PFAS Scoping Report: Identifying Social and Economic Impacts of PFAS in the Great Lakes and Lake Champlain Regions

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Introduction

The Great Lakes and Lake Champlain regions are potentially impacted by numerous contaminants of emerging concern (CECs). One such group of contaminants is per- and polyfluoroalkyl substances (PFAS), which is a suite of manufactured chemicals with wide applications in products including clothing, cookware, cosmetics, and firefighting foams. These chemicals and their related precursor compounds, metabolites and degradates, collectively referred to as PFAS throughout this document, have surfactant-type properties that make them waterproof, oil repellent, and resistant to stains and high temperatures. Their chemical structure also makes some of them very persistent in the environment, for which they are often labeled as "forever chemicals". While some aspects of PFAS toxicity to humans and wildlife are known, and limited monitoring and remediation efforts are underway, there is still much that is unknown. One particularly challenging aspect of PFAS involves the fact that there are thousands of structures. However, fate and toxicity data are currently available for only a relative handful of these structures and are being collected for some others. This leads to substantial uncertainties when assessing their human health and ecological risks. Like other CECs, PFAS also have implications for those dependent on the resources contaminated by these chemicals. There is anecdotal evidence that marginalized communities and Environmental Justice areas are often disproportionately exposed. However, the socioeconomic impacts of PFAS are relatively unknown.

To promote the assessment of PFAS in the Great Lakes and Lake Champlain regions, including their socioeconomic impacts, Illinois-Indiana Sea Grant (IISG; a partnership between NOAA, the University of Illinois at Urbana-Champaign, and Purdue University) was awarded a grant from the National Sea Grant Office and NOAA in 2022. Through this initiative, IISG will lead a Great Lakes and Lake Champlain regional research effort that is expected to support four research projects to further advance the knowledge of social or economic issues related to PFAS risk, exposure, and remediation in these regions.

The Great Lakes Region PFAS Scoping and Competitive Research project team at IISG includes IISG Director Tomas Höök, Research Coordinator Carolyn Foley, Pollution Prevention Specialist Sarah Zack and Project Coordinator Amanpreet Kohli. The project team identified an advisory committee of eight members to deliberate the best approach to bolster this research effort. Over the course of three meetings, the advisory committee recommended a regional scoping effort to guide the Great Lakes and Lake Champlain regional request for research proposals (RFP). The purpose of the scoping effort was to identify and subsequentially prioritize the knowledge gaps and potential socioeconomic barriers to PFAS evaluations in the Great Lakes and Lake Champlain regions. Details of this scoping effort are discussed in the next section. The competitive research opportunity is expected to open in May 2023, with the overall project, including research and outreach activities associated with the competition, to be completed by September 2025. While the project team sought to identify research gaps and needs specific to social and economic concerns, meetings with the advisory committee made clear that the region could benefit from discussion of additional PFAS-related topics, beyond those within the planned scope of the RFP. Information described in this document extends beyond what is expected to ultimately be included in the IISG-sponsored RFP.

Importantly, the authors of this report acknowledge that the science on PFAS and related compound risk and exposure is ever-evolving. The information contained herein is summarized from discussions and information gathered in early 2023, given what was available to experts at the time. The authors of this report expect that it can be used as one source of information, in conjunction with

other resources, as scientists and policymakers move forward with addressing PFAS contamination in Great Lakes and Lake Champlain regions.

Scoping session attendees and format

Three scoping sessions were organized to review the PFAS state of knowledge, and current and future efforts in the Great Lakes and Lake Champlain regions. These scoping sessions were held virtually in March 2023 with each session focusing on a different thematic area and having a distinct overarching question for the day. The focal areas and questions for the three scoping sessions are as follows:

> Session 1 – PFAS risk and exposure: Which communities are at risk, and what are their sources and routes of exposure?
>
> Session 2 – PFAS mitigation and remediation: What are the socioeconomic barriers to the adoption and implementation of some of the current/proposed solutions, and what are their alternatives?
>
> Session 3 – PFAS governance and prevention: What information is needed to ensure all who live, work and recreate in the Great Lakes region are treated in a just and equitable way with respect to governance and prevention of PFAS contamination and exposure?

Each scoping session featured several presentations, two facilitated discussions in smaller breakout rooms, and many interactive ways to provide information to the project team. Full session agendas and charge questions for the discussions can be found in Appendix I. Presentations from the three sessions, in an ADA compliant format, will be made publicly available on the project website. Over 70 participants from more than 45 federal and state agencies, tribal nations, academic institutions, and consulting firms joined over the course of the three sessions (participant details are listed in Appendix II). Participants outside the Great Lakes and Lake Champlain regions that are doing pioneering work related to PFAS were also invited. The session attendees brought a broad experience of PFAS expertise to the scoping sessions ranging from their work with human health and ecological risks, site remediation, prevention and mitigation measures, and regulations and policies.

Following the conclusion of the scoping sessions, a survey (Appendix III) was shared to gather additional input on sources and routes of exposure for PFAS, awareness level amongst different groups, approaches for risk communication, working towards a regional consensus, and key knowledge gaps. The survey was shared with those unable to attend the sessions as well as those that attended the sessions. Over 50 people participated anonymously in the survey. The ideas shared in these sessions and the survey will directly inform a Great Lakes and Lake Champlain regional RFP. A synthesis of all the knowledge shared in these sessions as well as the survey is presented in the next section. We have also highlighted the key research and information needs.

Key outcomes from the scoping sessions and survey

Main PFAS sources and exposure routes

Several PFAS sources and exposure routes were discussed (see Figures 1 and 2 in Appendix IV and Table 8 in Appendix V for more details). The top sources and routes of exposure are identified below –

1) Ingestion through food and water: Drinking water and fish consumption were listed among the top exposure routes. Water is a basic necessity and PFAS contamination of water can happen via several mechanisms. Water can further be a source of PFAS exposure for aquatic animals and plants (through irrigation water or surface run-off and leaching), and consumption of animals and plants is a route of exposure for humans via their diet. Many people consume fish as a protein source, and PFAS are known to bioaccumulate in some fish species, at some locations. PFAS can also be present in processed food or leach from food packaging to food. As food and water are essential commodities, exposure is inevitable. It was also highlighted that there is an abundance of data for exposure to PFAS through food and water as compared to other exposure routes.

2) Inhalation through air and dust: Another potential route of exposure for PFAS is inhalation through air and dust. Inhalation in a household is possible due to the presence of PFAS in several household products. Occupational exposure to PFAS is also possible in settings like the airport and military facilities as well as through industrial emissions at a PFAS manufacturing site. However, PFAS inhalation through air and dust remains poorly understood.

3) Dermal exposure with consumer products: PFAS are abundant in consumer products such as kitchenware, cosmetics and personal care products, clothing, food packaging, carpet, and paint, and their use is often undisclosed. The infiltration of PFAS in daily life combined with the lack of knowledge leads to high exposure to these contaminants.

Human health and ecological risks associated with PFAS

Various human health and ecological risks were listed by the participants with the following notes when evaluating such risks –

1) Dose varies with exposure route and total dose (cumulative for exposure through multiple pathways) is key for determining health outcomes for humans and wildlife.

2) Type of PFAS would affect associated risks as different compounds are linked to different health outcomes.

3) Much of the information linking PFAS to health risks remains unknown.

Overall, health risks of PFAS to humans include decreased infant birth weights and increased risks for cancers, thyroid issues, and other diseases due to suppression of immune response, including decreased vaccine response. Effects on pulmonary function are specific to ingestion through air.

Health risks for wildlife due to aquatic exposure and bioaccumulation include growth and developmental effects, diminished survival and reproduction success, immune system suppression, and other physiological or behavioral impacts.

Risk communication surrounding PFAS

There was a strong sentiment among the scoping session participants and survey respondents that, because PFAS are ubiquitous, everyone is at risk to PFAS. However, through both the scoping sessions and the survey, several specific groups with known or potentially higher risk levels were identified based on probable exposure.

When discussing risk communication surrounding PFAS in a scoping session, the participants were grouped into the following three groups based on their location –

Group 1: Lake Champlain, Lake Ontario, Eastern Lake Erie
Group 2: Central and Western Lake Erie, Lake St. Clair, Lake Huron, Eastern Lake Michigan
Group 3: Lake Superior, Western Lake Michigan

Across these regions, particular groups with potential to be at higher risk due to unique exposures were –

- All anglers and sea food consumers but especially tribal and subsistence communities, where adults are presumed to be more at risk than children due to the higher consumption of seafood by adults
- Wildlife (deer, wolf, turkey, etc.) and hunters
- Firefighters
- Military personnel
- People who work in or live near industries manufacturing PFAS
- People who live near superfund sites, military installations, airports
- Populations served by municipal water suppliers (surface water) and well-water (ground water) users in rural areas
- People with low income/low accessibility to fresh food and/or people who consume many processed foods

Group 3 further identified residents of Chicago and Milwaukee to be at risk due to contamination reported from Lake Michigan. Northern Minnesota Recreational Tribal Fishing Community was also identified as an additional at-risk population in this area due to their high fish consumption.

