Preparing for effective, adaptive risk communication about per- and polyfluoroalkyl substances in drinking water

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Abstract
Drinking water contamination and the potential subsequent long-term adverse health outcomes is an issue of high importance and personal interest to affected communities. Per- and polyfluoroalkyl substances (PFAS) further complicate these issues through their technical complexity; evolving scientific and public health data; and inconsistent, incomplete, and evolving governmental guidance on screening and mitigation. The use of a community-specific adaptive risk communication strategy can allow municipalities to assess and mitigate PFAS while addressing community concerns. Utilizing demographics data and the qualitative observations of the community’s concerns based on social media and news activity, the study team prepared two outreach strategies for PFAS assessment and mitigation. Overall, application of this strategy to two different case studies revealed that the framework is sufficiently flexible to meet specific community needs. Evaluation of the communities’ risk perception factors showed that while there were some commonalities, sufficiently different risk perception factors existed, which necessitated a community-specific strategy.

KEYWORDS
PFAS, public outreach, risk communication, risk perception

1 | INTRODUCTION

Recent and/or high-profile drinking water contamination events in the United States (e.g., water service lines leaching lead in Flint, Michigan and industrial per- and polyfluoroalkyl substances (PFAS) contamination in Parkersburg, West Virginia) as well as media coverage (e.g., press releases, news, social media, entertainment) have highlighted the impact that the discovery of drinking water pollutant(s) have on the community (Baxter, 2020; Beresford, 2017; Hayes, 2019; NPFASCC, 2021; Parliament of Australia, 2019; Riley, 2020). The public has responded to these events in a variety of ways, including participation in numerous class action lawsuits (Cohen Hubal, 2019), conducting their own research that may conflict with existing health information (Anderko, 2020; ASTDR, 2019; ITRCa, 2020), self-sampling of individual water sources (e.g., wells, ponds) and other environmental media (e.g., biosolids, compost, shellfish) (ITRCa, 2020; NGWA, 2021; WEF, 2021), as well as requesting municipalities and public utilities to proactively sample, treat, and manage these pollutants. An additional challenge is the increasing demands from the public to treat or remediate
Environmental contamination to the value of “zero,” which is difficult to define based on analytical laboratory constraints, and drives perception-based decision-making rather than science-based risk management decision-making. Maintaining high drinking water quality is further challenged by a municipality’s or utility’s financial limitations to fund sampling and treatment, the evolving regulations for different environmental media, and the level of uncertainty in the relative risk of exposure and perceived public health concerns (ITRCa, 2020; ITRCb, 2020; Chap. 14; Simon et al., 2019; Wickham & Shriver, 2021). All of these variables formulate into risk communication challenges (ITRCa, 2020, Chap. 14). The risk communication challenges associated with PFAS are accompanied by strong, and often polarized, public interest in drinking water contamination and in PFAS-related issues.

In many states, a lack of regulation or guidance on drinking water standards for PFAS makes it challenging for environmental agencies and drinking water utilities to effectively communicate the relative risk of exposure to the public (ITRCa, 2020, Chap. 14). At a minimum, the U.S. Environmental Protection Agency’s (USEPA) drinking water perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) human health advisory level (HAL) of 70 parts per trillion (ppt) provides a basis for states and public water utilities to determine next steps for monitoring and treating PFAS (EPA, 2021). A handful of states (e.g., Michigan, Vermont, New Hampshire, Massachusetts, New York, and New Jersey) have established, or are in the process of establishing, a significantly lower PFAS drinking water maximum contaminant level. An even smaller group of states have established non-drinking water standards, such as the Maine’s Soil Beneficial Use PFAS Solid Waste Management Rules (MDEP, 2020). Differences among federal and state risk-based criteria for drinking water and other environmental media can cause confusion, or a fear that one agency is less protective than another for the general public (Wickham & Shriver, 2021). These differences can also lead individuals, both the general public and PFAS management decision makers, to compare self-sampling results to a variety of standards of the same (or sometimes different) sample media, such as comparing biosolids to soils or drinking water to blood serum levels.

Another unique PFAS risk communication challenge is the continuous evolution of the scientific understanding of the PFAS contaminant life cycle, representing the circularity of PFAS movement within environmental, ecological, and human systems (American Water Works Association [AWWA], 2021a; ITRCa, 2020, Chap. 14). A community-specific PFAS cycle, an example of which is shown in Figure 1, can comprise potential primary and secondary sources, waste haulers and receivers, migration and transport pathways, and potential exposure pathways.

