Maine Policy Review

Volume 31
Issue 1 *Vol. 31, Nos. 1-2*

2022

Forever Chemicals Needing Immediate Solutions: Mainers' Preferences for Addressing PFAS Contamination

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Forever Chemicals Needing Immediate Solutions:

Mainers' Preferences for Addressing PFAS Contamination

By Charity Zimmerman, Caroline L. Noblet, and Molly Shea

Abstract

Per- and poly-fluoroalkyl substances (PFAS) are a diverse class of synthetic fluorinated chemicals also referred to as "forever chemicals." The release of these chemicals into the environment presents an urgent, emerging threat to human and environmental health. Decision-makers seeking to address a variety of PFAS-related issues need better understanding of citizens' knowledge of PFAS contamination and their preferences for managing the issue. To provide this vital information, we analyze data from a survey of Maine citizens. We assess Maine residents' baseline knowledge of PFAS contamination, as well as their preferences for generation and allocation of funds to address PFAS contamination in Maine.

ADDRESSING AN EMERGING CONTAMINANT

Public knowledge of the environmental and human health risks associated with per- and polyfluoroalkyl substances (PFAS) is varied and often limited, yet contamination of the ground and surface water from PFAS is a growing concern in Maine[1] and across the globe (Ng et al. 2021). PFAS are synthetic organic chemicals with a unique ability to repel both water and oil. In addition to their industrial uses, they are used in a range of consumer products from nonstick cookware to food packaging and breathable rain gear. This family of manufactured organofluorines are virtually indestructible and have earned the nickname *forever chemicals*. PFAS are associated with a wide range of human health issues including disruption of the endocrine system, cancer, reduced vaccine effectiveness, liver damage, and negative impacts on fetal development (Jha et al. 2021; Panieri et al. 2022). People may be exposed to these chemicals from the environment in multiple ways: inhalation from the atmosphere and absorption through drinking water and food (Brown et al. 2020). The ongoing release of these persistent chemicals into the environment creates one of the most consequential and widespread contemporary environmental crises in the United States (Saleh et al. 2019).

The state of Maine faces an unprecedented challenge to the well-being of its residents, economy, and environment. Agricultural fields in Maine, and throughout the nation, received residual wastewater sludge and other biosolids as fertilizer. This practice was authorized by the Clean Water Act,[2] under both current and historical licenses to sludge generators dating back to the late 1970s (Maine PFAS Task Force 2020). However, research has shown that PFAS migrate from agriculturally applied sludge, via leaching into groundwater, surface water runoff, and plant uptake by agricultural crops (Brown et al. 2020). Furthermore, dairy animals fed PFAS-contaminated crops also accumulate the chemicals in their milk, which creates another exposure path for humans (Smith and Simones 2017). Due to the dangers presented by PFAS to human and environmental health, Maine became the first state to ban land application of sludge (LD 1911—"An Act To Prohibit the Contamination of Clean Soils with So-called Forever Chemicals," effective August 2022).

Society's collective understanding of the impacts of PFAS on the environment and human health remains limited, yet we need to address contamination by and prevent exposure to these chemicals. The estimated costs to human and environmental health from exposure to PFAS (both past and continuing) are in the billions of dollars (Goldenman et al. 2019). However, the general public's limited knowledge of risks associated with toxins and management of public health dangers may constrain public engagement with important decision-making (Richter, Cordner, and Brown 2021). The current methods for addressing PFAS places the burden for management on public water utilities, state agencies, and other

taxpayer-funded entities (Cordner et al. 2021). Thus, understanding citizens' knowledge of risks of PFAS and their support (including financial support) for addressing the issue strengthens federal, state, and local policymakers' ability to create policies and programs to protect the health of Maine's residents and environment. This study collected baseline data from Maine residents on their knowledge of PFAS risks, their priorities for managing the problem options, and their opinions on sources that may be trusted to address the issue. Improved understanding of the knowledge, preferences and behaviors of Maine residents will assist policymakers as they consider effective and efficient tools for risk management and risk communication.

