NORTH CAROLINA PFAS Testing Network

RESEARCH TRIANGLE ENVIRONMENTAL HEALTH COLLABORATIVE

2019 Environmental Health Summit

PFAS: Integrating Science and Solutions in North Carolina

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North Carolina Biotechnology Center, RTP, NC

Introduction: Setting the Stage to Address PFAS

Advances in chemical manufacturing have led to countless innovations in industry and consumer-product development. An unfortunate consequence of these advances is the release of chemical substances into our world that have implications for public and environmental health. Per- and polyfluoroalkyl substances, or PFAS, comprise a diverse set of chemicals that have been used worldwide for nearly 70 years.

Many PFAS are incredibly stable and resistant to environmental degradation because of their chemical structure, though they are diverse group of chemicals. While they serve many useful purposes, some are highly persistent in the environment and travel through our air, soil, and water. With their ubiquitous presence, PFAS have also been found in humans, wildlife, and plants—yet their health effects are still being investigated. (See Figure 1: PFAS Origins And Migration Through The Environment)

Researchers are in the early stages of comprehending the issues created by the presence of PFAS. Exposure to PFAS and how they are distributed in the environment present a cascade of public and environmental health questions that require a diversity of perspectives to understand. Addressing them thoroughly and appropriately rests on the communication and collaboration between many stakeholders, including: policymakers, regulatory agencies, researchers, industry, communication teams, and the public. (See Figure 2: Community of Stakeholders)

The 2019 Annual Environmental Health Summit brought together these stakeholders to discuss the current status of PFAS research in an effort to develop strategies to limit human and environmental exposure. This year's Summit was a collaboration between the Research Triangle Environmental Health Collaborative (RTEHC) and the North Carolina PFAS Testing (NC PFAST) Network.

The NC PFAST Network was explicitly developed to address issues of PFAS in the state, including determining the levels of PFAS in public drinking water. The need for this arose from research that discovered the presence of PFAS in the Cape Fear

River (Sun et al., 2016), and in the blood of people living in and around Wilmington, NC (GenX Exposure Study). It stands that PFAS pose a pressing concern for environmental and human health, especially within North Carolina.

Throughout the two-day Summit, participants heard a variety of perspectives and discussed where PFAS is coming from, where it is now, how to stop PFAS pollution and remove it from the environment, and on-going work to evaluate human health endpoints. The goal was to develop a comprehensive list of recommendations and insights to guide the actions of the groups of stakeholders to address PFAS in the environment.