Through the survey, we were informed that the awareness about PFAS risks, as well as ways to protect oneself and others, varies amongst these groups but is overall low (Table 9 in Appendix V). Relatively, the most aware groups include manufacturers of PFAS, individuals exposed to PFAS at work (e.g., military personnel, firefighters), and individuals living near major sources of PFAS (e.g., airports, manufacturing facilities) while the least aware groups include tribal, rural, and subsistence communities, and people with private wells. Awareness level was also suggested as low among anglers, hunters, and consumers of commercially caught fish and municipal water. Lastly, certain groups such as adults >50 years old and pregnant or lactating females might also be at higher risk but unaware of it.

When communicating risks to the above listed at-risk groups, approaches that are currently used or can be used in the future include factsheets, trifold brochures, evening virtual meetings or focus groups, incentivized outreach events, citizen advisory groups, and environmental health clinics. Sharing information online via maps of known areas of PFAS contamination along with state agency contacts for questions from the community, as well as using existing programs that educate about fishing, have also been proposed. Encouraging comments during public comment periods for proposed regulations might also be beneficial. For example, a New Hampshire community health fair organized in the evening where government programs, health education departments, advocacy groups and other organizations shared information about the impacts of PFAS found in water near the factories and military bases in the states was well-received. There was also a suggestion that commercial products with known or potential PFAS content should be required to include information on the packaging with use/consumption guidelines, as this has been a way to successfully communicate risk and protect people in the case of other contaminants. However, the limitations of what to communicate and how to communicate make risk communication particularly challenging.

Knowing what information to communicate to different groups is essential for effective risk communication for PFAS. Survey participants identified several informational needs to effectively communicate risk to the at-risk groups who are least aware of PFAS risks and ways to protect themselves and others (Fig. 4 in Appendix V). As various PFAS contamination and exposure routes can be cumulative, it is difficult to ascertain response efforts in some cases. Further, many sources have shared regulatory jurisdictions such that there is a lack of consistent messaging across borders (e.g., differences between fish consumption advisories in different jurisdictions). Without clear guidance from scientists, regulatory authorities, and/or health and other professionals, risk communication can be especially tough. Lack of information further exacerbates the challenge of what to communicate. For instance, individuals may be looking to identify alternatives to replace products that were banned, but in many cases, at this point, such alternatives are unknown. Another example that could provide a challenge is stressing the importance of reducing fish consumption with a community that may rely on fish as a critical nutritional or cultural resource. Additionally, studies are limited and variability amongst the results is high when communicating about levels of PFAS found in fish tissues. Moreover, the few studies that exist lack the use of common methodology and terminology making comparisons problematic. The distinction between health-based guidance and technology-based cleanup criteria needs clear communication. Further, there is a lack of publicly available information from credible and trusted sources such as scientists, extension personnel, government agencies, personal doctors, and laboratories. It was emphasized that funding agencies have a critical role to play to alleviate the concern of lack of information to some extent by funding research that helps elucidate information that can then be communicated to relevant at-risks groups. Lack of information about environmental health, making patient counseling difficult, was also highlighted for health care providers.

Timely and easy access to information is a critical need for effective risk communication. Therefore, knowing how to communicate information to different groups is vital when communicating risks related to PFAS. No single approach can work for the range of groups possibly affected by PFAS. Using the most effective approach for communication involves considering the preferred method of communication for a group, and the perception of the group towards entities such as government agencies and academics. Partnering with organizations like Sea Grant which have fostered strong relations with local communities can be a successful approach.

Mitigation and remediation of PFAS contamination

Session participants suggested that sources of PFAS that are currently targeted or should be targeted for remediation within the Great Lakes and Lake Champlain regions include –

- Military bases
- Airports
- Industrial facilities (metal plating, electronics, automotive, chemicals)
- Oil refineries and bulk fuel terminals
- Agricultural lands with historical application of PFAS (biosolids, paper waste, tannery waste, or other waste materials
- Aqueous film forming foam (AFFF) sources (firefighting use locations and training facilities)
- Publicly owned treatment works (POTWs)
- Landfills
- Municipal water supplies (drinking and wastewater)
- Surface waterbodies, including sediments, due to direct and indirect discharges

Some of the main treatment and remediation solutions available today for PFAS are granular activated carbon (GAC, e.g., PlumeStop), ion exchange resins, deep well injection, plasma technology, smoldering, incineration, pyrolysis (for biosolids), super critical water oxidation (SCWO, e.g., PFAS Annihilator), electrochemical oxidation, foam fractionation, reverse osmosis, pressure destruction (ball mills), photocatalysis (UV technology), excavation and landfilling, phytoremediation, and bioremediation (with fungi). More technologies can be found in Fig. 3 in Appendix IV. These solutions differ in terms of their technical effectiveness, accessibility, scalability, cost-effectiveness, sustainability, creation of harmful by-products, and meeting regulatory guidelines. While most solutions are ex-situ, some in-situ solutions are available including bioremediation, phytoremediation, and soil amendments but they may not completely destroy PFAS and remain in the pilot stages requiring more research and development. These in-situ solutions and other solutions such as plasma technologies have not yet been applicable at a large scale. Commercially scaled technologies such as GAC, ion exchange, SCWO, incineration, and foam fractionation have prohibitive costs (~$12-16 million/pound of PFAS), vary in their effectiveness, and are energy intensive with a big carbon footprint, which can make them unsuitable as long-term solutions. Methods like reverse osmosis, foam fractionation, and excavation and landfilling generate extremely concentrated waste streams and air emissions. For destruction of such concentrated wastes, SCWO can be a very effective treatment. Deep well injection is also a solution for disposal of such wastes but with a limited capacity.

As discussed above, cost-effective solutions are rare. Participants suggested that the burden for treatment costs needs to shift away from the municipalities and taxpayers and towards the parties responsible for PFAS contamination. For instance, in-home drinking water GAC filters have high installation and maintenance costs which may preclude residents being able to effectively implement this as a solution. Participants noted that PFAS manufacturers often do not have permit limits, plus that lack of mitigation of PFAS in discharge from facilities or homes means that treatment cost is borne by POTWs. Finally, participants suggested implementing PFAS screening of waste products intended for land application, and developing standards for acceptable soil concentrations of PFAS in agricultural lands. It should be noted that the concern about costs passing on to others is also present in the case of agricultural lands, as those managing the lands may not have the funds to support large-

scale remediation if their levels exceed levels deemed safe. Participants suggested that a policy approach focused on controlling PFAS at sources, preventing discharge of PFAS, and even banning PFAS use may be warranted. However, with multiple levels of jurisdiction, implementation and oversight of such policies will be challenging.

PFAS governance and prevention at the state level

Scoping session participants and survey respondents had much to share regarding challenges and opportunities surrounding PFAS governance and prevention. States in the Great Lakes and Lake Champlain regions have invested, at different capacities, in PFAS monitoring and surveillance, pollution prevention, public engagement, and research efforts in addition to setting up and enforcing environmental guidelines and regulations. While public drinking water supplies are benefitting from several states adopting maximum contaminant levels (MCLs) and treatment methods, there is resistance from private well owners and homeowners for treating water given the cost. Fish consumption advisories have been issued by many states to protect their residents from PFAS exposure, but trigger levels for the advisories vary from state-to-state, leading to variable degree of protectiveness. The level of public awareness and adherence to these advisory recommendations is also unknown. Moreover, certain tribal or subsistence communities may not have reasonable alternatives to fish consumption as a source of key nutrients, especially protein. An overall lack of risk communication also results in the general population being unaware of potential health effects of PFAS. Product bans have been issued in some states but enforcement of the ban has been particularly challenging due to the ambiguities in defining PFAS and lack of testing. While some bans have also been directly met with resistance from the manufacturers, in other cases, changes are already being incorporated for manufacturing of certain products. For example, AFFF manufacturers have switched from PFAS to non-PFAS formulation, but the cost of cleaning fire trucks is being borne by the fire departments. However, it is too early to detect the effectiveness of this action. Data sharing, even though slower than ideal, between the state agencies and tribes has increased but bureaucracy tends to interfere with this especially for ecological data. More details about PFAS strategy of different states can be found in Tables 1-7 in Appendix IV.