SURVEY DESIGN AND METHODS

Sampling and Survey Administration

In the spring of 2022, we administered a mixed mode survey (invitation by postal mail to an online survey) to a sample of 4,000 Maine residents. An additional 4,000 Maine residents received the survey through electronic means only (invitation by email to an online survey, 781 emails bounced). Of the Maine residents invited to participate, 2,500 were from communities designated as Tier 1 testing sites[3] by the Maine Department of Environmental Protection (DEP) (1000 mixed mode, 1,500 electronic only). These are communities where application of sludge was known to have occurred, and based on knowledge of sources contributing to the sludge, it likely contained PFAS. These communities also had the greatest volume and frequency of land applications of sludge. At the time of the survey, residents of these Tier 1 communities were already receiving information from the Maine DEP about local sampling efforts was of private drinking water wells and soils. A total of 432 Mainers responded to the survey, 276 to the mixed mode and 136 to the electronic only (158 respondents were from Tier 1 communities). An additional 20 responses were from attendees of the Maine Water and Sustainability Conference held in March 2021.

Survey Questionnaire

The survey instrument was greatly informed by reviewers from multiple Maine state agencies responsible for, and nonprofit organizations interested in, the health of Maine's people and environment. The final survey consisted of seven sections that investigated (1) respondents' current drinking water (source of and concerns about); (2) their knowledge of PFAS and exposure pathways; (3) an embedded information experiment (described below); (4) their willingness to pay for PFAS management and remediation; (5) their preferences for various types of management options; (6) potential behavioral changes they might make to avoid PFAS, and (7) their perceptions about entities that should be blamed for the PFAS problem or entrusted to carry out mitigation options. Because we knew that many of our respondents were learning about PFAS for the first time, we provided baseline information about PFAS that was consistent with existing Maine state communications (Appendix A-1, https://digitalcommons.library.umaine.edu/mpr/vol31/iss1/10/) to all participants.

Residents are often reluctant to designate funds to environmental cleanup when they do not feel responsible for the damage. To capture the role of possible differences in ascribing responsibility for PFAS, we embedded an information experiment in the survey instrument. Respondents were shown one of three messages. Message 1 included information from Maine state agencies with a brief description of PFAS, how they may affect human health, and background on their creation (138 respondents viewed this message, Appendix A-2). Message 2 repeated this information, but noted that PFAS can be found in a variety of *industrial uses* such as firefighting foams, paints, carpets, and more (138 respondents). Message 3 repeated the state agency brief, but noted that PFAS can be found in a variety of *consumer uses* such as fast-food containers, nonstick cookware, and more (137 respondents). The information experiment tested whether focusing on specific sources of PFAS affected respondents' willingness to pay for cleanup and their preference for management choices. Analysis of this information experiment is ongoing and beyond the scope of this current paper.

The survey tested two potential mechanisms of payment for PFAS mitigation efforts: an increase in annual property taxes or a sales tax on certain products that contain PFAS. Each respondent saw only one of the two possible mechanisms. The hypothetical annual property tax increase ranged from $15 to $100. The sales tax ranged from 2 percent to 10 percent (above the existing 5.5 percent sales tax in Maine). After viewing the information experiment and payment options, respondents were invited to express their preferences for spending priorities for a Maine PFAS program. They were shown six potential options (randomized in order of presentation) and asked to order them from highest to lowest priority.

TABLE 1: **Demographics characteristics of survey sample and Maine residents**

	Maine Survey Respondents	Maine Census & Maine Geological Survey
Gender (percentage female)	60.3	50.7
Age (mean, years)	56	45
Income (median household)	$75,000	$59,489
Education (percentage with bachelor's degree or higher)	59.9%	32.5%
Bottled water	12.0%	-
Private well	47.0%	40%
Public water	41.0%	-

Survey Respondents

Survey respondents were older, had higher incomes and educations, and were more likely to be female and retired than Mainers on average (Table 1). While our respondents include participants from all 16 counties, we recognize that our limited response rate may yield a set of survey participants that is not fully representative of the general Maine population.

