Water Policy 22 (2020) 365–375

Community water fluoridation perceptions and practice in the United States: challenges in governance and implementation

Thomas Walker[a,*], Lori Dickes[b] and Elizabeth Crouch[c]

[a]South Carolina Water Resources Center, Clemson University, #E137, 509 Westinghouse Rd, Pendleton, SC 29670, USA
*Corresponding author. E-mail: tcwalke@clemson.edu

[b]Public Administration Program, Department of Parks, Recreation, and Tourism Management, Clemson University, Barre Hall #221, McGinty Ct, Clemson, SC 29631, USA

[c]South Carolina Rural Health Research Center, Arnold School of Public Health, University of South Carolina, 220 Stoneridge Drive #204, Columbia, SC 29210, USA

Abstract

The primary objective of this research is to reveal potential challenges in achieving the finalized water fluoridation recommendation made by the Federal Water Fluoridation Panel in the United States (U.S.) with data extracted from consumer confidence reports. A secondary objective is to understand community water system manager's perceptions of and ability to meet this new standard using a survey instrument. Mean fluoridation levels are above the recommended level. The confidence interval does not capture the nationally recommended 0.7 mg/L. The *t*-test revealed two statistically significant results: that the sample mean is not equal to 0.7 mg/L and that the sample mean is higher than 0.7 mg/L. Respondents felt engaged in the policy process, but preferred state over federal policymaking. There is evidence that the optimal fluoridation level may not have been reached by water systems and that some water systems are under-fluoridating, while others are over-fluoridating. Several large water systems and pockets across the U.S. are not practicing artificial water fluoridation which reduces the effectiveness of this policy. Regular engagement by states with water system managers and feedback from water management professionals could be encouraged to better understand local constraints in meeting the federal recommendation.

Keywords: Fluoridation; Public health policy; Water supply

Introduction

For the last 60 years, water fluoridation has become deeply rooted in communities and their water systems across the United States (U.S.) (CDC, 2014). In 2014, the Center for Disease Control (CDC) reported that approximately three-fourths of the U.S. population are served by Community Water Systems

doi: 10.2166/wp.2020.044

(CWS) that artificially fluoridate their water or are one of over 6000 consecutive water systems that receive artificially fluoridated water from another system (wholesale buyer) (CDC, 2014). Water fluoridation policy exemplifies an epidemiologic structured intervention to prevent a serious infectious disease in the community (CDC, 1999). Public health interventions of this type are used to improve health through community-based prevention efforts (Blankenship *et al.*, 2006). This public health achievement has accounted for significant declines in dental caries (Ripa, 1993; Horowitz, 1996; CDC, 1999).

Yet, the development and enforcement of water fluoridation policy are sometimes hard to achieve; it is a federal public health policy recommendation implemented at the local level without federal enforceability (DHHS, 2015). Throughout the history of artificial water fluoridation in the U.S., state and local decision-making has taken priority for determining water system fluoridation levels. These determinations are based on the state code or local ordinance using a federally recommended fluoridation range. The Federal Panel contends that a single optimal level for the U.S. is much easier to implement than a range based on temperature (DHHS, 2015). After years of review and public debate, the Federal Panel on Community Water Fluoridation finalized a policy recommendation in 2015 to reduce the fluoride level in artificially fluoridated water systems from the previous range of 0.7–1.2 mg/L to a fixed 0.7 mg/L across the U.S. (DHHS, 2015). This recommendation was in response to scientific consensus on total fluoride exposure, water consumption rates, and dental fluorosis concerns (Heller *et al.*, 1999; DHHS, 2015). There remains some uncertainty about the efficacy of lowering water fluoride levels on caries prevalence or fluorosis levels (Newbrun, 2010). As well, challenges to policy implementation exist as this is a centralized recommendation in an inherently decentralized policy environment and one that is not enforceable at the federal level (DHHS, 2015).

The departure from a range of 0.7–1.2 mg/L to a universal, flat 0.7 mg/L is considered by many to be an important step towards ensuring effective health policy. However, it has been argued in the public comment period, that the recommendation, even lowered to 0.7 mg/L, is both too high and too low (DHHS, 2015). The minimum level of 0.5 mg/L, which the World Health Organization (WHO) recognized as the lowest threshold to derive systemic dental benefit from fluoridated water (WHO, 2004), could have been an appropriate policy recommendation as well. Other scholarship has put into question the decision as to whether further research to better weigh the balance between dental caries and dental fluorosis outcomes could have been useful (Spencer & Do, 2016). Given the 2015 policy change, additional research is needed to examine the complex nature of achieving this policy recommendation at the local level.