Challenges to adopting a regional consensus

Despite the efforts by different states, it has been abundantly highlighted that like other CECs, PFAS also require combined, integrated efforts across regions, from countries to states to Tribal Nations. A prime reason for this is that contamination is widespread even though there might be only a few key polluting sources. For instance, even though PFAS are not manufactured in Canada, the problem of water contamination is shared between US and Canada. Also, regulations suitable for one purpose may not adequately represent the interests of all stakeholders. For example, tribal lifestyle may present additional exposure to contamination that couldn't necessarily be considered in state or federal negotiations. Finally, like other CECs, several challenges arise when adopting consensus on a regional scale on how to best remediate, mitigate, or prevent PFAS contamination. Some of these challenges are discussed below.

- Identifying sources and financial responsibility – While non-point sources are harder to identify and monitor, scoping session participants and survey respondents suggested that focusing on point source(s) will help enforce the appropriate regional regulations. This will also help investigate the extent of remediation needed and shift the financial responsibility to the polluting party, which can otherwise be a large challenge for all federal, state, and tribal governments.

- Setting regulations – Setting effective regulations has been challenging because regulating PFAS as a class of contaminants has received pushback from some groups. The regulations (e.g., product bans) that do currently exist face enforcement issues and have timelines associated with them. Moreover, due to numerous exposure routes, different agencies need to be involved as substances are regulated independently for PFAS (e.g., water, food, and consumer products) and inter-agency decision-making can be challenging.

- Political boundaries – The regulation issues discussed above are further complicated by presence of political boundaries and different levels of government. Dispersion of funds and the process of establishing policies and regulations, among other things, vary at different governmental levels. Logistics of inter-governmental decision making can delay consensus and action. Regulations across states vary from one another and from those at the national level, and there are limited binational strategies for addressing PFAS contamination. To determine the best management practices for PFAS remediation, scoping session participants and survey respondents suggest that there is a need to form regional (interstate and binational) working groups or access groups like Interstate Chemicals Clearing House and Interstate Technology and Regulatory Council which are already working on PFAS. Additionally, at times, proposals for new regulations are met with strong resistance from those responsible for production and distribution of contaminants. This reinforces the need to effectively and efficiently communicate the known level of risk associated with PFAS, as well as the potential level of risk if left unchecked.

- Geographical boundaries – Regulations not only vary across political boundaries but also geographically, which can further make setting consistent regulations or mitigation options complex. For example, within a region, geology and depth to ground water, as well as resource use, can be different which can in turn alter the effectiveness of particular remediation strategies.

- Knowledge gaps and data sharing – The challenges of what to communicate and how to communicate discussed earlier in this report in the context of risk communication also perpetuate the delay in adoption of a regional consensus on PFAS mitigation and remediation efforts. Scoping session participants and survey respondents strongly indicated that more research is needed for understanding the toxicology of PFAS, and establishing standards and best treatment methods. However, the level of research and monitoring efforts vary amongst states and nations and reliable, high-quality data that allows comparison and trend assessment is lacking. Also, sharing of information, especially health impacts, in a timely manner with consumers is important for success of efforts. For example, information isn't always widely shared from state to tribes in time or as actionable items.

- Involving end users of the information – Adopting a regional consensus for mitigation and remediation of PFAS can also be hindered when the various entities affected by actions or

lack of action are not involved early on. The individuals who are potentially most exposed to and affected by PFAS can be difficult to identify and reach (e.g., coastal communities that rely heavily on locally caught fish), and are not typically included in these interstate or international groups.

Research and knowledge needs

There are numerous research and knowledge needs surrounding PFAS in the Great Lakes and Lake Champlain regions. Selected results are presented in Appendix V (Tables 10 and 11) of this report. The gaps listed below represent a brief summary across all information gathering methods.

1) Sources of PFAS – A better understanding of the several potential sources of PFAS in the environment is needed. This will help prevent exposure and improve detection of PFAS across different locations.

2) Fate and transport of PFAS – PFAS are persistent and their fate and transport in the environment is understudied. More sophisticated modelling is needed to predict the complex nature of PFAS and their precursors. Research on fate and transport of PFAS in the environment, especially atmospheric transport, transformation and deposition, can help us understand their long-term trends in the environment. While some exposure routes have been studied, an understudied route is inhalation through air and dust. Research is also needed to understand crop uptake, ecosystem cycling of PFAS, and role of precursors, degradates and metabolites as potential long-term sources in soil and sediments.

3) Human health impacts of PFAS – More studies need to be conducted on human health impacts of PFAS and how specific exposures link to particular impacts. Related to this, consistent standards for consumption limits of PFAS and public awareness of the risk and consumption limits would be beneficial. While monitoring PFAS in humans (e.g., in serum) is extremely costly, there is a need for this information in addition to that modeled from animal exposure data.

4) Ecological impacts of PFAS – Information on links between PFAS exposure and ecological effects is essential. This should include assessment of impacts on fish and wildlife (including birds and mammals), and also on organisms not traditionally researched (e.g., wild rice, aquatic plants). Research areas include basic toxicological effects of PFAS to ecologically relevant species, and bioaccumulation of PFAS with respect to trophic level, food sources, sex, age etc. For example, it appears that some PFAS accumulate fairly readily in rainbow smelt in some areas of the Great Lakes but smelt usually are less prone to substantial bioaccumulation of other types of organic chemicals than fish at higher trophic levels. In terms of population-level impacts, there is a need to identify those species which are more/less susceptible to PFAS based on their exposure and innate sensitivity to PFAS of concern.

5) Spatio-temporal variability of PFAS – PFAS concentrations and exposure levels differ by state, province, country, etc. It is important to understand the variations in PFAS levels in the environment with time and in different locations. When comparing variations in PFAS levels in different locations, it is important to compare PFAS levels in fish tissues from different locations, e.g., are Great Lakes region fish more contaminated than ocean fish? And if so, why?

6) Drivers of PFAS toxicity – Little is known about the differences in toxicity of PFAS based on the exposure routes or effects on different endpoints. Questions such as how much does toxicity depend on diet and what is the combined toxicity through multiple exposure routes remain unanswered. For most PFAS, there are very little to no toxicity data for informing the estimation of risk.

7) Quantification methods for PFAS – Analytical capabilities for PFAS are limited due to the high cost, but concentration comparisons in different media across space and time are needed.

8) Alternatives to PFAS – Product bans are currently met with resistance not only because of their economic impacts but are due to the lack of sustainable alternatives. Information about alternative products to avoid regrettable substitutions can ease product phase outs.

9) PFAS and traditional practices – Knowledge related to how exposure and consumption translate within the context of traditional knowledge is limited. Differences in PFAS exposure of different communities are not clearly understood. It needs to be researched if some communities are at a higher risk because of consumption of fish on a regular basis. Moreover, tribal water and other resources are often tested less than non-tribal water and other resources, further limiting our knowledge of exposure to PFAS in these communities.

10) PFAS exposure prevention actions – Continuous guidance on which actions are most effective at reducing or preventing PFAS exposure is sought by the public.

11) PFAS mitigation and remediation methods – Research is underway for determining the most effective and cost-efficient treatment methodologies for PFAS. Considerations for determining the best method include complex mixtures of contaminants present at sites and technologies for dilute waste streams versus concentrated waste streams. There is also interest in determining the relative ease of removing/treating long-chain PFAS as compared to short-chain PFAS.

12) Land application of PFAS – To inform PFAS efforts in the Great Lakes and Lake Champlain regions, impacts of historic land application on PFAS levels need to be investigated. Standards to understand the risk levels associated with soil concentrations of PFAS in farm land need to be developed. Furthermore, both land application and non-hazardous landfill leachate need solutions for sustainable operational practices.

13) PFAS and private well contamination – A better understanding of groundwater contamination and the risk to private well owners is needed, especially in areas where PFAS have been manufactured or released. The potential for self-contamination of private wells with PFAS by septic systems also needs to be understood.

14) Wastewater treatment plants and PFAS – As the operation of wastewater treatment plants cannot be stopped, there is a need to find solutions for their sludge which can be overloaded with PFAS (as well as other contaminants).

15) Effective policy for PFAS – Effective policies and regulations controlling PFAS production and discharge are needed.

16) Public perception of PFAS – While the harmful effects of PFAS are understood to some extent, the public perception of these impacts remains unknown. It is not understood if there is enough awareness about impacts of PFAS in public, and if the degree of impacts is enough to mobilize and demand action by the public. For the community to be engaged with and

support the actions against PFAS, there needs to be more scientific data to support the actions. Information about what is not known, as well as why people should act now, should be shared with the public.

Given the current amount of funding IISG has available to support research projects, and the feasibility of accomplishing activities within the timeline of the overall grant, the IISG-sponsored RFP to be issued in May 2023 is expected to prioritize research that addresses challenges associated with some combination of items 3, 8, 9, 10, 11, 15, and 16, as well as social science, economics, and policy questions surrounding any particular group identified in any item. Particular research priorities will be clearly listed in the RFP document which will be separate from this report. The authors of this report encourage individual Sea Grant programs and other organizations to consider supporting research to address any and all of the research and knowledge needs identified throughout this document.