RESULTS

PFAS Baseline Knowledge

Policymakers are interested in Mainers' baseline knowledge regarding PFAS, particularly in currently held perceptions of Maine drinking water safety. We found that many Maine residents still lack awareness of the PFAS issue, with almost 20 percent of respondents having not heard of PFAS. When presented with a list of acronyms for chemicals from the family of individual chemical compounds that make up PFAS (e.g., PFOA, PFOS, etc.) the most recognized terms were *forever chemicals* and *PFAS,* with 63 percent of respondents recognizing these two terms. Of interest, the group of respondents who had never heard of PFAS prior to our survey were indistinguishable from other respondents across sociodemographic categories of age, gender, or income. Respondents who had never heard of PFAS were more likely to get their drinking water from a public water supply rather than from a private drinking water well (20 percent of public water respondents had never heard of PFAS, 14 percent of private well respondents had never heard of PFAS). Interestingly, there was no difference between general respondents and Tier 1 residents with respect to prior PFAS knowledge.[4]

Respondents indicated that while they may currently lack knowledge about PFAS, informing themselves about PFAS is important. When asked on a scale of 1 (know nothing) to 100 (know everything) how much they *currently know* about PFAS, respondents reported on average of 35, but when asked how much they *should know*, responses shot to 80. Qualitative responses indicated that people felt this knowledge was important for their own health and the health of their family (the most frequently cited response). They also noted that they wished to learn more about potential exposure to PFAS through the water and food they consume. When asked to describe why they *should know* about PFAS in an open-ended question several common themes emerged: health, [drinking] water, and family. Figure 1 shows the frequencies of the six most common terms in the text responses.

Mainers may face different levels of exposure to PFAS depending on their sources of drinking water, as some Maine municipalities are working to address PFAS contamination in public water supplies. Respondents' drinking water sources were close to state estimates of drinking water sources, with 47 percent of respondents using private well water, 41 percent public water supplies and 12 percent primarily drinking bottled water; current statewide estimates

FIGURE 1: **Survey Responses to "Why Do You Think You Should Know about PFAS" (n=377)**

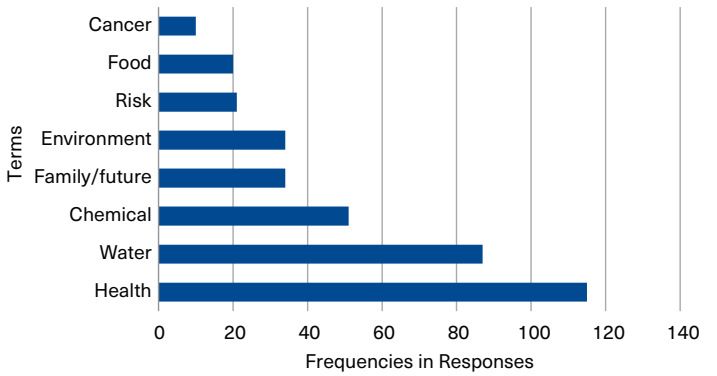


FIGURE 2: **Word Cloud with Responses to "How Might a Person in Your Community Be Exposed to PFAS?"**

Note: Larger font indicates a greater frequency in response (n=352)

have 40–50 percent of the state's population using a private well.[5] Respondents felt safe drinking water from their faucets/taps. On a scale of 0 (strongly disagree that they feel safe) to 100 (strongly agree that they feel safe), the mean response was 73 although 46 percent of our respondents across all water sources already filter their drinking water in some way. Of respondents who filter, 31 percent are trying to filter out a specific substance they *know* is a problem; one-quarter of these respondents are from Tier 1 communities. Respondents' knowledge of existing issues with their drinking water may be limited as 16 percent of private well users reported they never test their well water. Forty percent of nontesters reported no previous water issues. Importantly, 10 percent of the private well nontesters found testing too expensive, and 15 percent said they could not afford to address any issues that arose from testing.

Our respondents also provided insight into how the risks of PFAS are seen in comparison to other everyday encounters that may be risky or perceived as risky. When asked to rate eight items on a scale of 0 (low risk) to 10 (high risk), respondents on average rated PFAS in drinking water at 7.35, statistically lower than the risk of arsenic in drinking water (7.93) and lead in drinking water (8.21).[6] In comparison, the highest rated item was smoking cigarettes (9.32) and the lowest was exposure to UV rays from the sun (7.10). These results seem to indicate that Maine residents are still learning about the dangers of PFAS and how the risk from PFAS compare to the myriad of other risks they are exposed to daily.