The cyclical movement of PFAS within a community creates a risk communication challenge for the general public to understand where PFAS sources and extent of related contamination is or may be present and the authority(ies) responsible for overseeing cleanup and risk management. The PFAS cycle is further complicated by the ongoing consumer use of PFAS-laden products. This evolving understanding of the complex nature and cyclical behavior of PFAS compounds within the environment can be difficult to communicate effectively, especially in public-facing communication materials. Differing perceptions of the community-specific PFAS cycle, responsibilities of remediation authorities, and the applicability of regulatory standards at each cycle component among the general public and stakeholders can misdirect implementation of PFAS source control and PFAS reduction measures (Wickham & Shriver, 2021).

A further challenge complicating PFAS risk communication is the general uncertainty and evolving science regarding the health impacts of PFAS. There are no clinical reference levels for PFAS exposure, which contributes to uncertainty among both medical providers and patients. This uncertainty extends to other public health aspects of PFAS exposure, including the public’s inability to pursue PFAS removal therapies and blood testing. This public health uncertainty drives a greater focus on preventing or mitigating exposure in the first place (Anderko, 2020).

The ubiquitous and persistent presence of PFAS in the environment makes the perceived and realized impacts to an individual’s or community’s quality of life difficult to assess and manage. Finding PFAS on private property, such as a private well or septic system, can cause financial stress from implementing treatment and/or accessing alternate water/sewer sources. Property values and business revenue may also be stressed if PFAS is detected on a property or within the community itself. Quality of life impacts can also extend to emotional and physical stress (Wickham & Shriver, 2021). These stressors are not uncommon among a community that has been exposed to pollutants (Sandman, 2013); however, these stressors and related outrage effects further challenge PFAS risk communication (ITRCa, 2020, Chap. 14).

General PFAS informational resources are available from a variety of sources, including the Centers for...
Disease Control (CDC), Agency for Toxic Substances and Disease Registry (ATSDR), and USEPA (ATSDR, 2020; CDC, 2017; USEPA, 2021). Over the past 6 months, numerous specialized resources have also been developed to guide municipalities, drinking water utilities, and other PFAS stakeholders in addressing these complexities in PFAS risk communication activities as they relate to drinking water and wastewater treatment. The AWWA has prepared informational summary reports for drinking water practitioners and utilities that address drinking water treatment technologies for PFAS treatment, source water evaluation guidelines, and toxicological research, as well as concise fact sheets (AWWA, 2021a, 2021b). The Water Environment Federation (WEF) has prepared similar resources for practitioners with respect to wastewater treatment. WEF has prepared a communications toolkit focused on biosolids that also addresses PFAS issues (WEF, 2021). The communications toolkit provides messaging and strategy resources to practitioners to effectively communicate with the public on beneficial reuse of biosolids and includes PFAS-specific messaging and strategy resources. Finally, the ITRC has prepared technical guidance on PFAS risk communication, as well as a general risk communication toolkit with PFAS-specific outreach tools, to help practitioners consider public or stakeholder risk perception, address communication challenges, and facilitate risk communication and public outreach planning (ITRCb, 2020).

This study presents two case studies on the application of select risk communication tools within a public outreach framework. Both case studies address contamination of drinking water sources and other PFAS cycle components. A desktop community assessment and proactive collaboration among PFAS stakeholders informed the identification, selection, and application of risk communication planning tools to assist public outreach strategy development. These tasks also helped identify community-specific risk communication challenges to address in the public outreach strategy.

2 | METHODS

Both case studies discussed herein pertain to municipalities in the United States where PFAS contamination has affected environmental resources (public drinking water system, private drinking water wells, or land-applied biosolids) where the municipality or utility is beginning to evaluate the extent to which they have been affected, and then determine a path forward. Location- and stakeholder-specific information of the case studies have not been included herein, in order to protect community anonymity. Another reason this information has not been included is that the outreach strategy has been recently initiated and is being periodically refined to incorporate community feedback and municipal or utility communication team input.

2.1 | Public outreach plan development

In both cases, the study team prepared a PFAS public outreach plan in alignment with the ITRC Risk Communication Toolkit for Environmental Issues and Concerns.
ITRC’s risk communication planning process is an iterative eight-step process to facilitate and integrate ongoing, continuous dialogue with the community and other
stakeholders. The modified step-wise risk communication planning process performed for this study is shown in Figure 2. The first step in the communication planning process is to set the outreach plan mission; from there, the planning process moves clockwise through the framework presented in Figure 2, with a return to the “Review and Evaluate” step at each interval. The methods, results, and discussion presented in this study correspond to the steps highlighted blue in Figure 2.

A community and stakeholder assessment was performed for each case study, which summarizes community demographic information, public and private stakeholders, and community and stakeholder PFAS concerns and needs. This assessment was based on a desktop analysis of news media and social media websites, and community and stakeholder input provided to the municipalities. Review of local and regional news media and social media provided a basic understanding of the extent to which the public are engaged in PFAS issues, as well as themes present in media reporting and public discussion (Wickham & Shriver, 2021). Social media activity reviewed consisted of the Facebook and Twitter activity of local news sources and community organizations, and community dialogue represented by the posts (comments, likes, and shares). For each case study, websites for all local news sources (print, online, and television) were reviewed; two news sources were identified for each case study, which were actively covering PFAS topics. American Census Survey demographic data were evaluated to define community context and identify targeted community outreach considerations, such as income rate, educational attainment rate, and languages spoken in the area.