Conclusion

There is recognition that little enough is known about PFAS at the moment. PFAS are widespread which makes their source and exposure route identification difficult. Risk amongst communities is assumed to vary based on several factors including diet (fish consumption), occupation, and location which may stem from social justice issues. Reducing human exposure will likely take many years of education across multiple industrial sectors (producers) as well as consumers and organizations that make large consumer decisions--e.g., packaging, clothing, food, education, etc. Presently, risk communication, and therefore overall awareness for PFAS, is considered to be low in the public.

It is believed that public is not currently benefiting from the current state of affairs. Phasing out products needs sustainable alternatives which are currently lacking. Water treatment facilities may be hesitant to acknowledge the potential for contamination due to the risk of negative public perception. Regulations are still being developed as regulatory changes face resistance from industries due to economic impacts, in addition to numerous other challenges. This creates a divide between the regulators, regulated entities, and the public as the regulators have limited resources and the burden lies on the regulated entities but the public wants immediate actions. Mitigating and remediating PFAS is challenging with the current lack of knowledge. Where remediation and prevention are likely, the solutions are expensive and take a long time. To effectively address the issue of PFAS, a multidisciplinary approach involving toxicologists, environmental engineers, epidemiologists, policy makers, and legal experts, as well as a well-engaged community is needed.

APPENDICES

Appendix I – Scoping session agendas and charge questions

Session 1: PFAS Risk & Exposure

Date: March 8, 2023
Time: 2:00 – 5:00 pm Eastern (1:00 – 4:00 pm Central)

Question of the day: Which communities are at risk and what are their sources & routes of exposure?

Agenda:

Time	Presentation/Activity
2:00 – 2:30	**Welcome & Introduction** **Presentation 1: Overview presentation of IISG's effort** - Speaker: Project team (Illinois-Indiana Sea Grant)
2:30 – 3:00	**Presentation 2:** PFAS exposure pathways for humans and wildlife - Speaker: Elsie M. Sunderland (Harvard University) **Presentation 3:** PFAS exposure and human health outcomes - Speaker: David Collier (East Carolina University) **Presentation 4:** Ecological risks of PFAS - Speaker: Gary Ankley (US Environmental Protection Agency, MN)
3:00 – 3:35	**Breakout Discussion 1:** Key exposure routes and associated ecological and human health risks of PFAS in Great Lakes and Lake Champlain basins
3:35 – 3:45	**Break**
3:45 – 4:10	**Presentation 5:** PFAS variability in Great Lakes - Speaker: Christy Remucal (University of Wisconsin-Madison) **Q & A** **Group Discussion:** Additional locations, PFAS incidents, resources
4:10 – 4:20	**Presentation 6:** Risk communication - current approaches - Speaker: Jonathan Petali (New Hampshire Dept of Environmental Services)
4:20 – 4:50	**Breakout Discussion 2:** Communities at risk - who, where, why?
4:50 – 5:00	**Closing**

Charge questions:

Breakout Discussion 1: Key exposure routes and associated ecological and human health risks of PFAS in Great Lakes and Lake Champlain basins *[30 minutes]*

1) Exposure routes and risks *[20 minutes]*
    - What is the exposure route?
    - What are the associated human health risks?
    - What are the associated ecological risks?

2) Top 3 exposure routes and reasons *[10 minutes]*
    - Exposure route
    - Why?

Breakout Discussion 2: Communities at risk - who, where, why? *[25 minutes]*

1) Note: Three breakout rooms based on location
    - Room 1 - Lake Champlain, Lake Ontario, Eastern Lake Erie
    - Room 2 - Central and Western Lake Erie, Lake St. Clair, Lake Huron, Eastern Lake Michigan
    - Room 3 - Lake Superior, Western Lake Michigan

1) Where and who is at risk?
2) Why is this community at risk (source and exposure route)?
3) What approaches of risk communication are currently used or might be helpful? Are they helpful, or would something else be helpful?
4) What information is needed for effective risk communication (e.g. - languages spoken, cultural beliefs, issues unique to those populations that we know are at risk)?

Session 2: PFAS Mitigation & Remediation

Date: March 10, 2023
Time: 10:00 am – 1:00 pm Eastern (9:00 am – 12:00 pm Central)

Question of the day: What are the socioeconomic barriers to the adoption and implementation of some of the current/proposed solutions and what are their alternatives?

Agenda:

Time	Presentation/Activity
10:00 – 10:20	**Welcome & Introduction** **Presentation 1: Overview presentation of IISG's effort** - Speaker: Project team (Illinois-Indiana Sea Grant)
10:20 – 10:50	**Presentation 2: Reducing PFAS exposure/risk** - Speaker: Brian Koch (Illinois Department of Public Health) **Presentation 3: PFAS treatment in water** - Speaker: Balaji Seshasayee (Geosyntec Consultants, Inc.) **Presentation 4: PFAS Annihilator** - Speaker: Kavitha Dasu (Battelle)
10:50 – 10:55	**Activity**
10:55 – 11:30	**Breakout Discussion 1:** Pros and cons of various solutions to PFAS
11:30 – 11:40	**Break**
11:40 – 12:10	**Presentation 5 and 6: Case studies of PFAS exposure mitigation & remediation in Great Lakes and Lake Champlain region** - Speaker: Cheryl Murphy (Michigan State University) - Speaker: Sara Latessa (NY State Dept of Env Conservation) **Q & A**
12:10 – 12:50	**Breakout Discussion 2:** Sources of PFAS contamination & appropriate solutions
12:50 – 1:00	**Closing**

Charge questions:

Breakout Discussion 1: Pros and cons of various solutions to PFAS *[30 minutes]*

1) List additional solutions that are already being implemented or are of interest (anywhere, not just in Great Lakes/Lake Champlain). *[10 minutes]*

2) Discuss and create a table that includes the solutions (including those taken on a personal, municipal, or broader scale) presented in terms of their pros and cons. For the pros and cons, consider the following: technical effectiveness, accessibility, scalability, cost-effectiveness, sustainability, creation of harmful by-products (land application of biosolids), meeting regulatory guidelines (current and future), and any other concerns. *[20 minutes]*

Breakout Discussion 2: Sources of PFAS contamination & appropriate solutions *[35 minutes]*

Revisiting the solutions from discussion 1, now talk about what is happening in the Great Lakes/Lake Champlain region.

1) Based on your experience, what/where/why are specific sources of PFAS contamination being targeted for remediation? Which others should be targeted for remediation? *[10 minutes]*.

2) Which of the solutions presented earlier in the session can be implemented by different agencies (e.g., municipal or state level)? In homes (i.e., personal actions)? Consider pros and cons, for example: Are there substitutes? What are the costs associated with the substitutes? Are there implications for industries whose products are/will be banned (e.g., workers)? Are some more appropriate for short-term vs. long-term solutions? Feel free to add lines to the table as necessary. *[20 minutes]*

3) What are up to 5 key knowledge gaps for the Great Lakes/Lake Champlain region around these topics? *[5 minutes]*

Session 3: PFAS Governance & Prevention

Date: March 15, 2023
Time: 2:00 – 5:00 pm Eastern (1:00 – 4:00 pm Central)

Question of the day: What information is needed to ensure all who live, work, and recreate in the Great Lakes region are treated in a just and equitable way with respect to governance and prevention of PFAS contamination and exposure?

Agenda:

Time	Presentation/Activity
2:00 – 2:15	**Welcome & Introduction** **Presentation 1: Overview presentation of IISG's effort** - Speaker: Project team (Illinois-Indiana Sea Grant)
2:15 – 3:00	**Presentation 2:** Actions to address PFAS by Canada - Speaker: Stacey Cherwaty (Environment and Climate Change Canada) **Presentation 3:** PFAS as injustice to Tribal Nations - Speaker: Page Hingst (Tribal PFAS Work Group) **Presentation 4:** Reasons driving variations in drinking water Standards - Speaker: Kimberly Parr (GZA GeoEnvironmental, Inc.) **Q & A**
3:00 – 3:30	**Breakout Discussion 1:** Challenges in moving towards a regional consensus on PFAS
3:30 – 3:40	**Break**
3:40 – 4:25	**Presentation 5: Lightning talks – Policy actions by different states** - Speaker: Summer Streets (Minnesota Pollution Control Agency) - Speaker: Gavin Dehnert (Wisconsin Sea Grant) - Speaker: Matthew Prater (Indiana Dept of Environmental Management) - Speaker: Abigail Hendershott (Michigan PFAS Action Response Team) **Q & A** - Speaker: OH – Andy May (Ohio State University) - Speaker: VT – Eamon Twohig (VT Dept of Environmental Conservation) - Speaker: NY – Pamela Hadad-Hurst (NY State Dept of Env Conservation) **Q & A**
4:25 – 4:55	**Breakout Discussion 2:** Efficacy and equity of current actions to address PFAS
4:55 – 5:00	**Closing**

Charge questions:

Breakout Discussion 1: Challenges in moving towards a regional consensus on PFAS *[30 minutes]*

1) List the major challenges to adopting consensus on a regional scale on how to best remediate, mitigate, or prevent PFAS contamination. This could be a consensus between the U.S. and Canada, between multiple states, among Tribal Nations, etc. *[10 minutes]*

2) Discuss and create a table of the challenges to adopting regional consensus on this issue and what information is needed to address the challenge, particularly considering questions that could potentially be addressed with policy, social science, and/or socioeconomic research. *[20 minutes]*

Breakout Discussion 2: Efficacy and equity of current actions to address PFAS *[30 minutes]*

1) Considering current actions being taken by agencies to address PFAS contamination, remediation, mitigation, prevention, etc. in the Great Lakes and Lake Champlain region, select examples of actions and answer the following questions: *[25 minutes]*
    - How effective have these actions been? Can we tell?
    - Has there been any resistance to adoption or implementation on the part of particular communities or audiences?
    - Who is not currently benefiting from actions (in terms of seeing reduced exposure, risk, etc.)?