PFAS Exposure Pathways in Maine

Understanding pathways that expose humans to PFAS is important in mitigating future health impacts. With this issue in mind, we sought to explore Mainers' current understanding of these potential pathways. When asked to consider ways in which people in their community may be exposed to PFAS, the most cited response was through water/drinking water. However, consumer products such as pots and pans, food packaging, and dairy products were also cited (Figure 2).

We specifically explored perceptions of how PFAS enters Maine's drinking water.The most recognized pathway for entry into drinking water was through wastewater sludge spread on agricultural fields; 68 percent of respondents noted this as a means of PFAS entering drinking water.[7] Consistent with earlier information that some Mainers are unfamiliar with PFAS, 22 percent of respondents were unsure of what pathways may lead to PFAS in drinking water (Table 2).

Early in the survey—before we presented any information about PFAS—we asked respondents about their perceptions of their own tap water's safety. In responses to questions in the survey that follow our brief description of PFAS and their general health impacts (Appendix A-1), we see a substantial shift in respondents' feelings of safety concerning their water (Figure 3). Despite this shift, respondents on average indicated that they think PFAS are more of a problem outside their communities than within their communities (scale 0 = not a problem, 10 = very much a problem). Respondents from Tier 1 communities, however, were statistically more likely to perceive PFAS as a problem within their own communities than were respondents from outside the Tier 1 range. Additionally, when asked if PFAS was a problem in a community near them, Tier 1 respondents were statistically more likely to indicate this was true.[8] A small percentage (3 percent) of respondents indicated concern with their drinking water at the start of the survey, but showed a relative lack of concern regarding PFAS in their drinking water after the presentation of PFAS information. These respondents may be concerned about a different set of contaminants unrelated to PFAS. Given these varied

TABLE 2: **Responses to "What Are Ways That You Have Heard That PFAS Could Enter Maine's Drinking Water?"**

Pathways for PFAS to Contaminate Water Sources	% of Respondents
Wastewater sludge spread on agricultural fields	68
Industrial waste/discharge	64
Leaks from unlined landfills	55
Consumer products that are made to be resistant to heat, grease, or water (e.g., nonstick cookware, water-resistant rain gear, etc.)	51
Firefighting foam	39
Wastewater from households (laundry, etc.)	35
I am not sure	22

Note: Respondents could select multiple responses.

levels of concern, we wanted to understand what people are willing to do about PFAS in Maine.

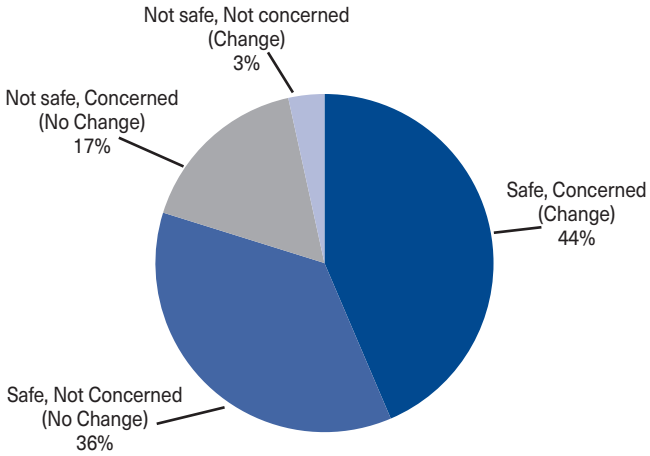
Allocation and Willingness to Contribute

While awareness of a problem is a key component of future solutions, funding mitigation efforts is often challenging. The burden of payment often falls to citizens affected by an environmental emergency. The state of Maine is pursuing legal action against the manufacturers of many PFAS products (Maine Attorney General 2021). In the meantime, however, Maine residents will likely be asked to fund sampling, education, and cleanup efforts. Across the board, respondents indicated they were willing to contribute financially towards hypothetical programs that help address PFAS contamination: 66 percent of participants responded "Yes" when asked to contribute funds. Recognizing that how funds are collected may also influence citizens' willingness to contribute towards environmental contamination issues, we embedded an experiment that tested two different mechanisms for collecting contributions. Respondents were presented with a hypothetical sales or property tax that would be used to fund PFAS cleanup and prevention in Maine for the next 10 years (Appendix B). Of the 203 respondents faced with increased property taxes, 69.5 percent said they would contribute to hypothetical programs to address PFAS. Similarly, of the 200 respondents faced with increased sales tax, 63.0 percent indicated they were willing to incur the additional expense associated with PFAS programs. These findings indicate that citizens are willing to pay to address PFAS, but may have differing preferences for how the funds are collected.