This background on the shifting federal policy recommendation from a range of 0.7–1.2 mg/L to a flat 0.7 mg/L leads to the primary research question; what are the potential challenges post-policy recommendation for achieving national compliance? Using quantitative and qualitative approaches, this study will shed light on the current landscape of fluoridation practice and potential challenges in meeting the new recommendation. The objectives of this paper are to understand the current practice of water fluoridation and to understand CWS manager's perceptions of this new industry standard. The approach to quantify these objectives was completed in the following ways: analysis of local water fluoridation levels collected from consumer confidence reports (CCRs) and a survey distributed to U.S. water system managers.

Methods

A quantitative and qualitative approach was chosen to understand potential gaps in fluoridation policy research with the goal of elucidating how this federal policy change will impact levels of fluoridation at

the local level. Analysis of water reporting data and perceptions regarding the policy are two different quantitative approaches. The data generated from each approach provides complementary information to provide a complete understanding of the underlying research question.

The quantitative approach collects and analyzes water fluoride data similar to the 2005 U.S. Department of Agriculture (USDA) National Fluoride Database study: specifically, the fluoride data on U.S. municipal drinking water systems from across the country and analyzed by the region (USDA, 2005). The regions are identified as All Regions, mid-West, Northeast, South, and West (USDA, 2005). As the policy is now a recommendation for all of the U.S. uniformly, data were aggregated by regions which would be similar to All Regions in the 2005 report. These two reports utilize different data collection methodologies; the data collected for this analysis use CCR reporting, while the USDA report used an in-home collection technique. CCR reporting uses testing samples at the point of water treatment, which is a difference between the two datasets. The CCR data for this research were analyzed and presented in an identical fashion, allowing for comparative data analysis of over a decade.

Data were collected using 2016 CCRs. The 2016 data were collected from the three most populous municipalities served in each state. Larger water systems generally have the ability and resources available to comply with these recommendations and represent best case scenarios to implement federal guidelines. Consecutive water systems also buy finished water wholesale from larger water systems that include fluoride treatment. Characterizing the total population served is within the scope of this research but is a limitation as wholesale water sales to connected water systems are not uniformly available publicly. CCRs identify the amount of fluoride in the water to aid in dental caries prevention. The data collected from 2016 represent water system data reporting after the final policy recommendation was released in 2015. This provides an opportunity to analyze national fluoride levels after the finalized policy announcement. Analyzing only 1 year of data after the federal announcement may be too early to see a change or even a trend. This was a data limitation and is, therefore, a limitation of our study.

Inferential statistics and means testing were used to analyze water fluoridation implementation in the two data sets. A one-sample mean *t*-test was performed using the primary data collected in 2016 and compared against the 2005 study results. The hypothesized mean is 0.7 mg/L, as recommended by the Federal Panel on Community Water Fluoridation. Utilizing this test allows for the detection of a statistical difference between the sample mean and the hypothesized population mean, which provides insights into potential policy compliance issues moving forward. Statistical analyses of water system reporting across the U.S. were performed using the statistical software JMP (SAS Institute, Cary, NC).

The second method of analysis is a survey instrument directed at those who are directly affected by the policy decision and must implement the recommendation. A qualitative, consumer survey has been used in the literature which focused on water consumers and their perceptions of water fluoridation (Griffin *et al.*, 2008). This research adds to the literature by surveying water managers to better understand the supply side of this policy relationship, perceptions of water fluoridation practices in the U.S., and recent changes in regulatory oversight (Table 3). Eliciting feedback from water managers and professionals in the water supply industry is an important consideration as it appears that many of these professionals were left out of the fluoride policy decision-making process until the Federal Register response period opened (DHHS, 2015). Public comment periods are standard for many regulations and policies in the U.S. There was ample time for comments, and the Federal Panel did receive comments from organizations representing water supply professionals such as the American Water Works Association (AWWA) (DHHS, 2015).