    Consider examples from any of the following categories:
    - Environmental Guidelines and Regulations, Compliance Promotion and Enforcement
        - *Examples:* Groundwater/drinking water measures, water quality standards, fish consumption advisories
    - Monitoring and Surveillance
        - *Examples:* Site investigations, monitoring efforts
    - Pollution Prevention
        - *Examples:* Bans on PFAS use, substitutes for PFA
    - Public engagement
        - *Examples:* Information sharing sessions, flyers, other outreach efforts
    - Research and other efforts
        - *Examples:* Increased research capacity (health risks, technology)

2) (Optional question) If we want more effective and equitable actions, what is needed? List some ideas. *[5 minutes]*

Appendix II – Scoping session participants

Name	Organization
Abigail Hendershott	Michigan PFAS Action Response Team
Amanpreet Kohli	Illinois-Indiana Sea Grant
Amina Salamova	Emory University
Andy May	The Ohio State University
Balaji Seshasayee	Geosyntec Consultants Inc
Brian Alford	Ohio Sea Grant - Strone Laboratory
Brian Koch	Illinois Department of Public Health
Caren Ackley	Great Lakes Indian Fish & Wildlife Commission
Carol Miller	Wayne State University, CEE and Healthy Urban Waters
Carolyn Foley	Illinois-Indiana Sea Grant; Purdue University
Cheryl Murphy	Michigan State University
Chiara Zuccarino-Crowe	Michigan Sea Grant
Christina Remucal	University of Wisconsin-Madison
Chunjie Xia	Indiana University Bloomington
Daniele Miranda	University of Notre Dame
David Collier	East Carolina University and North Carolina State University
Dianne Barton	National Tribal Toxics Council
Eamon Twohig	Vermont ANR-DEC, Waste Management
Edward (Ned) Witte	Godfrey & Kahn
Elsie Sunderland	Harvard University
Gerald Ankley	United States Environmental Protection Agency
Gary Lamberti	University of Notre Dame
Gavin Dehnert	Wisconsin Sea Grant
Geoff Rhodes	Michigan Department of Environment, Great Lakes and Energy
Hailey Connell	South Carolina Sea Grant
Jaki Peters	Environment and Climate Change Canada
Jason Lagowski	Brown and Caldwell
Jill Bartolotta	Ohio Sea Grant
Jonathan Petali	Interstate Technology Reg Council/New Hampshire Department of Environmental Services
Kavitha Dasu	Battelle
Kevin Cox	Michigan Department of Environment, Great Lakes and Energy
Kimberly Parr	GZA GeoEnvironmental, Inc.
Kristen Hanson	Lac du Flambeau Band of Lake Superior Chippewa
Kyle Hay	Brown and Caldwell
Leigh-Anne Krometis	Virginia Tech; Biological Systems Engineering
Linda Lee	Purdue University
LISA SEALOCK	Environment and Climate Change Canada
Luke Loken	United States Geological Survey
Maria Sepulveda	Purdue University
Mariah Hood	Ohio Environmental Protection Agency
Marta Venier	Indiana University

Martin Griffin	Madison Metropolitan Sewerage District
Michael Jury	Michigan Department of Environment, Great Lakes and Energy/Michigan PFAS Action Response Team
Nathan Podany	Sokaogon Chippewa Water Quality Program
Noah Saperstein	Red Cliff Band of Lake Superior Chippewa
Page Hingst	Santee Sioux Nation
Paige Huhta	Fond du Lac Band of Lake Superior Chippewa
Pam Hadad-Hurst	New York State Department of Environmental Conservation
Rajendra Poudel	International Joint Commission/US Department of State
Reginald DeFoe	Fond du Lac Band of Lake Superior Chippewa
Rich Budnik	Ohio Environmental Protection Agency
Robin Taylor Wilson	Temple University College of Public Health; Temple Fox Chase Cancer Center
Ryan Lepak	United States Environmental Protection Agency
Sara Latessa	New York State Department of Environmental Conservation
Sara Pearson	Michigan Department of Environment, Great Lakes and Energy/Drinking Water and Environmental Health Division
Sarah Balgooyen	United States Environmental Protection Agency; SpecPro Professional Services
Sarah Zack	Illinois-Indiana Sea Grant, University of Illinois Extension
Simon Belisle	Michigan Department of Environment, Great Lakes, and Energy
Stacey Cherwaty-Pergentile	Environment and Climate Change Canada
Staci Capozzi	Indiana University Bloomington
Stephanie Kammer	Michigan Department of Environment, Great Lakes and Energy/Water Resources Division
Summer Streets	Minnesota Pollution Control Agency
Susan Burden	United States Environmental Protection Agency (Office of Research and Development)
Suzanne Lea	East Carolina University
Tamara Sorell	Brown and Caldwell
Tomas Hook	Illinois-Indiana Sea Grant
Tory Gabriel	Ohio Sea Grant
Tyler Hoskins	Purdue University
Wayne Amber	Geosyntec Consultants, Inc.

Appendix III – Post-session survey

All survey questions were optional. For all questions where survey respondents were asked to provide a ranking, the choices were presented in a random order.

Sea Grant PFAS Scoping Effort 2023

Information: This survey provides an opportunity for you to inform research and communication needs surrounding PFAS exposure, mitigation, remediation, and prevention in the Great Lakes and Lake Champlain regions. Information shared during three scoping sessions held in March 2023 served as the basis for the survey. You should answer the questions based on your own experience and expertise. All answers are anonymous.

Unless otherwise noted, all answers should focus on those who live, work, and recreate in the Great Lakes and Lake Champlain regions, and consider the broad suite of PFAS and related chemicals (e.g., precursors) rather than a single class or suite of PFAS/PFOA chemicals.

Results will inform a Sea Grant-managed request for proposals (RFP) focused on Social and Economic Impacts of PFAS in the Great Lakes/Lake Champlain Regions; however, Illinois-Indiana Sea Grant, who is administering this effort, anticipates that there will be research and communication needs identified beyond the scope of their RFP. Given this, results will also be incorporated into a workshop report, which will be publicly-available on the project website in late spring 2023.

For ranking questions: you can rank something as high priority even if you believe it already exists. These questions will ask you to drag-and-drop your priorities into order. If you have trouble with this, contact Carolyn Foley (cfoley@purdue.edu) or Sarah Zack (szack@illinois.edu) who will provide you with a different ranking option.

This survey is expected to take 12 minutes to complete. Some questions are best viewed on a laptop or desktop computer, but they can be completed via mobile app if that is preferred.

Exposure to PFAS and related chemicals

Focusing on those who live and work in the Great Lakes and Lake Champlain regions, and considering the broad suite of PFAS and related chemicals (e.g., precursors), rank the following PFAS EXPOSURE ROUTES from 1 (most important to investigate right now) to 5 (least important to investigate right now).

Drinking water
Eating fish
Inhaling dust
Exposure due to broad, commercial application/use of PFAS and related chemicals (e.g., AFFF, biosolids)
Exposure due to local, personal application/use of PFAS and related chemicals (e.g., food packaging, makeup)

If you would like to explain why your list is ranked as it is, please do so here. Please also use this space to suggest key routes of exposure that are not captured in the current ranking list.

_____

_____

Communicating risk related to PFAS

Focusing on those who live, work, and recreate in the Great Lakes and Lake Champlain regions, and considering the broad suite of PFAS and related chemicals (e.g., precursors), identify the relative level of awareness the following groups have about the risks of PFAS exposure plus ways to protect themselves and others.