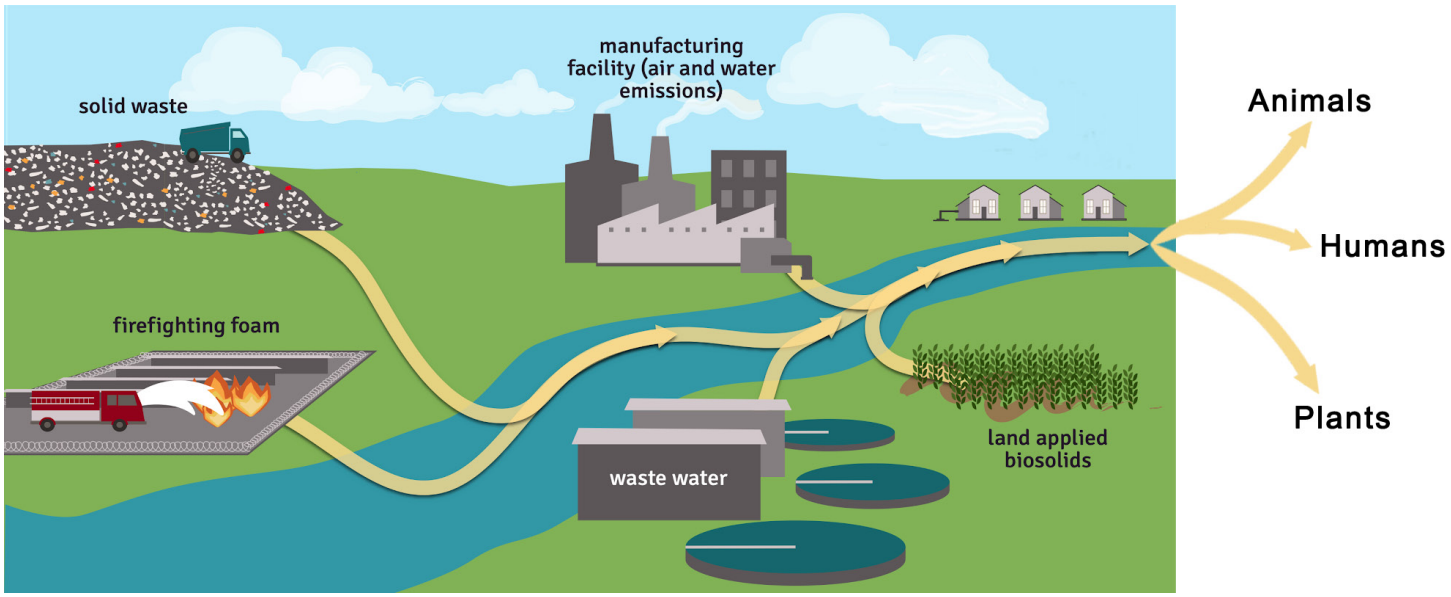

Figure 1: Main routes PFAS compounds are released into the environment and cause exposure in humans, animals, and plants.

Figure 2: Community of Stakeholders

Summit Overview

The Summit began with an introduction and overview of PFAS contamination from the national and state levels, including remarks from the Centers for Disease Control Prevention. Representatives from the NC PFAST Network also described the goals and objectives of the network and their current research findings regarding water sampling and air emission.

These were followed by two panel discussions. The first focused on how regulatory agencies and impacted communities are responding to PFAS contamination in North Carolina. The second focused on the perspectives of policymakers and legislative actions needed to address PFAS in the state, with bipartisan representation.

The central component of the Summit comprised of breakout sessions of three working groups to facilitate discussion of critical PFAS issues, which will be described at length in the Working Group Sessions and Central Themes Sections. The other sessions included a discussion of the legal history and nature of PFAS-related issues, an overview of PFAS from the perspective of Superfund research, and a talk centered on the industry's efforts to understand and minimize PFAS contamination in the environment.

These sessions provided a comprehensive examination of PFAS and PFAS-related issues from the perspectives of all stakeholders involved as well as opportunities for extensive dialogue to drive us toward solutions.

More information about the 2019 Environmental Health Summit
as well as all presentations can be found online, here:
http://environmentalhealthcollaborative.org/2019-summit/

Summit Presentation Summary

PERSPECTIVES FROM THE STAKEHOLDER COMMUNITY

The community of stakeholders who are a part of the PFAS story is broad and diverse. The Summit ensured that these different voices had a platform to share their perspective. In order to fully grapple with the issue of PFAS in our environment, communication needs to flow between the different stakeholder communities, and this component of the Summit aimed to do just that.

NATIONAL RESEARCH COMMUNITY

CDC/ATSDR's Involvement in PFAS and Health

Patrick Breysse, Ph.D., Director of the CDC National Center for Environmental Health, Agency for Toxic Substances and Disease Registry

Dr. Patrick Breysse provided a broad overview of the activities on the national stage, at the CDC and ATSDR, regarding PFAS contamination. He likened research about the PFAS family to an iceberg because while part of the problem they create is visible, there is much more lying beneath the surface. This is particularly important because PFAS are produced in industrial manufacturing. As manufacturers change their product lineup in response to industrial and consumer demands, there is potential for as of yet uncharacterized PFAS to emerge in the environment for consideration.