The AWWA is arguably the largest professional organization for those who treat and manage water. While the AWWA does engage with its members at conferences regarding the handling of fluoridation and related community perceptions, there was no evidence in this process that the AWWA, any of its state-affiliated chapters, or members had been consulted on the potential challenges facing local water districts in meeting the new policy recommendation prior to the public comment period (DHHS, 2015). It was reported that the Federal panel was collaborating with water supply organizations, such as the AWWA, the National Association of Water Companies and possibly others, to update operational guidance for implementation (DHHS, 2015). As such, this research includes broad stakeholder perceptions of the policy recommendation.

The survey instrument was developed in collaboration with water resource professionals at the South Carolina Department of Health and Environmental Control (SCDHEC). In addition, the survey was initially vetted by several local South Carolina CWS managers. Known respondents came from several water professional distribution lists: the national Water Resource Center's directors list which was forwarded to water professionals, Rural Water Association professionals in South Carolina and West Virginia, and water system contacts through SCDHEC. The sampling technique performed for this data collection and analysis used a convenience sampling approach (Etikan *et al.*, 2016). The survey was distributed over the late spring and summer of 2016 with an approximate distribution to 425 individuals who self-selected whether or not to take the survey and the survey allowed for one submission only so as to prevent ballot stuffing. Without access to distribution lists, exact numbers of individuals who received the list cannot be provided. To ensure both individual and organizational anonymity, the surveys were distributed through individuals at these different organizations. The survey had national distribution, with two states, South Carolina and West Virginia, heavily represented based on confirmed state listserv distributions. Water works or rural water associations in all 50 states were contacted to offer the distribution of the survey to their listservs with no response from the majority of distribution attempts. The AWWA was contacted for list distribution, but no response was received.

All stakeholders received the same series of questions with a predetermined number of response categories. The questions were standardized, ordered, and phrased the same for all respondents. An exact response rate is not possible to report due to the distribution of the survey through several third parties but using approximate distribution numbers, 16% is a reasonable estimate. The survey targeted water supply professionals to collect feedback regarding the policy recommendation, and their responses should be contextualized as representing one perspective from the policy environment. The survey is intended to provide insights into perceptions of the policy recommendation only. Without knowing how many and what size plants responded, it is hard to draw valid conclusions from the survey results and is a limitation of this research.

Prior to taking the survey, there was an information page describing the research study, which included an overview of the policy recommendation and the purpose of the survey. The Internal Review Board (IRB) compliance ensures the confidentiality of the research collected that respondents could choose not to participate, could stop at any time, and that there was no understood benefit to the respondent. The IRB approval number was IRB2016-119; exempt under category B2 based on federal regulations 45 CFR 46. While respondent bias is always a concern, the nature of this analysis was to hear directly from professionals in the field, so their willingness to complete the survey was important to our understanding of the policy environment.

Results and discussion

CCR results and discussion

The 2016 data reveal water fluoridation levels ranging from 0.0 mg/L (major municipalities that do not fluoridate) to 1.855 mg/L ($n = 150$). The 2016 mean was 0.652115 mg/L ($p < 0.05$) (Table 1). The results of the mean testing resulted in significance at the 5% level of the sample mean and the hypothesized mean (0.7 mg/L) not being equal (Table 1). Additional results revealed that significance at the 5% level of the sample mean is less than the hypothesized mean of 0.7 mg/L (Table 1). This provides some evidence that many Americans are potentially underexposed to fluoride at federally recommended levels, which was a concern made in the public comment period prior to the final recommendation (DHHS, 2015), although these levels are well above the minimum threshold to achieve the benefit of fluoridating CWS according to the WHO (WHO, 2004). However, these results highlight the potential challenges for communities that are not benefitting from CWS fluoridation at the 0.7 mg/L federal recommendation. The argument could be made that including data from communities that are not fluoridating could potentially skew the results downward and are discussed below. These municipalities are the exception and not the rule, along with those that are fluoridating at higher levels. The inclusion of major municipalities that do not fluoridate in this dataset is important, as are those with higher water fluoridation values, as the larger picture of fluoridation practice in the U.S. affects the efficacy of this policy and plays a role in health outcomes. It is important for effective outcomes to understand why some communities choose not to implement this practice or why challenges remain for some water systems to lower the levels to meet the recommendation. While this is beyond the scope of this paper, it is important to include these systems to understand future challenges.

To better understand fluoridation practice, outliers were dropped from the 150 observations, a total of 25, 1 on the higher end and 24 on the lower end. The literature cites most freshwater as naturally

Table 1. 2016 CCR data.