Respondents had a chance to reflect on why they supported or did not support each program. Figure 4 provides examples of their comments; there were several common themes across choices to support or decline to support the programs. Most often those who chose to support programs did so because of health concerns for themselves or their families. For those who chose to not support the programs, concerns were raised about the affordability for the potentially taxed products and already high property taxes. Many also believed that the producers of the chemicals should be responsible for cleanup, while still others signaled distrust that the government was well suited to address PFAS because of the lack of current regulations.

Previous research that examined citizens' willingness to contribute towards public goods such as a clean environment noted that while there may be a willingness to fund programs, there may also be strong preferences for how the taxpayer-raised funds are used (Noblet et al. 2015, 2017). In the survey, we provided respondents with the opportunity to allocate PFAS management funds towards specific

FIGURE 3: **Changes in Respondents' Perceptions of Safety of Own Tap Water before and after PFAS Information***



*Note: We see that 44% of respondents changed their perceptions about the safety of their own drinking water over the course of the survey.

FIGURE 4. **Responses from Survey Respondents to "Why Did You Choose to Support the Program, or Not? (n=351).**

alternatives and noted the emergence of strong preferences. The highest priority (34 percent of respondents ranked as top) was placed on treating public water for PFAS (Figure 5). Perhaps not surprising given the impact on Maine's rural residents and farmers, providing subsidies to Maine residents, farmers, and businesses affected by PFAS—for treatment or reimbursement of losses—was ranked the top priority by 15 percent of respondents.

Trusting Management and Changing Behavior

While we have established that some Maine residents may not know much about PFAS, there is also a clear mandate for action. Funding for and implementation of PFAS mitigation and management strategies will likely require both increased citizen awareness of the issue and trust in the agencies or organizations that provide information or perform actions. The literature of natural resource management shows that citizens hold various levels of trust for entities engaged with management, and this trust is a critical component in environmental management (Smith et al. 2013). Thus, our survey was designed to capture information on trust as a key component in addressing PFAS.

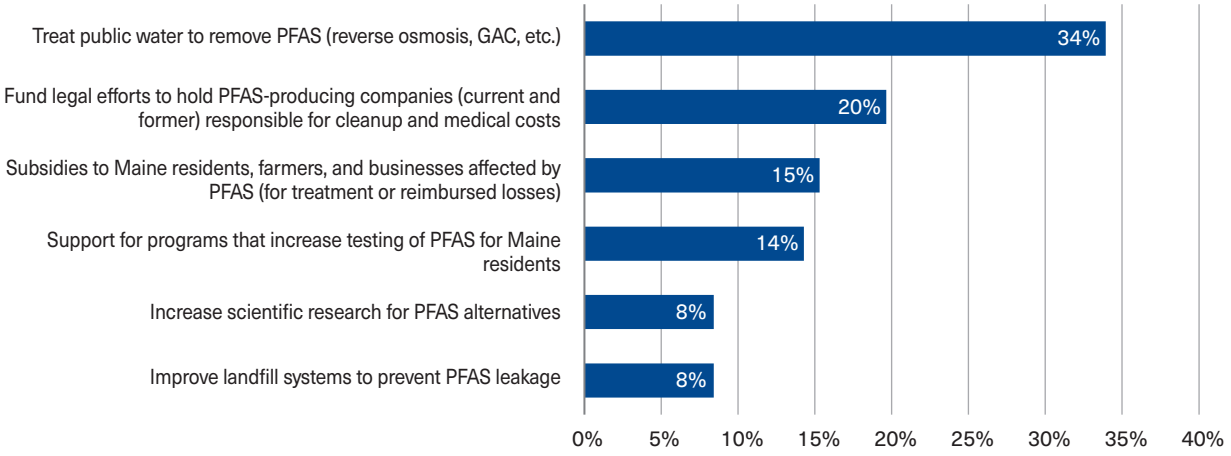
Respondents were asked to indicate their trust in various agencies and organizations that may be involved in addressing PFAS and other contaminants on a scale of 1 (do not trust) to 10 (fully trust). The average score for Maine state agencies, including the Department of Environmental Protection; Department of Agriculture, Conservation and Forestry; and Department of Health and Human Services, was 5.61. The average trust rating of federal agencies, such as the Environmental Protection Agency, Food and Drug Administration, and US Department of Agriculture, was statistically significantly lower at 5.02.[9] Although many respondents rated federal agencies at a middle rating, there was more variation in the rating of state agencies, with a cluster of responses hovering around 8. Respondents on average rated universities and colleges, such as the University of Maine, at 7.23 and farming organizations, such as Maine Organic Farmers and Gardeners Association (MOFGA), at a 7.10.