Local news sources and community organizations were identified for each case study based on an Internet search and consultation with municipality stakeholders. The study team reviewed recent (within 2 years) news coverage from each of the identified news sources and organizations, as well as associated social media (primarily Facebook and Twitter) activity and online engagement (posts, comments) for each entity. The specific articles and social media activity identified for each case study are discussed further under the Results section.

Qualitative observations of the public perception of the PFAS issues and the assessment of community demographics data were synthesized into community risk perception factors (Harclerode et al., 2016; ITRCa, 2020, Chap. 14), which informed the messaging and approach of the outreach strategy. The outreach strategy was tailored around each municipality’s or utility’s stakeholder engagement decision factors, which varied between the two case studies due to fundamental differences in the nature of the respective PFAS issues. Engagement decision factors are defined as triggers for community and other public stakeholder outreach and included both municipality–internal and municipality–external events. For example, detection of PFAS above the applicable screening level in public water supply wells would serve as an engagement decision factor since it would necessitate communication to the public about the sampling results and the municipality’s plan for corrective action. For each engagement decision factor, a specific outreach strategy was developed. This specific outreach strategy consisted of key message topics, targeted private and public stakeholders, communication materials, communication distribution methods, timelines, and specific–measurable–achievable–relevant–timely goals meant to facilitate outreach implementation, evaluation, and follow-up. The final component of strategy formulation considered specific outreach implementation challenges and additional community outreach considerations given the community-specific risk perception factors identified earlier in the process.

The application of tools to define stakeholder roles and relationships, as it pertains to PFAS risk management and public outreach, can help maintain consistency in risk communication and in the messaging among the various parties directly and indirectly involved. Stakeholder mapping tools vary widely and should be chosen based on the specific needs of each outreach strategy (ITRCa, 2020). For Case Study Town #1, an actor-linkage matrix stakeholder mapping tool was used to identify the relative level of influence and interest of the PFAS private and public stakeholders, and the potential need for relationship building. For Case Study #2, a responsible–authorize–consult–inform (RACI) matrix stakeholder responsibility charting tool was used to direct the collaboration and decision-making process for preparing and distributing outreach materials and for performing community engagement events. These two approaches were selected based on the specific needs for each community given the existing stakeholder relationships.

In addition to the process described above, for Case Study Town #2, the development of the risk communication and public outreach strategy was facilitated by a town-wide PFAS communication team that was comprised of multiple municipal departments and facility operators. The study team facilitated the development of a PFAS communication team charter and held meetings to collect input on the proposed public outreach strategy, and then refined the strategy based on the feedback received. Due to the novel coronavirus COVID-19 pandemic, all activities, including both the communication team and public town meetings, were completed virtually using interactive meeting tools (Adobe Connect and Zoom, respectively). Interactive features were used
during the communication team meetings, such as sticky notes and text boxes, which enabled town-wide communication team members to provide simultaneous “real time” feedback on the meeting topics. This empowered the meeting participants among multiple departments and facilities to contribute and to participate in the meeting discussion. Although these virtual engagement tools proved to be effective for Case Study #2, especially during the Covid-19 pandemic, this study does not evaluate the relative effectiveness of virtual engagement as compared with traditional, in-person engagement methods. A good rule of thumb for any engagement, virtual and in-person, is to assess whether all applicable stakeholders and community populations are present.

The background, contextual details, and key issues that were addressed through public outreach for each of the case studies are discussed in the following sections.

2.2 | Case Study Town #1

In this case study, PFAS contamination had affected the underground aquifer, which is a drinking water source for the region, including Town #1. Town #1 is not directly responsible for the extraction and treatment of the source water, and instead purchases the treated water from a different municipality. At the time of preparing the outreach plan, PFAS had only been detected at the source water wells and sampling had not been performed within the distribution system of either municipality. The study team prepared an outreach plan for communication of sampling results from the distribution system located within Town #1. Key issues to address through public outreach in this case study included: communication of Town #1’s plan for sampling and mitigation (if applicable) to the residents, businesses, and other customers; communication of PFAS sampling analytical results that accurately and clearly portrayed the potential risks to residents and customers of Town #1; and navigating the relationships between neighboring municipalities in a way that maintained positive and transparent communication.