Data results Summary statistics	
Mean (mg/L)	0.652115
Mean (μg/100 g)	65.2115
Standard error mean	0.0239335
Number of data points	150
Minimum value	0
Maximum value	1.855
Lower CI	0.604822
Upper CI	0.699408
1-Alpha	0.95
Test mean *t*-test.	
Test statistic	− 2.0007
Prob > [*t*]	0.0472**
Prob > *t*	0.9764
Prob < *t*	0.0236**

Significance: **5% level.

containing fluoride levels between 0.01 and 0.3 mg/L, and every value from 0 to 0.3 mg/L was dropped (Agalakova & Gusev, 2012). Results of the subset of the 2016 dataset reveal water fluoridation levels ranging from 0.34 to 1.245 mg/L ($n = 125$) (Table 2). The 2016 subset mean was 0.741652 mg/L ($p < 0.05$) (Table 2). The results of the mean testing resulted in significance at the 5% level of the sample mean and the hypothesized mean (0.7 mg/L) not being equal (Table 2). Additional results revealed that significance at the 5% level of the sample mean is higher than the hypothesized mean of 0.7 mg/L (Table 2). This additional refinement of the data provides preliminary evidence that some water systems have not yet responded to the policy recommendation.

Additionally, these results provide some evidence that the policy recommendation is making an impact on national fluoridation levels. The 2016 mean and subset mean (0.652115 and 0.741652 mg/L) (Tables 1 and 2) are lower than 2005 (0.81 mg/L) (USDA, 2005), which is important in preventing dental fluorosis from excess fluoride. Additionally, the confidence intervals narrowed from 0.11 mg/L in the 2005 data (0.75–0.86 mg/L) to 0.095 mg/L in the 2016 full dataset and 0.0612 in the 2016 subset (Tables 1 and 2), which provides the evidence of movement to a more uniform policy outcome at the local level.

Stakeholder engagement survey results and discussion

The survey was completed by 68 water management professionals across the country ($n = 68$) (Table 3). Not all questions had responses from all 68 respondents (Table 3). Hundreds of survey links were distributed, with the highest representation from South Carolina and West Virginia with confirmed distribution to listservs. South Carolina still has an older fluoride recommendation range of 0.8–1.2 mg/L (South Carolina Code of Regulations, 2005), while West Virginia had changed its rule to a range of 0.6–0.8 mg/L with an optimal level of 0.7 mg/L (West Virginia Legislative Rule, 2018/2020) in response to the policy recommendation announcement. Among the stakeholder survey respondents, almost 50% (47.05%) felt as though they were represented in the process for developing

Table 2. 2016 CCR data subset.

Data results Summary statistics	
Mean (mg/L)	0.741652
Mean (μg/100 g)	74.1652
Standard error mean	0.015463203
Number of data points	125
Minimum value	0.34
Maximum value	1.245
Lower CI	0.7110459357
Upper CI	0.7722580643
1-Alpha	0.95
Test mean *t*-test	
Test statistic	2.6936
Prob > [*t*]	0.0080**
Prob > *t*	0.0040**
Prob < *t*	0.9960

Significance: **5% level.

Table 3. Stakeholder engagement survey results.

