiva e Odontologia. Recebeu 18 prêmios e/ou homenagens. Atua na área de Saúde Coletiva, com ênfase na Vigilância da Saúde Bucal, linha de pesquisa na qual coordena projetos de interesse da Saúde Bucal Coletiva. É coordenador de projetos do Centro Colaborador do Ministério da Saúde em Vigilância em Saúde Bucal da FSP-USP e participa da Rede Brasileira de Vigilância da Fluoretação da Água de Abastecimento Público. É membro da Comissão de Políticas Públicas do Conselho Regional de Odontologia de São Paulo. Em suas atividades profissionais interagiu com 71 colaboradores em coautorias de trabalhos científicos. Em seu currículo Lattes os termos mais frequentes na contextualização da produção científica e tecnológica são: Políticas de Saúde Bucal, Fluoretação da Água, Epidemiologia, Saúde Bucal, Cárie Dentária, escolares, Saúde Pública, Políticas Planejamento e Adm Sistemas e Serviços de Saúde, Medicalização, Má oclusão, Pessoal Auxiliar Odontológico, Cooperação Interprofissional, Sistemas locais de saúde. **(Texto informado pelo autor)**

Identificação

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Endereço

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Formação acadêmica/titulação

1996 - 1999 Doutorado em Saúde Pública (Conceito CAPES 6).
Universidade de São Paulo, USP, Brasil.
Título: Epidemiologia da oclusão dentária na infância e os sistemas de saúde, Ano de obtenção: 1999.
Orientador: Professor Doutor Roberto Augusto Castellanos Fernandez.
Palavras-chave: Epidemiologia; Má oclusão; crescimento e desenvolvimento infantil; sistemas de saúde; dentição decídua; Dentição permanente.
Grande área: Ciências da Saúde
Setores de atividade: Saúde Humana.

1991 - 1995 Mestrado em Saúde Pública (Conceito CAPES 6).
Universidade de São Paulo, USP, Brasil.
Título: A participação do pessoal auxiliar odontológico em dez sistemas locais de saúde de cinco municípios no estado de São Paulo, 1994,Ano de Obtenção: 1995.
Orientador: Professor Doutpr Antonio Galvão Fortuna Rosa.
Palavras-chave: Saúde Pública; Sistemas locais de saúde; Programas odontológicos; Pessoal Auxiliar Odontológico.
Grande área: Ciências da Saúde
Grande Área: Ciências da Saúde / Área: Saúde Coletiva / Subárea: Saúde Pública / Especialidade: Recursos Humanos Em Saúde.
Setores de atividade: Saúde Humana.

1991 - 1991 Especialização em Saude Pública. (Carga Horária: 1115h).
Universidade de São Paulo, USP, Brasil.

1981 - 1985 Graduação em Odontologia (Prótese-Buco-Maxilo Facial).
Universidade de São Paulo, USP, Brasil.

Livre-docência

2009 Livre-docência.
Universidade de São Paulo, USP, Brasil.
Título: Custo-efetividade da escovação dental supervisionada na prevenção da cárie dentária infantil, Ano de obtenção: 2009.
Palavras-chave: Avaliação econômica; Avaliação de Impacto em Saúde; Escovação dental supervisionada; Cárie dentária.