2.3 | Case Study Town #2

In this case study, Town #2 performed a preliminary assessment to define the community-specific PFAS cycle, resulting in the identification of known or potential discrete releases affecting an underground aquifer used as a drinking water source. The PFAS cycle also considered the potential consumer use of PFAS-containing household and commercial products that may affect landfill municipal solid waste, and wastewater treatment and residuals handling processes, including the land application of compostable general refuse and biosolids. The study team prepared an outreach plan for communication of the Town #2 PFAS cycle assessment results, the ongoing efforts to refine the assessment findings, and the proposed short- and long-term source control and reduction action items. Key issues to address through public outreach in this case study included: communication of applicable regulatory frameworks for differing environmental media that are likely or known to be impacted; communication of municipal department and other public stakeholder roles in PFAS assessment and management; and communication of PFAS sampling analytical results that accurately and clearly portrayed the potential risks to residents and customers of Town #2.

3 | RESULTS

3.1 | Case Studies Town #1 and #2: Community risk perception factors

A review of publicly available news coverage and social media activity informed the identification of PFAS-specific community risk perception factors (Harclerode et al., 2016; ITREc, 2020). These factors also incorporated findings of the demographics assessment. A summary of each case study’s community risk perception factors pertaining to the potential PFAS impacts within their community is presented in Table 1. The risk perception factors are sorted into three categories to represent the three major themes identified within the public experience of pollution exposure (Bickerstaff, 2004). A case study-specific assessment of the community risk perception factors is presented in the following Results sections. An evaluation of both case studies’ findings regarding community risk perception factors is presented in the Discussion section.

3.2 | Case Study Town #1: Community assessment findings

A summary of Case Study Town #1’s community risk perception factors that pertain to the potential PFAS impacts to a drinking water source is presented in Table 1. The study team reviewed:

- Eleven articles from local news sources discussing local and regional PFAS issues
- Seven Facebook and Twitter posts that garnered substantial community discourse (ranging from 4 to 20 comments)
Case Studies Town #1 and Town #2 per- and polyfluoroalkyl substances (PFAS) specific community risk perception factors

| Place and locality | Trust and communication | Agency and power |
|--------------------|-------------------------|-----------------|
| • Unknown extent of health impacts of exposure to PFAS (drinking water, biosolids use, and occupational use of firefighting foam) | • Desire for consistent messaging throughout all of the municipal departments, neighboring utilities, and associated stakeholder organizations | • Demographics, low-income households, minority populations, and non-English speakers |
| • Unknown extent of water supply issues (public and private well contamination) | • Importance of establishing a regularly-updated timeline of events to help ensure understanding of actions and key events | • Awareness of impacted water supply resources and land-applied biosolids |
| • Potential unknown sources from business and household use of consumer and commercial products | • Public desire to identify responsible party(ies) and enforce accountability measures | • Ability to participate in the decision-making process |
| • Need for periodic sampling and reporting protocol | • Lack of confidence among some stakeholders in regulatory authority, public utility, mitigation measures, and treatment technologies | • Accessibility to experts and medical professionals |
| • Resources (drinking water and biosolids use) impacted by PFAS sources are associated with employment and local economic stimulus | • Gratitude and relief for public water supply (and other media) sampling and proactive communications | • Ability to treat public and private source water |
| • Potential lack of confidence in closed-loop municipal systems that have been impacted by PFAS contamination | • Need for clarity of information and knowledge transfer | • Ability to reduce and eliminate PFAS product use within the community |
| • Potential impact of PFAS contamination on property values | • Isolated events of distrust noted due to previous delays in communication of potential PFAS impacts to the community | • Financial limitations of community members to reduce use of PFAS products and/or treat private well water |
| • Potential impact of PFAS contamination on tourism and the local economy | | • Role and extent of state and federal oversight and regulations to address public health concerns |
| • Potential impact of PFAS contamination on ecological assets, including food sources such as fish, shellfish, and deer | | |

Overall, the Case Study Town #1 community assessment findings are as follows:

- Based on Facebook comment discourse, the public was generally uncertain regarding the protectiveness of the USEPA PFOA and PFOS HAL.
- Some members of the public had connected the potential PFAS contamination to an entity that was a significant employer for the area. Online discussions touched on concerns that pursuing source mitigation action could affect the local economy.
- Various members of the community demonstrated a lack of access to resources to support their understanding and response to PFAS exposure. For example, one member of the community commented on a post made by the local newspaper inquiring whether a point of entry treatment (POET) system existed for PFAS treatment. Other members of the community expressed a desire for researchers or medical professionals to be made available to support the town.
- In general, there seems to be an overall lack of understanding and distrust with authorities around the potential health concerns related to PFAS.
- Some connections were made by community members connecting their community’s PFAS issue to the lead-impacted drinking water issues in Flint, Michigan.
- Both social media discussion and news coverage reflected a concern that Town #1 and another primary stakeholder were not communicating or cooperating. There is also a general concern about a perceived lack of testing being performed and a reporting of that testing.