Question	Strongly agree	Agree	Disagree	Strongly disagree	Do not know
As a stakeholder in community water fluoridation programs, water manager's input was considered in adopting the new fluoridated water recommendation ($n = 68$)	11.76% (8)	35.29% (24)	11.76% (8)	7.35% (5)	33.82% (23)
The American Water Works Association (AWWA) had input into adopting the 0.7 mg/L fluoridated water level ($n = 67$)	8.96% (6)	41.79% (28)	2.99% (2)	1.49% (1)	44.78% (30)
National fluoridation policy experts involved a broad range of stakeholders in the process of adopting the new optimal water fluoridation level for the U.S. ($n = 67$)	19.4% (13)	32.84% (22)	8.96% (6)	2.99% (2)	35.82% (24)
National fluoridation policy experts understand the complexities of delivering the new 0.7 mg/L fluoridation level to local communities ($n = 67$)	20.9% (14)	29.85% (20)	11.94% (8)	7.46% (5)	29.85% (20)
Community water fluoridation programs can consistently deliver the newly recommended fluoridated water level of 0.7 mg/L across the U.S. ($n = 67$)	25.37% (17)	44.78% (30)	10.45% (7)	5.97% (4)	13.43% (9)
Our community fluoridates water at 0.7 mg/L ($n = 67$)	34.33% (23)	32.84% (22)	11.94% (8)	7.46% (5)	13.43% (9)
The federal government should make fluoride policy and decide fluoride limits for local water systems ($n = 67$)	17.91% (12)	22.39% (15)	25.37% (17)	29.85% (20)	4.48% (3)
State governments should make fluoride policy and decide fluoride limits for local water systems ($n = 67$)	20.9% (14)	28.36% (19)	16.42% (11)	28.36% (19)	5.97% (4)
Local water managers should be able to continue to fluoridate water at the level they deem appropriate based on local conditions ($n = 66$)	10.61% (7)	28.79% (19)	28.79% (19)	30.3% (20)	1.52% (1)
Other methods of fluoridation should be explored by the federal government to achieve the same public health outcome (using fluoridated salt, milk, supplements which already exist, etc.) ($n = 67$)	7.46% (5)	41.79% (28)	16.42% (11)	29.85% (20)	4.48% (3)
Community water fluoridation programs, as they are currently implemented in this country, are equitable ($n = 67$)	8.96% (6)	38.81% (26)	20.9% (14)	11.94% (8)	19.4% (13)
Water consumers should be allowed to opt out of community water fluoridation programs ($n = 65$)	20% (13)	27.69% (18)	24.62% (16)	24.62% (16)	3.08% (2)

a new national water fluoridation level (Table 3). More than half of respondents disagreed (11.76%), strongly disagreed (7.35%), or did not know (33.82%) if water manager's input was taken into consideration for the final policy recommendation (Table 3). Nearly half (44.78%) of respondents did not know whether the water management professional association had input or had a seat at the table for the adoption of the new policy recommendation, but over 50% agreed or strongly agreed that the AWWA did have input (Table 3). The quantitative results further indicate that water managers and their professional associations felt engaged in the policy process. This is despite a weaker decision-making approach in that the recommendation, while open for public comment, had been more or less finalized prior to their participation (DHHS, 2015).

Over 50% of stakeholders strongly agreed or agreed that a broad range of stakeholders was engaged in this process, with 35% of respondents indicating they did not know (Table 3). A strong positive revealed that over half of respondents agree or strongly agree that the complexities involved in meeting the recommendation are understood by the policy experts, i.e. the panel on community water fluoridation. The other half of respondents disagreed, strongly disagreed, or did not know whether policy elites understood the complexities involved in water provision and hitting a specific water quality target.

Importantly, over 70% of respondents agreed or strongly agreed that this target could be met with existing water utility infrastructure and local delivery mechanisms of water fluoridation policy in this country (Table 3). However, while the infrastructure and delivery systems are in place, the range of fluoride levels in the 2016 data, and across all sets in municipal drinking water, demonstrates fragmented practices at the local level.

Roughly 67% of respondents agreed or strongly agreed that their community currently fluoridates their water at approximately the 0.7 mg/L level, while 33% of respondents answered their community does not fluoridate at the recommended policy level or they do not know if their community fluoridates at this level (Table 3). Almost 60% of respondents disagree or strongly disagree that local water managers should decide what level to fluoridate the water supply (Table 3). However, nearly 40% strongly agreed or agreed with the idea that there should be complete local control over this decision (Table 3). The results from this series of questions are mixed, with approximately the same number of responses supporting local or federal decision-making authority. There was a stronger relative response for the state controlling the policy decision-making in this area. Consistency and variability with any policy, but especially one that has public health implications, raises ongoing questions about state and local control and the potential variance that could occur across the states. Approximately 40% of respondents agree with the idea that water fluoridation policy is an equitably applied policy across the U.S. (Table 3).

The final survey question focuses on providing choice to the local water consumer with opt-out provisions built into federal or state policies. This question also prompts the discussion of policy design and implementation options which are important in a contemporary public policy setting. The original policy recommendation in 1962 provided an opt-out provision, so this survey question is centered on the belief systems around local choice and policy control (DHHS, 2015). Slightly more (49.24%) respondents disagree or strongly disagree that individuals should be able to opt out of community water fluoridation programs than those who agreed or strongly agreed (47.69%). Similar to earlier responses, there is a mixed perspective among water managers, but this question is useful for understanding the breadth of support for variations in decision-making control over the design of policy and in its implementation across the country. At present, for consumers to opt out of this policy, they would have to move to a water system that does not add fluoride to the drinking water, purchase drinking water that was untreated or have a private, untreated source, or get enough of the community to reject water fluoridation treatment to stop treatment altogether.