Item	MOST aware of PFAS risks and ways to protect themselves and others	MEDIUM level of awareness of PFAS risks and ways to protect themselves and others	LEAST aware of PFAS risks and ways to protect themselves and others	Unsure where this group should fit
Tribal community members				
Manufacturers of PFAS and related materials				
Students and workers at schools				
Workers exposed via use of PFAS products (e.g., military personnel, firefighters)				
Health care providers				
Anglers and hunters				
Residents of rural communities				
Consumers of commercially caught fish				
People served by municipal water suppliers				
Residents of large cities				
Subsistence communities				
Adults over 50 years old				
People who use well-water				
People who live near major sources of PFAS (e.g., airports, manufacturing facilities)				
People who are pregnant or lactating				

Please identify additional, key individuals or communities (including professional communities) that are LEAST aware of PFAS risks and ways to protect themselves and others here.

_____

_____

Generally, what information is needed to effectively communicate risk to the groups who are LEAST aware of PFAS risks and ways to protect themselves and others? Select all that apply.

- ☐ Information about alternative products to avoid regrettable substitutions
- ☐ Information on links between PFAS exposure and environmental health
- ☐ Information on fate and transport of PFAS in the environment
- ☐ Guidance on which actions are most effective at reducing or preventing PFAS exposure
- ☐ Information about what is not known balanced with why people should act now
- ☐ Explanation of why PFAS exposure levels differ by state, province, country
- ☐ Information related to how exposure and consumption translates within the context of traditional knowledge
- ☐ Good news stories related to PFAS exposure and mitigation
- ☐ Information about fish and wildlife beyond those traditionally researched (e.g., wild rice, aquatic plants, lake whitefish)

Please list other information needs not currently captured in the list here.

_____

_____

Knowledge gaps

Focusing on those who live and work in the Great Lakes and Lake Champlain regions, and considering the broad suite of PFAS and related chemicals (e.g., precursors), rank the following KNOWLEDGE GAPS related to PFAS remediation and mitigation from 1 (MOST important to investigate right now) to 6 (LEAST important to investigate right now). This question focuses on general or broad-scale actions.

What are the best treatment methodologies for complex mixtures of contaminants that may be present at sites?
What are the best treatment technologies for dilute waste streams versus concentrated waste streams?
Do we have a good understanding of all of the potential sources of PFAS to the environment?
What is the relative ease of removing or otherwise treating long-chain PFAS and related chemicals vs. short-chain PFAS and related chemicals?
What is the impact of historic land application on PFAS levels in the Great Lakes and Lake Champlain systems?
How are PFAS and precursors moving through the environment (i.e., fate and transport of the suite of chemicals)?

Focusing on those who live and work in the Great Lakes and Lake Champlain regions, and considering the broad suite of PFAS and related chemicals (e.g., precursors), rank the following KNOWLEDGE GAPS related to PFAS remediation and mitigation from 1 (MOST important to investigate right now) to 5 (LEAST important to investigate right now). This question focuses on topics related to personal exposure.

How serious is the PFAS and related chemical contamination of fish and wildlife?
Are some communities at more risk because they consume fish on a regular basis?
How much does PFAS toxicity depend on how a person was exposed?
Are Great Lakes region fish really more toxic than ocean fish? If so, why?
How important is the proximity of private wells to septic systems to raising the risk of PFAS exposure and contamination?

List up to 5 major challenges to adopting regional consensus on how to remediate, mitigate, or prevent PFAS contamination. This could include consensus between the U.S. and Canada, between multiple states, among Tribal Nations, etc.

_____
_____

What information is needed to address these challenges, particularly considering questions that could potentially be addressed with policy, social science, and/or socioeconomic research?

_____
_____

Regional Challenges

For actions currently being undertaken in the Great Lakes and Lake Champlain regions to mitigate, remediate, or otherwise prevent PFAS exposure:

Has there been any resistance to adoption or implementation on the part of particular communities or audiences? (Provide examples and suggestions for improvement, as appropriate.)

_____
_____

Who is not currently benefiting from actions (in terms of seeing reduced exposure, risk, etc.)? (Provide examples and suggestions for improvement, as appropriate.)

_____
_____

Details about respondents

Did you attend any of the virtual scoping sessions related to this effort?

- Yes
- No

If Did you attend any of the virtual scoping sessions related to this effort? = Yes

Which session(s) did you attend? Check all that apply.

- ☐ Session 1: Risk & Exposure
- ☐ Session 2: Mitigation & Remediation
- ☐ Session 3: Governance & Prevention

Please answer the following questions considering all sessions you attended.

	Agree	Moderately Agree	Neutral	Moderately Disagree	Disagree
This session was a good use of my time					
I learned something in this session					
I made a professional connection I did not previously have through this session					

Please provide constructive feedback on improving future sessions like these.

_____

_____

If Did you attend any of the virtual scoping sessions related to this effort? = No

Why did you not attend the virtual sessions? Select all that apply.

- ☐ Time conflicted with other appointments
- ☐ Did not seem relevant to me
- ☐ Sessions were too long
- ☐ Other (please describe)

  _____

  _____

Details about respondents (contd.)

What type of institution describes your primary professional affiliation?

- Federal employee
- State or provincial employee
- Tribal agency employee
- Academic institution
- Non-profit organization
- Industry
- Other (please describe)

  _____
  _____

Please list any additional feedback related to this effort that you wish to share here.

_____
_____

Appendix IV – Information gathered during scoping sessions

Session 1: PFAS Risk & Exposure

Fig. 1. Word cloud generated by session participants for PFAS sources in the Great Lakes and Lake Champlain regions (based on 34 responses).

Fig. 2. Word cloud generated by session participants for PFAS exposure routes in the Great Lakes and Lake Champlain regions (based on 28 responses).

Session 2: PFAS Mitigation & Remediation

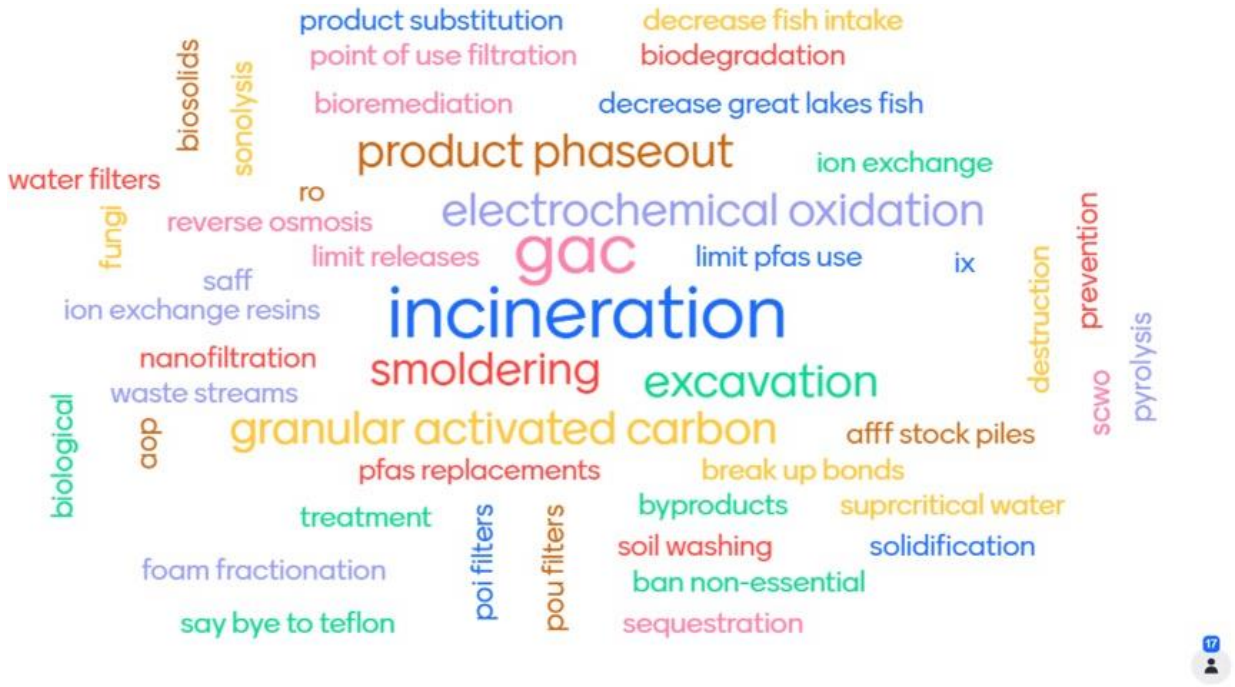

Fig. 3. Word cloud generated by session participants for possibilities for mitigating and/or remediating PFAS (based on 17 responses).

Session 3: PFAS Governance & Prevention

During the third session, representatives from different states in the Great Lakes and Lake Champlain regions were invited to share PFAS strategies currently underway in their respective locations. The following summary tables were shared.