### 3.3 Case Study Town #1: Public outreach strategy

Town #1’s primary PFAS management activities pertained to drinking water supply sampling activities. The outreach strategy that was developed centered on the potential results of sampling and on communicating the relative risk to the public based on the potential results. The outreach strategy was framed around three stakeholder engagement decision factors based on potential sample result scenarios: (1) results were non-detect, (2) PFAS were detected but below screening levels, and (3) PFAS were detected above screening levels.
A summary of how the community assessment informed outreach strategy development is shown in Table 2. In general, the key message topics derived from the community assessment findings and the risk perception factors focused on the communication and implementation of the ongoing sampling results. It also focused on connecting community members with resources to answer questions and to assuage community concerns over the exposure risks and the mitigation of contamination.

The community assessment also identified the need for consistency in messaging between the different utilities that may serve overlapping communities or closely-connected geographical areas. The municipality decided to manage this finding internally among utility stakeholders and not include the geographical aspects in key message topics for public-facing materials to avoid adding further complexity in communicating PFAS issues with the general public. Stakeholders and their relationships were mapped using an actor-linkage matrix to categorize them in similar, or compatible, groupings and to establish the nature of each relationship, as shown in Figure 3. This stakeholder mapping tool helped identify the relative level of influence and interest of PFAS private and public stakeholders, and potential need for relationship building. The outreach strategy, as laid out in the final plan deliverable, called for iterative updates and the

| Select community assessment findings                                                                 | Select community per- and polyfluoroalkyl substances (PFAS) risk perception factors                                                                 | Select key message topics                                                                 |
|-------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Community concern regarding chronic PFAS exposure and lack of information about and access to POET systems | **Current lack of confidence in regulatory authority, public utility, mitigation measures, and treatment technologies**                         | Interim mitigation measures are available and being implemented and description/efficacy of treatment technologies |
|                                                                                                      | **Health impacts of PFAS**                                                                                                                        | Communicate results of drinking water distribution sampling and the relative risk of exposure based on the sampling results |
|                                                                                                      | **Water supply issues (well contamination)**                                                                                                     | Drinking water with PFOA + PFOS above HAL may pose a risk to human health |
| General community concern observed regarding perceived lack of testing or communication of testing results | **Periodic sampling and reporting protocol**                                                                                                     | Short-term actions performed to mitigate exposure to PFAS levels above HAL |
|                                                                                                      | **Ability to participate in the decision-making process**                                                                                        | Long-term treatment will be evaluated to perform PFAS source control, reduction, and mitigation |
| Community discourse indicated lack of access to supportive resources and distrust of authorities      | **Accessibility to experts and medical professionals**                                                                                            | Town teamed with drinking water treatment and public health PFAS experts |
|                                                                                                      | **Ability to treat source water**                                                                                                                 |                                                                                     |
|                                                                                                      | **Health impacts of PFAS**                                                                                                                        |                                                                                     |

Note: Table does not include all of the findings, risk perception factors, and key message topics identified, rather, it offers examples of the process to prepare messaging themes based on the risk perception factors identified. Bolded indicates a risk perception factor relating to place and locality. Italicized indicates a risk perception factor relating to trust and communication. Underlined indicates a risk perception factor relating to agency and power.

Abbreviations: HAL, human health advisory level; PFOA, perfluorooctanoic acid; PFOS, perfluorooctane sulfonic acid; POET, point of entry treatment.
consistent monitoring of local news sources, close communication with other utilities, and triggers for updating the strategy if other utilities identified PFAS contamination within their distribution systems or engaged in public communication regarding PFAS issues.

Based on the complicated stakeholder relationships, different communication needs and strategies were identified for the public, as opposed to the communication approaches that would be used with the other municipalities or utilities that used the same source water. Through the desktop review, it was determined that the state environmental regulatory agency had prepared analytical letter templates to help communicate PFAS sampling results. These templates were identified by the project team as an acceptable starting point for public-facing communications prepared under this outreach strategy. A different format, such as email or memorandum, would be acceptable for internal or intra-decision maker communication. A press release was also identified as the preferred communication method with news media and other local press outlets.

Due to circumstances outside of Town #1’s control, sampling had not yet been performed of their distribution system, so insights into the efficacy of the communication strategy could not be evaluated. However, the creation of a detailed outreach strategy, as well as triggers for revisiting the strategy if regulatory or PFAS cycle conditions change, has enabled the municipality and utility to be pencil-ready in the event of sampling authorization. This proactive strategy also prepares for the event of a neighboring utility detecting PFAS within their distribution system. Developing a public outreach strategy, in advance of completing PFAS assessment activities that may require public communication, enables timely response to the results of sampling if risk mitigation is required. It also enables a communication of the results to the public in a time-effective manner.