Additional discussion

This research utilized a mixed quantitative and qualitative approach to explore the recent changes in national fluoridation policy in the U.S. Results revealed that the mean fluoridation level (Tables 1 and 2) and variability (SEM, Tables 1 and 2) in levels have fallen since the 2005 USDA study. It does appear that the recommendation is close to being met, but there was enough variation to suggest the need for

close monitoring of reported fluoride levels for the coming decades to ensure desired dental caries and dental fluorosis outcomes.

The analysis, mirroring the 2005 municipal drinking water data released in the USDA study of fluoride in select foods and beverages, revealed several interesting findings. First, the mean water fluoridation level across the country has fallen since 2005. The data provide evidence that that there is still variance in policy implementation and water fluoridation levels such as 0–1.855 mg/L in Table 1 and 0.34–1.245 mg/L in Table 2. This variance may imply different policy outcomes across the U.S.

The water manager stakeholder survey revealed that water managers felt engaged in the process and that the AWWA had a say in the policy decision. Water managers further indicated the belief that the recommendation can be met, and national policy experts understand the complexities involved in water treatment. As far as which legislative body determines water fluoridation policy and which regulatory body enforces it, a slight edge is given to the status quo, with state-based policy recommendations and enforcement being the federalist layer of choice. This is most likely due to the majority of states already having water fluoridation guidelines or laws in place. For the most part, water managers believe that they can meet this policy goal and have been doing so since the final recommendation.

Responses to exploring other models of delivery, equitability, and consumers having the option to opt out met with mixed results. Results underscore the value of these issues being seriously reconsidered by policymakers should this reach the national policy agenda once again. These results reinforce generalizability problems from a limited set of respondents but do provide insights for future research and policy considerations.

The mixed results of the survey instrument may also be a sign of the times. In a national environment of increasing polarization, especially around issues of federal/state policy divisions, these results may be a small window into perceptions regarding this policy recommendation. While we do not have specific evidence, these results support the impetus for concern around successful policy outcomes and the need for ongoing research to ensure that recommendations are being met across communities.

While the survey does not meet requirements to suggest that these results are representative of the total population of water managers, it outlines specific issues worthy of additional exploration in the future. Based on a scan of the policy recommendation panel, it could be argued that a broad range of health professional stakeholders was engaged, but no panelists who delivered the recommendation were Professional Engineers for water utilities or related organizations. Given that these professionals are the ones who actually implement the policy; this is an important stakeholder group that may not have been broadly considered. A broader, more inclusive stakeholder-driven decision-making process is an important consideration for this policy environment.

Conclusion

The mixed-methods approach of this research adds several key components to the broad policy literature around water fluoridation. The quantitative results provide some evidence that local water systems are technically and professionally able to meet this new national standard and are trending towards full policy implementation. The increase in precision in practice will help to limit over- or under-exposure in artificially fluoridated water and bring systems closer to the policy recommendation. Survey results reveal potential conflict over the division of control around fluoridation policy setting and related areas

of policy implementation and compliance. Policy process research that fully explores the success and/or failure of policy implementation around intersectional natural resource and public health issues would be of value to researchers, policymakers, and the public at large. As policy implementation and evaluation is the final stage of the policy process, a more thorough understanding of potential implementation gaps is critical.

Policy implementation further assumes a behavioral and/or organization change. A better understanding of how these changes occur within and across organizations is also of importance. Policy adoption of the recommendation by states or municipalities in updated codes or ordinances will be important for policy success. States and regions may adopt policies and practices providing examples of policy innovation for other states and regions. Over the next few years, reviewing the approaches different states and regions have taken to implement and evaluate this standard will add value to our holistic understanding of policy success.

The results of this research highlight potential opportunities to enhance transparency and knowledge sharing across these organizations. These results highlight many bi-modal agree/disagree responses along with a number of do not knows. This points to the need for continuing education and publication efforts from professional organizations such as the AWWA and other stakeholder organizations. These efforts are important not only to inform water managers of the policy but also to understand any ongoing challenges in implementation. A systems-oriented policy feedback loop from researchers, professional organizations like the AWWA, and water managers with the Federal panel will help to develop updated operational fluoridation guidance parameters.