Table 1. An overview of PFAS strategies in Illinois (Credits: Brian Koch)

Environmental Guidelines and Regulations, Compliance Promotion and Enforcement	Monitoring and Surveillance	Pollution Prevention	Public Engagement	Research and Other Efforts
• PFAS Reduction Act (Public Act 102-0290): Regulates the use of Class B firefighting foam to minimize PFAS exposure to humans and reduce PFAS releases to the environment • Proposed PFAS Groundwater Quality Standards (IPCB R2022-018) • Developed Statewide Health Advisories for 6 PFAS	• Conducted statewide PFAS testing of Community Water Supplies from 2020-2021 • Beginning statewide PFAS testing in fish tissue beginning in 2024	• PFAS Reduction Act (Public Act 102-0290): Regulates the use of Class B firefighting foam to minimize PFAS exposure to humans and reduce PFAS releases to the environment	• Ongoing community engagement in areas of known PFAS contamination in drinking water	

Table 2. An overview of PFAS strategies in Michigan (Credits: Abigail Hendershott)

Environmental Guidelines and Regulations, Compliance Promotion and Enforcement	Monitoring and Surveillance	Pollution Prevention	Public Engagement	Research and Other Efforts
• Groundwater Cleanup Criteria • Surface Water Quality Values • Drinking water MCLs • Fish consumption advisories • Biosolids Interim Strategy • NPDES permits with PFOS & PFOA • Requirements to report to EGLE when PFAS AFFF is used for emergencies	• Stormwater Characterization • NPDES Monitoring • Site investigations monitoring • Property transactions (Baseline Environmental Assessments) • Statewide surface water sampling	• AFFF Pick-up & Disposal of 60,000 gallons • AFFF no longer allowed for training purposes	• Local official calls with legislators • Town hall meetings • Comprehensive website w/all PFAS sites listed • Citizens Advisory Workgroup	• EGLE/DHHS labs: 537.1, 533, Fish, beef, blood, deer & crop analysis • Pending budget proposal includes funding designated for site cleanups in EJ communities

Table 3. An overview of PFAS strategies in Minnesota (Credits: Summer Streets)

Environmental Guidelines and Regulations, Compliance Promotion and Enforcement	Monitoring and Surveillance	Pollution Prevention	Public Engagement	Research and Other Efforts
• HRLs/HBVs (drinking water) • Site-specific WQCs (surface water and fish) • Fish consumption guidance • Soil reference values (remediation) • Air inhalation risk values (guidance) • Impaired waters	• Ambient monitoring since 2002 (surface water and fish) • Numerous site investigations and remediation • PFAS Monitoring Plan	• PFAS ban in food packaging • Ban on PFAS fire-fighting foam for testing or training • In the legislature now: PFAS product ban; ban on use of AFFF once a non-PFAS foam passes MIL-SPEC	• PFAS Blueprint (2021) • East Metro work groups	• Asking legislature for increased staffing and resources • DNR – wildlife • MDH – risk assessment • MPCA – biosolids, fish

Table 4. An overview of PFAS strategies in New York (Credits: Pamela Hadad-Hurst)

Environmental Guidelines and Regulations, Compliance Promotion and Enforcement	Monitoring and Surveillance	Pollution Prevention	Public Engagement	Research and Other Efforts
• $2.5 billion Clean Water Infrastructure Act (2017) • Added PFOA, PFOS, and salts to list of hazardous substances (2017) • Adopted drinking water MCLs of 10 ppt for PFOA/PFOS (2020) • Proposed MCLs for 4 additional PFAS and proposed 19 PFAS for screening in Drinking Water (2022) • Drinking Water Remediation Authority (ECL § 27-1205) • Ambient water quality guidance values for PFOA/PFOS (2023) • Proposed SCOs • Fish Advisories	• Water Quality Rapid Response Team (2016) • Statewide PFAS AFFF Survey • Technical Guidance on PFAS sampling and analysis • Fish and wildlife sampling • Multi-site Health Study • Biomonitoring	• PFAS bans in firefighting foam, food packaging, apparel, carpets, anti-fogging sprays/wipes, menstrual products, procurement • DEC/DHSES program collected and disposed of 25,000 gallons of AFFF	• Engage communities on water supply issues and concerns • Provide consultation and advice • Drinking water testing (public/private) • Characterize and address exposures	• SUNY ESF biosolid research on content, reduction methods, and treatment • Screening Superfund Sites • Comprehensive plan for landfill screening and remediation • Assist multiple communities with alternative water sources

Table 5. An overview of PFAS strategies in Ohio (Credits: Andy May)

Environmental Guidelines and Regulations, Compliance Promotion and Enforcement	Monitoring and Surveillance	Pollution Prevention	Public Engagement	Research and Other Efforts
• Currently following US EPA guidelines for drinking water; House bills from 133rd and 134th General Assemblies requiring the Ohio EPA director to establish MCLs appear to have stagnated in House Committees	• Ohio EPA for public drinking water systems; Ohio Department of Health for private drinking water systems	• HB 158 from the 134th General Assembly prohibits Class B foams for "testing and training" … but it can still be used for firefighting	• Collaborative outreach between Ohio EPA and ODH on drinking water and other exposure pathways	• Environmental fate and transport; treatment technologies

Table 6. An overview of PFAS strategies in Vermont (Credits: Eamon Twohig)

Environmental Guidelines and Regulations, Compliance Promotion and Enforcement	Monitoring and Surveillance	Pollution Prevention	Public Engagement	Research and Other Efforts
• Drinking Water MCL: **20ppt** for sum of PFNA, PFOA, PFOS, PFHpA, PFHxS ("VT-5") • Groundwater Enforcement Standard mimics the MCL • Proposed soil screening standards (ppb) for soil to GW pathway via iRULE: PFNA: 0.44 PFOA: 1.6 PFOS: 3.4 PFHpA: 0.84 PFHxS: 0.34 • Pretreatment permits for LF leachate and select industrial discharges	• Background soil study (2019) • Testing at all public water systems • Private water systems – 500 state-wide at random in 2023 • Wastewater and landfill leachate study (2020) + and state-wide WWTF sampling effort 2023-2024 • Surface water and fish tissue – ongoing • Biosolids and soil/GW at land application sites	• Bans on PFAS in AFFF, Carpets, Food Packaging, Ski Wax (Act 36) • EPA Pollution Prevention (P2) grant for PFAS discharges from metal finishers • EPA P2 grant for PFAS and microplastics in food waste streams and packaging • Landfill leachate pretreatment permit	• PFAS Road Map update in April 2023 • Website reboot • Collaborating with Vermont Dept of Health on FAQs for drinking water testing results • Developing FAQ for EPA proposed MCL	• Airport sites (2) investigations (AFFF releases) • Public drinking water systems/schools as contaminated sites • Town of Bennington work completed – new water lines, POETs • Study of sources to wastewater from two municipalities (residential vs industrial inputs) • Developing interim guidance for Class A biosolids management

Table 7. An overview of PFAS strategies in Wisconsin (Credits: Gavin Dehnert)

Environmental Guidelines and Regulations, Compliance Promotion and Enforcement	Monitoring and Surveillance	Pollution Prevention	Public Engagement	Research and Other Efforts
• Drinking water standards PFOA and PFOS 70 ppt • Recommended Health Standards - Hazard Index Approach • Fish Consumption Advisories • Water quality in chs. NR 101-299 • Soil standards in ch. NR 720 • Hazardous air contaminants in the NR 400 rule series • Site-specific sediment standards in ch. NR 722	• Public water system testing • Fish and wildlife monitoring, and other biota • Air • Surface water, wastewater, drinking water, groundwater • Soil and Sediment	• Wisconsin PFAS Action Plan 383.2 Amend Firefighting Foam Law, Wis. Stat. § 299.48 • Collection and disposal of AFFF	• Collaboration between DNR and DHS on PFAS on health risks, drinking water, fish consumption advisories, and other exposure routes • Town hall meetings	• Environmental fate and transport • Bioaccumulation • Remediation • Fingerprinting • Source Reduction • Laboratory Analysis

Appendix V – Selected survey results

Exposure to PFAS and related chemicals

Table 8. Summary statistics for answers (n = 42) given to the question, "Focusing on those who live and work in the Great Lakes and Lake Champlain regions, and considering the broad suite of PFAS and related chemicals (e.g., precursors), rank the following PFAS EXPOSURE ROUTES from 1 (most important to investigate right now) to 5 (least important to investigate right now)." Lower ranks correspond to a more pressing need to investigate right now.

Choice	Mean Rank	Std Deviation	Variance
Drinking water	2	1.51	2.29
Eating fish	2.62	1.09	1.19
Exposure due to local, personal application/use of PFAS and related chemicals (e.g., food packaging, makeup)	2.93	1.2	1.45
Exposure due to broad, commercial application/use of PFAS and related chemicals (e.g., AFFF, biosolids)	3.38	1.25	1.57
Inhaling dust	4.07	1.03	1.07

The findings summarized above suggest that there is relatively little difference between the top three choices in terms of importance to investigate right now. All choices were each listed by at least one respondent as "least important to investigate right now". The first four choices were each listed as the most important to investigate right now by at least one respondent, but no respondent listed "Inhaling dust" as the most important to investigate right now.