3.4 | Case Study Town #2: Community assessment findings

A summary of Case Study Town #2’s community risk perception factors that pertain to potential PFAS impacts to a drinking water source and other PFAS cycle components is presented in Table 1. The desktop assessment included:

- Review of 13 articles from local news sources discussing local, regional, and national PFAS issues
- Review of website and social media activity (Facebook and Twitter) associated with two community organizations advocating for PFAS remediation from the town
- Discussion with town stakeholders of community concerns voiced during previous public meetings
For Town #2, the social media accounts of local news sources were also reviewed, but few posts were made regarding PFAS issues, and no posts were identified that had garnered substantial comments and dialogue from community members.

Overall, the Case Study of Town #2's community assessment findings are as follows:

- Based on local news coverage, PFAS groundwater contamination is a prominent environmental issue among public correspondence, driven largely by high-profile investigation and treatment projects in the regional area.
- Given the presence of multiple small airports in the regional area, the relationship between aqueous film forming foam (AFFF) and PFAS contamination of groundwater has been well-documented by local news agencies and generally understood by the public. However, the role of the municipality versus the responsible party for addressing PFAS contamination due to an AFFF release is not well understood by the general public, whereby the community is perceiving the municipality as being involved in the regulatory cleanup process.
- PFAS are generally understood by the public and the local news agencies to be persistent, widespread, and dangerous to human health. There is also a general concern among the community for firefighters who may have been exposed to AFFF or interact with equipment that has been contaminated by AFFF.
- The tone of the social media activity of a community action group reveals a desire for the source to be identified and for the responsible parties to be held accountable for the environmental and public health consequences.
- There is a general tone of gratitude and relief in the community organization posts that the municipal water department is performing testing of drinking water sources.
- The municipality utilizes environmentally friendly and sustainable systems for drinking water, wastewater, and solid waste, and this is a source of local pride. A consequence of these systems is that wastewater treatment residuals, possibly containing PFAS, were land-applied as beneficial reuse biosolids. The community has expressed concern on whether they are or were exposed to PFAS due to the land application of biosolids and the subsequent consumption of vegetables and other plants grown in the biosolids.
- A portion of the population uses a private potable well for drinking water, and there have been independent sampling efforts of some private wells.

### 3.5 Case study town #2: Public outreach strategy

Town #2 is characterized by a generally highly-engaged public with a strong interest in the issue of PFAS contamination of drinking water and land-applied biosolids. During the desktop review, multiple citizen-led activist groups were identified as having a strong interest in the evolving PFAS issues within the municipality. Similarly, the local newspaper had been providing close coverage of the issues since the first PFAS detection in 2019. Together with anecdotal feedback from municipal intra- and inter-departmental representatives, it was clear that high levels of public interest in this issue necessitated a proactive public outreach strategy approach from the municipality.

Additionally, the presence of multiple sources (both commercial and industrial) of PFAS contamination, and the fundamental difference in those sources presents a risk communication challenge with respect to the origin of PFAS detected in the drinking water source and biosolids. The desire among the public to identify the responsible stakeholders and call for accountability is complicated by the PFAS cycle, in that one of the PFAS sources identified is general refuse from usage of PFAS-laden commercial products by the community, and thus cannot be attributed to one stakeholder.

Town #2 had multiple stakeholders with varying levels of responsibility and capacity for PFAS action but are all technically affiliated with the municipal government, although some maintain substantial operational autonomy from the central municipal government. As a result, it was identified during the desktop review process that the communication strategy would require some form of collaborative framework. In this way, there would be a facilitation of the strategy implementation and decision-making among all of the municipal government stakeholders, as the understanding of the PFAS cycle developed. A communication team was formed specifically to facilitate multi-stakeholder collaboration in the development and implementation of the PFAS public communication and outreach strategy. The communication team consisted of one representative from each of the municipal intra- and inter-departmental stakeholders.

Several tools were created to support the municipal communication team, including a charter comprised of a mission statement, engagement rules, team member roles and responsibilities, and critical success factors. A RACI matrix responsibility charting tool was also used to direct the collaboration and decision-making process among communication team members when preparing and distributing outreach materials and performing community engagement events. An example completed RACI matrix
is shown in Figure 4. For the engagement decision factor shown, the town administration would be responsible to prepare and finalize draft materials, while all other stakeholders would be consulted as necessary in the material preparation, or informed that materials were being prepared. The roles would shift for each later stage of the material preparation process. The study team facilitated virtual, web-based workshops with the communication team members in order to complete group visioning and brainstorming exercises that guided the development of the charter and established priorities of the team.

The outreach strategy developed in collaboration with the communication team involves an iterative process that facilitated periodic updates to the communication strategy as new PFAS data are collected. These updates include public inquiries that are received and changes to the regulations or scientific understanding of PFAS as well as the effects to the community-specific PFAS cycle, including risks or exposure. Community risk perception factors informed the development of communication and outreach materials, specifically related to the content and messaging that address the community’s needs and concerns. The formulation of the core messages of the outreach strategy is summarized in Table 3.