In combination, this study has added contemporary data and research following the final policy recommendation in the U.S. future research in this area will help researchers understand when and if the full benefit of this policy is realized across communities and demographic groups. Finally, this research provides the evidence of possible pockets of Americans not receiving the benefit of this policy recommendation due to non-fluoridated water practice or possible over-fluoridation of municipal drinking waters. Given these results, continued monitoring of community fluoride levels in drinking water is a key area of ongoing research to ensure that health outcomes around dental fluorosis and dental caries are met.

Acknowledgements

This research was completed solely by the identified researchers. There were no outside sponsors or sources of funding to complete any phase of this research.

References

Agalakova, N. I. & Gusev, G. P. (2012). Molecular mechanisms of cytotoxicity and apoptosis induced by inorganic fluoride. *ISRN Cell Biol. 2012*, 16. Article ID 403835. https://doi.org/10.5402/2012/403835.

Blankenship, K. M., Friedman, S. R., Dworkin, S. & Mantell, J. E. (2006). Structural interventions: concepts, challenges and opportunities for research. *J. Urban Health. 83*, 59–72. doi:10.1007/s11524-005-9007-4.

Etikan, I., Musa, S. A. & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *Am. J. Theor. Appl. Stat. 5*(1), 1–4. doi:10.11648/j.ajtas.20160501.11.

Griffin, M., Shickle, D. & Moran, N. (2008). European citizens' opinions on water fluoridation. *Commun. Dent. Oral. Epidemiol. 36*, 95–102. doi:10.1111/j.1600-0528.2007.00373.x.

Heller, K. E., Sohn, W., Burt, B. A. & Eklund, S. A. (1999). Water consumption in the United States in 1994–96 and implications for water fluoridation policy. *J. Public Health Dent. 59*, 3–11. https://doi.org/10.1111/j.1752-7325.1999.tb03228.x.

Horowitz, H. S. (1996). The effectiveness of community water fluoridation in the United States. *J. Public Health Dent. 56*, 253–258. https://doi.org/10.1111/j.1752-7325.1996.tb02448.x.

Newbrun, E. (2010). What we know and do not know about fluoride. *J. Public Health Dent. 70*, 227–233. doi:10.1111/j.1752-7325.2010.00171.x.

Ripa, L. W. (1993). A half-century of community water fluoridation in the United States: review and commentary. *J. Public Health Dent. 53*, 17–44. https://doi.org/10.1111/j.1752-7325.1993.tb02666.x.

South Carolina Code of Regulations Chapter 61-58.7 (B. 11) (2005). Available from: https://www.scstatehouse.gov/coderegs/Chapter%2061-18%20through%2061-58.17.pdf.

Spencer, A. J. & Do, L. G. (2016). Caution needed in altering the 'optimum' fluoride concentration in drinking water. *Commun. Dent. Oral. Epidemiol. 44*, 101–108. doi:10.1111/cdoe.12205.

U.S. Centers for Disease Control and Prevention (1999). *Achievements in Public Health 1900–1999: Fluoridation of Drinking Water to Prevent Dental Caries*. Available from: https://www.cdc.gov/mmwr/preview/mmwrhtml/mm4841a1.htm.

U.S. Centers for Disease Control and Prevention (2014). *Fluoridation Growth 1940–2014*. Available from: https://www.cdc.gov/fluoridation/statistics/fsgrowth.htm.

U.S. Department of Agriculture (2005). *USDA National Fluoride Database of Selected Beverages and Foods, Release 2 [Internet]*. Nutrient Data Laboratory, Beltsville Human Nutrition Research Center, Agricultural Research Service, Beltsville, MD. Available from: https://data.nal.usda.gov/system/files/F02.pdf.

U.S. Department of Health and Human Services Federal Panel on Community Water Fluoridation (2015). US Public Health Service recommendation for fluoride concentration in drinking water for the prevention of dental caries. *Public Health Rep. 130*, 318–331.

West Virginia Legislative Rule §64-3-8 (8.1) (2018/2020). Available from: http://apps.sos.wv.gov/adlaw/csr/readfile.aspx?DocId=53177&Format=PDF.

World Health Organization (2004). *Fluoride in Drinking-Water: Background Document for Development of WHO Guidelines for Drinking-Water Quality*. WHO. Available from: http://www.who.int/water_sanitation_health/dwq/chemicals/fluoride.pdf.

Received 4 March 2019; accepted in revised form 2 April 2020. Available online 6 May 2020