Unfortunately, the recent COVID-19 pandemic has eroded citizen trust in scientific entities and their ability to protect public health (Cairney and Wellstead 2021; Provenzi and Barello 2020). This sentiment was demonstrated by 26 percent of our respondents agreeing with the statement "My trust in science has been shaken by the COVID-19 pandemic." This link between scientific uncertainty and trust in management organizations is particularly disconcerting because the uncertainty surrounding PFAS is reminiscent of early states of COVID-19; per our respondents 27 percent agree that "The uncertainty in PFAS science reminds me of the uncertainty in COVID-19 science."

To address PFAS contamination, citizens must have a level of trust in those agencies responsible for legislation and management. However, this level of trust may not be present with existing water-related public health issues: 43 percent of respondents did not agree with the statement, "I trust that the federal recommended level of *other environmental contaminants,* such as arsenic, in drinking water is safe for me and my family."

At the time of this survey (spring 2022) the federal health advisories for PFAS in drinking water, set by the EPA at 70 parts per trillion,[10] were less stringent than Maine's legislative interim mandate of 20 parts per trillion. It is also

FIGURE 5. **Respondents' Management Preferences for the Question "What Do You see as Spending Priorities for a Maine PFAS Program?"**



important to note that the federal health advisories are nonenforceable and nonregulatory. Maine's statute[11] for the interim drinking water standard for PFAS were at the time of the survey, and continue to be, enforceable through statutory mandate. Thus, it is not surprising that 43 percent of respondents disagreed with the statement "I trust that the federal recommended level of PFAS in drinking water is safe for me and my family."

Our survey revealed that Mainers are learning about PFAS and are willing to make financial contributions towards addressing this critical issue, but we wanted to explore whether people are willing to make changes in their own lifestyle to ensure a PFAS-free future? We asked participants to indicate their willingness (on a scale of 1–5, with 5 being they strongly agree to the behavior change) to alter certain behaviors to help avoid PFAS in their everyday life. For example, participants would, on average, be willing to switch to buying popcorn kernels instead of microwave popcorn (4.24 rating). All other prompts averaged responses ranging from 3.96 to 4.35, suggesting respondents' willingness to make changes to their everyday life to avoid PFAS.

Respondents believe that PFAS contamination is an important issue in Maine: 87 percent of respondents strongly disagreed with the statement, "The PFAS problem in Maine has been overstated." However, the question remains: Whom do citizens blame for the current problem? On the scale of 0 (strongest disagreement) to 100 (strongest agreement), when asked to reflect on the statement "I blame *Maine government* for allowing the spread of PFAS contaminated waste on farm fields," 13 percent of respondents indicated the strongest agreement with that statement (100 out of 100). Respondents expressed their greatest ire at "*companies* who used PFAS in production, even after they knew it was a problem," with 42 percent of respondents indicating strongest agreement with the statement (100 out of 100). As news about PFAS has been heavily focused on farms, we asked respondents about their level of blame for "*Maine farmers* who spread PFAS contaminated waste on their fields": 25 percent of respondents assigned a score of 10 to farmers, though a small group (9 percent) assigned a score of 80 or above. Even though respondents indicated that they believe various entities are at fault for the current PFAS problem, they believe it is "their personal responsibility to be careful about the products they buy to help protect the environment" 50 percent of people strongly agreed (assigning an 85 or above). These results indicate that informational campaigns helping Maine citizens to understand the consumer products that contain PFAS may meet with success.