Town #2’s public outreach strategy consists of updating and maintaining a municipal PFAS website with frequently asked questions and fact sheets. Targeted communication materials, such as a press release and a community forum, were integrated into the outreach strategy as needed, based on the nature of the communication.

### 4 | DISCUSSION: COMMUNITY ASSESSMENT FINDINGS

Overall, there were common themes among Town #1 and Town #2’s PFAS-specific community risk perception factors. Table 1 provides a full list of all risk perception factors identified for both case studies, and demarcates which factors were common and which were unique. Both communities had risk perception factors related to the need for transparent communications and decision-making on behalf of the municipality and the PFAS decision makers. Both communities were also concerned with access to financial assistance for implementing POET or other mitigation measures, as well as technical assistance in understanding the PFAS cycle, public health risks, treatment mechanisms, and whether their respective municipality was responding appropriately. Both communities also had similar risk perception factors related to stakeholder relationships and cooperation, including the community’s participation in the decision-making process.

There were unique themes to each community’s risk perception factors, generally related to the stakeholder engagement decision factors each town’s public outreach strategy was to address. In Town #1, there was community distrust of the screening level that applied to the sampling activities performed in this state (the EPA HAL of 70 ppt). The utility stakeholder relationships were clear to the community; however, they contributed to a level of distrust due to conflicting messages among stakeholders. In Town #2, a more robust understanding of PFAS sources had already been established, so the community risk perception factors expanded beyond risk to drinking water resources and to include other environmental media (such as biosolids), ecological resources (such as fish and deer), and quality of life impacts (such as property values). In contrast to Town #1, Town #2’s stakeholder cooperation was important as a way to effectively communicate the distinct (but not contradictory) projects that were undertaken by different town departments. Gratitude from the community was expressed regarding how Town #2 was proactive with the sampling and the communication of results. However, a level of
| Select community assessment findings | Select per- and polyfluoroalkyl substances (PFAS) community risk perception factors | Select key message topics |
|-------------------------------------|---------------------------------------------------------------------------------|--------------------------|
| Statewide and national actions on PFAS issues influences community perception and stakeholder response at a local level, including town actions and spending decisions for PFAS sampling and assessment | Role and extent of state and federal oversight and regulations to address public health concerns Gratitude and relief for public water supply (and other media) sampling and proactive communications Need for clarity of information and knowledge transfer | Town is in compliance with applicable regulations, and collaborating with regulators and other PFAS decision makers on assessment and related activities PFAS regulations and standards are specific to sample media and exposure routes, and cannot be applied broadly to multi-media sampling results |
| PFAS are generally understood by the public and the local news agencies to be persistent, widespread, and dangerous to human health | Ability to treat source water for potable consumption Ability to reduce personal exposure Ability to reduce and eliminate PFAS-laden commercial product use Impacted resources are associated with employment and local economic stimulus Potential impact of PFAS contamination on property values, ecological resources, and local economy | A plan to further assess and eventually control or mitigate PFAS loading to public water supply is underway Home filters and treatment systems are available to remove PFAS from private water supply sources Community can play a role in reducing PFAS loading from general refuse and other commercial products Sampling is being performed in the interest of protecting the health and financial well-being of the community, drinking water sources, and natural resource assets |
| Desire among community groups to identify responsible stakeholders and hold them accountable | Unknown extent of health impacts of exposure to PFAS Unknown extent of water supply issues Potential unknown sources from business and household use of PFAS-laden consumer and commercial products | PFAS Cycle has been developed and will continue to be updated with new data to continue to evaluate potential sources, receivers, and routes of exposure to receptors |
| Several stakeholders pursuing independent PFAS-related actions with separate communication strategies | Desire for consistent messaging throughout all of the town departments and associated stakeholder organizations Importance of establishing a regularly-updated timeline of events to help ensure understanding of actions and key events | Town is proactively collaborating with the communication team and other affected stakeholders to educate and engage the public with consistent messaging |
| Several citizen-based action groups identified as having high levels of interest in PFAS issues | Ability to participate in the decision-making process | Town is proactively communicating with the public via town meetings and communication team collaboration Community input can be provided via a designated email and hotline |

Note: Table does not include all of the findings, risk perception factors, and key message topics identified, rather, it offers examples of the process to prepare messaging themes based on the risk perception factors identified. Bolded indicates a risk perception factor relating to place and locality. Italicized indicates a risk perception factor relating to trust and communication. Underlined indicates a risk perception factor relating to agency and power.
distrust was also present due to the delayed communication of other sampling events and result findings. The differences in community risk perception factors between Town #1 and Town #2 stress the importance of performing a community-specific assessment in order to inform communication materials and outreach strategy development.