Communicating risk related to PFAS

Table 9. Summary statistics for answers (n = 35) given to the question, "Focusing on those who live, work, and recreate in the Great Lakes and Lake Champlain regions, and considering the broad suite of PFAS and related chemicals (e.g., precursors), identify the relative level of awareness (most, medium, least, unsure) the following groups have about the risks of PFAS exposure plus ways to protect themselves and others". Grey shading indicates that group was among the top 3 groups placed in that category (* indicates a tie).

Group	Number of times placed in the category 'MOST aware'	Number of times placed in the category 'MEDIUM aware'	Number of times placed in the category 'LEAST aware'	Number of times placed in the category 'Unsure where this group fits'
Manufacturers of PFAS and related materials	29	4	1	1
Workers exposed via use of PFAS products (e.g., military personnel, firefighters)	23	9	1	1
People who live near major sources of PFAS (e.g., airports, manufacturing facilities)	18	10	5	1
Health care providers	7	20	4	3
People served by municipal water suppliers	2	19	10	3
Residents of large cities	2	14	14	5*
People who are pregnant or lactating	2	12	15	5*
Anglers and hunters	0	13	16	4
Adults over 50 years old	0	11	16	7
Tribal community members	1	10	19	4
Consumers of commercially caught fish	0	10	21	3
Students and workers at schools	1	5	23*	5*
People who use well-water	0	7	23*	4
Subsistence communities	1	3	24	6
Residents of rural communities	0	2	28	4

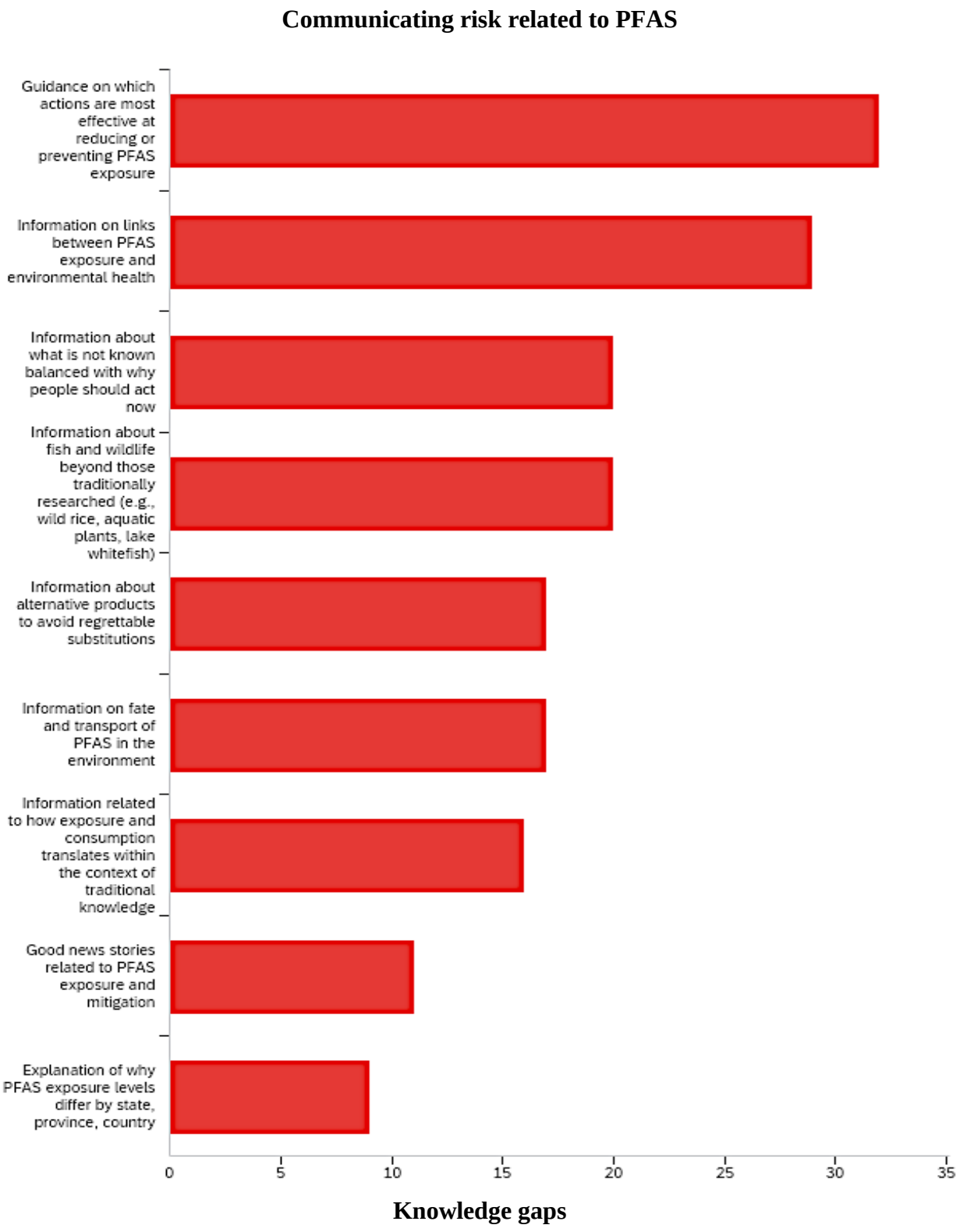

Fig. 4. Responses to the question, "Generally, what information is needed to effectively communicate risk to the groups who are LEAST aware of PFAS risks and ways to protect themselves and others? Select all that apply." Bars indicate frequency of a choice being selected.

Knowledge gaps

Table 10. Summary statistics (n = 36) for question, "Focusing on those who live and work in the Great Lakes and Lake Champlain regions, and considering the broad suite of PFAS and related chemicals (e.g., precursors), rank the following KNOWLEDGE GAPS related to PFAS remediation and mitigation from 1 (MOST important to investigate right now) to 6 (LEAST important to investigate right now). This question focuses on general or broad-scale actions." Lower ranks correspond to a more pressing need to investigate right now.

Choice	Mean Rank	Std. Deviation	Variance
Do we have a good understanding of all of the potential sources of PFAS to the environment?	2.58	1.67	2.8
How are PFAS and precursors moving through the environment (i.e., fate and transport of the suite of chemicals)?	2.78	1.36	1.84
What are the best treatment methodologies for complex mixtures of contaminants that may be present at sites?	3.28	1.57	2.48
What is the relative ease of removing or otherwise treating long-chain PFAS and related chemicals vs. short-chain PFAS and related chemicals?	3.92	1.42	2.02
What are the best treatment technologies for dilute waste streams versus concentrated waste streams?	3.94	1.63	2.66
What is the impact of historic land application on PFAS levels in the Great Lakes and Lake Champlain systems?	4.5	1.71	2.92

Each choice was ranked number 1 (i.e., MOST important to investigate right now) by at least one respondent. The findings summarized above suggest that the first two categories were nearly equally ranked as "most important to investigate right now"'. "How are PFAS and precursors moving through the environment (i.e., fate and transport of the suite of chemicals)?" was never ranked as the least important to investigate right now, but all other choices, respectively, were ranked most important or least important by at least one respondent. "What are the best treatment methodologies for complex mixtures of contaminants that may be present at sites?" was frequently ranked in the middle.

Knowledge gaps

Table 11. Summary statistics (n = 33) for the question, "Focusing on those who live and work in the Great Lakes and Lake Champlain regions, and considering the broad suite of PFAS and related chemicals (e.g., precursors), rank the following KNOWLEDGE GAPS related to PFAS remediation and mitigation from 1 (MOST important to investigate right now) to 5 (LEAST important to investigate right now). This question focuses on topics related to personal exposure." Lower ranks correspond to a more pressing need to investigate right now.

Choice	Mean Rank	Std. Deviation	Variance
How serious is the PFAS and related chemical contamination of fish and wildlife?	2.21	1.27	1.62
Are some communities at more risk because they consume fish on a regular basis?	2.64	1.25	1.56
How much does PFAS toxicity depend on how a person was exposed?	3.09	1.38	1.9
How important is the proximity of private wells to septic systems to raising the risk of PFAS exposure and contamination?	3.39	1.3	1.69
Are Great Lakes region fish really more toxic than ocean fish? If so, why?	3.67	1.36	1.86

Each choice was ranked number 1 (i.e., MOST important to investigate right now) by at least one respondent. Each choice was also ranked number 5 (i.e., LEAST important to investigate right now) by at least one respondent. The findings summarized above suggest that there is relatively little differentiation between the topics identified as most important to investigate right now.