DISCUSSION AND CONCLUSION

This work provides empirical evidence that Maine residents hold strong preferences for how to address PFAS contamination in the state. Limited or incorrect knowledge about the issue leaves an opportunity for Maine policymakers to engage in communication efforts focusing on the risks of PFAS, exposure pathways, current sampling or

mitigation efforts, along with information campaigns about consumer products that contain PFAS. Importantly, our findings indicate Maine residents are willing to contribute financially towards solutions and change their own behaviors to limit additional PFAS contamination in Maine. Overwhelmingly, survey respondents want to ensure that all Mainers have access to safe drinking water. Our results indicate that unequal baseline knowledge regarding risks and exposure pathways of PFAS yields an opportunity for trusted Maine entities to continue educating the public about the issue. When faced with concrete costs of PFAS mitigation and adaptation, however, citizens may make different choices. For example, the town of Fairfield (a Tier 1 community) recently voted not to extend their public water lines to homes with private wells that may have been contaminated by PFAS.

Importantly, although the news media frequently focus on the role that sludge spreading on agricultural lands has played in the contamination, Maine residents do not blame farmers for the current PFAS issues. Consumer perceptions of Maine agricultural products, however, are of increasing concern given the continued media scrutiny. To test the potential erosion in consumer confidence for Maine foods we asked respondents to rate, on a scale of 1 to 5 (5 being very safe), how safe both food and milk from Maine farmers was. Food and milk were both rated at a 3.7 for safety, on average, while the average score for organic food from Maine farmers was rated at a 4. These results indicate that Mainers continue to support Maine's food system, but future research should focus on consumer confidence (for both Maine residents and other consumers) throughout New England for Maine-produced food.

It will be important to continue gathering information from citizens regarding their evolving preferences for addressing the PFAS issue in Maine. Our team is currently administering a second survey to assess how continued information and media coverage on PFAS may have impacted Maine citizens' preferences. Additionally, future research must quantify how much Maine citizens are spending to avoid PFAS (e.g., home filtration systems), as well as spending by Maine agencies to address the issue. Anticipated future costs include testing of private and public water, landfilling of sludge from wastewater treatment facilities, and related regulations enforcement. Education for citizens on the interconnectedness between the products they purchase and subsequent impact on PFAS levels in sludge and septage may yield new opportunities for product labeling. Creation, evaluation, and enforcement of PFAS-related labels will also require trust between consumers and regulating agencies. Unfortunately, research indicates management of PFAS will not be solved quickly and requires extensive collaboration between scientists, citizens, and policymakers alike.

NOTES

1 Information about PFAS in Maine is available from the Maine Department of Environmental Protection: https://www.maine.gov/dep/spills/topics/pfas/.

2 Please see EPA Biosolids webpage (https://www.epa.gov/biosolids) for additional information on biosolids licensing.

3 Additional information on tier designation can be found at https://www.maine.gov/dep/spills/topics/pfas/.

4 Public vs private water sources: (3) = 9.65, p <0.02. General vs Tier 1 respondents: (M for general = 35.73, M for Tier 1 = 34.30; T stat = 0.51, p = 0.61).

5 Information on water resources in Maine is available through the Maine Geological Survey: https://www.maine.gov/dacf/mgs/explore/water/facts/water.htm.

6 Risk of arsenic in drinking water (M=7.93; (121) = 424.6, p <0.01); risk of lead in drinking water (M=8.21; (121) = 376.9, p <0.01).

7 Respondents were given a list of seven potential pathways and could select all that they thought applied.

8 PFAS problem within community (mean for non-Tier 1= 4.66, mean for Tier 1 = 5.78, p < 0.01); PFAS problem near respondent (mean for non-Tier 1= 5.86, mean for Tier 1 = 7.02, p < 0.01).

9 ((121) = 675.2, p <0.01)

10 EPA's Updated Interim Health Advisory (June 2022) for PFOA is 0.004 nanograms per liter or parts per trillion, PFOS 0.02 nanograms per liter or parts per trillion.

11 SP 64 — LD 129 Resolve to Protect Consumers of Public Drinking Water by Establishing Maximum Contaminant Levels for Certain Substances and Contaminants: https://www.maine.gov/dhhs/mecdc/environmental-health/dwp/pws/pfas.shtml.

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