Identified community risk perception factors can be used as metrics to evaluate the community’s response to the municipality’s (or other organization’s) PFAS management activities, as well as its ongoing public outreach efforts. As the outreach strategy is implemented, community risk perception factors evolve and may need to be updated to include new information that is obtained during public outreach meetings or from information presented in public comments. The outreach strategies were developed within an iterative risk communication planning framework in order to streamline the updates to the existing communication materials and to refine the communication methods to align with the community’s expectations and needs.

A primary limitation to the community assessment approach is the lack of data collected directly from the community under evaluation through the use of surveys or similar methods. However, the community assessment phase can serve as an important screening process to preliminarily identify community concerns and focus further outreach efforts, including surveys. The desktop community assessment findings for Case Study #2 were validated via truth-checking with the town-wide communication team and by comparing these findings to public inquiry to the town directly via email, phone calls, and comments during town meetings.

A review of the community demographics can also help identify and confirm the community outreach considerations. These considerations may include financial support to low-income populations, the translation needs of outreach materials, and the sensitivity to existing environmental and social justice inequities. This review is only the first step to incorporating environmental justice into the outreach strategy. Ultimately, adequate consideration of environmental and social justice would require involvement of community liaisons in the decision-making process to understand what unique outreach and risk management considerations may be applicable to their community. Although Case Study #2 focused on liaising with community stakeholders and affected property owners, the best practice is to not only confirm all interested parties are engaged but also to assess demographics of engaged citizens in comparison to the community demographics and track website user data.

5 | DISCUSSION: PUBLIC OUTREACH STRATEGY FINDINGS

Despite differences in the stakeholder engagement decision factors for each town, there were general themes consistent between them. For both communities, the representatives of the municipality, utility, or department directing and planning the outreach process are also citizens of their respective town. Therefore, they feel an obligation to their community to protect them from PFAS public health risks. This need inspired the consistent themes of urgency and transparency in both of the outreach strategies, as both towns favored strategies that would facilitate the quick turnaround of new data or information to help understand the community’s PFAS exposure and respond to the citizen’s inquiries.

A key lesson learned during outreach strategy development was that the available demographics data may not accurately reflect the nature of the community, and that “ground-truthing” is required to confirm that the observations of community demographics during the desktop review are accurate. “Ground-truthing” may consist of solicitation of any previously conducted demographics studies performed by the municipality (or another stakeholder) to validate the current understanding of the community demographics, as well as engagement of community stakeholders such as schools, community centers, and faith-based organizations. “Ground-truthing” should also be applied to the identified community risk perception factors based on the desktop review. During the outreach strategy development, these factors were discussed with the municipality, utility, and other intra- and inter-departmental municipal stakeholders in order to validate, revise, and add to identified community risk perception factors.

Due to the COVID-19 pandemic, all community assessment and outreach strategy development activities were performed virtually, including stakeholder workshops. The use of innovative web-based collaborative tools allowed for the successful virtual facilitation of multi-stakeholder workshops during the plan development stage. This helped refine the outreach strategy and identify the related actions to implement the strategy. Future applications of this approach should consider similar workshops in order to collect feedback from the stakeholders throughout the strategy development process and confirm that the plan is actionable. However, it is also noted that exclusively virtual or exclusively in-person engagement may not result in a fully representative picture of the community. Any
outreach strategy should comprise multiple modes of virtual and in-person engagement tools such as neighborhood canvassing and tabling at community events, to communicate and reach the full breadth of a community.

6 | CONCLUSION

The PFAS cycle is technically complex, and mitigation and treatment for PFAS public health concerns are similarly complex. An effective communication approach regarding PFAS issues should account for community-specific risk perception factors in order to address the community concerns head-on. This helps build trust and support within the community for the town (or other PFAS decision maker's) planned approach for PFAS management. A detailed community assessment, in combination with technical expertise with PFAS issues, can minimize opportunities for misperception and misunderstanding, effectively identify significant issues for the community, and build an outreach strategy that will be effective, iterative, adaptive, and inclusive. Risk perception factors represent the intersection between the technical complexity of PFAS issues and the community’s concerns. Municipalities and other PFAS decision makers should strive to be innovative in their public communication approach and be open to working with multiple stakeholders, including the community, in defining the PFAS cycle, risk perception factors, and the preferred modes of outreach. An engaged public should be viewed as an opportunity, rather than a barrier, since strong public engagement results in successful, sustainable risk management solutions.

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CONFLICT OF INTEREST

The authors declare no competing financial interests.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no data sets were generated or analyzed during the current study.

AUTHOR CONTRIBUTIONS

Melissa Harclerode: Conceptualization; formal analysis; methodology; writing—original draft. Sarah Baryluk: Formal analysis; methodology; writing—original draft. Heather Lanza: Writing—review & editing. John Frangos: Writing—review & editing.

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