Breysse brought attention to the NHANE survey that has documented PFAS levels in people in the United States. The cohort from 2003-2004 showed that over 98% of national participants in the study had detectable PFAS present in their blood. The data from 1999-2008show a decrease in levels of PFAS in people over time because of industrial phase outs, demonstrating that when industry reduces its reliance on some PFAS, the prevalence of these chemicals in the population is reduced.

While this is true, he showed that this has led to other challenges. As some PFAS were phased out of use and production, other novel PFAS have been produced in their place, and it is still unknown whether these replacement PFAS would pose any adverse health effects. Additionally, since PFAS are so prevalent in the population, it is practically impossible to conduct a study with a non-PFAS-exposed control group.

However, Breysse showed that the prevalence of PFAS "hot spots" (areas with elevated levels of PFAS) across the US have presented a need to begin a more intensive investigation of PFAS. Besides North Carolina, there are studies in other states, such as Michigan, New Jersey and New Hampshire, working to understand the extent of PFAS contamination more comprehensively, which can be used as models for future PFAS research. In these cases, there has been extensive water testing, and having thorough knowledge of the surface to groundwater network as well as historical data has proven to be highly impactful for understanding PFAS contamination.

The story is a bit more complex when it comes to understanding PFAS and human health. Breysse recounted that research is only beginning to have evidence of the health effects of these chemicals. As of right now, there is no health-based metric to interpret PFAS levels in the body, and, as Breysse said, "the best we can do is to tell people how they measure in comparison to the 'typical' levels of PFAS we see in the average American".

This is changing though. There are studies that are investigating the human health effects of several PFAS, including PFAS Biomonitoring (DoD funded effort), the Pease Study (Superfund project in NH), and the Multisite Health Study (ATSDR study). Across the nation, more work is being done to develop tools and resources, as well as monitor and assess exposure to these compounds. The importance of understanding PFAS contamination has also been elevated since PFAS are found in fire-fighting foams, which could impact our first responders and military communities.

Overall, Breysse recounted the role of societal responsibility regarding PFAS. He highlighted

the importance of distinguishing between when society may accept chemicals like PFAS entering the consumer market—when do are they needed for a particular purpose—versus where alternatives can be used. He also discussed managing chemicals from cradle to grave to ensure that the fates of chemical contaminants are known and safe for the public. This is a nod to adopting the precautionary principle, which will be discussed later in the Central Themes section.

Potential Solutions for PFAS: NIEHS Superfund Research Program Remediation Research

Heather Henry, Ph.D., National Institute of Environmental Health Sciences

Heather Henry from the NIEHS Superfund Research Program shared her perspective on PFAS and remediation technology that is being developed. She noted that to solve the problem of PFAS contamination in the environment, it takes a coordinated effort between businesses, universities, agencies, and policymakers. Collectively, stakeholders need to identify the problems and develop environmental health research that allow researchers to answer those questions and provide solutions. Additionally, when it comes to developing those solutions, society needs engineers and environmental scientists to play an integral role, as well as basic scientists (biologists, chemists, physicists) to help understand the toxicity of these chemicals and develop strategies of their remediation.

She noted that PFAS creates a unique challenge, because it is such a large family of chemicals, that to remediate the contamination sites requires a combination of methods. There is no silver bullet to seek and destroy all PFAS. Instead, multiple remediation technologies are being developed to remove PFAS from water and soil by adsorption, separation, and destruction. Many of these technologies are well into development, and are showing promising results. The prevailing removal methods are ion exchange resins, granular activated carbon, reverse osmosis, and nanofiltration, but researchers from across the country are working on more solutions. These various methods have an array of benefits and challenges, and the hope is that used in combination, they can address the PFAS issues in our environment.

STATE RESEARCH COMMUNITY

NC PFAS Testing Network: Initial Findings Related to Water and Air Quality

Overview of the Study

Jason Surratt, Ph.D., Program Director, NC PFAST Network, Professor, Environmental Sciences and Engineering, UNC-CH

Jason Surratt, the program director for the NC PFAST Network, provided an introduction to the organization—its origins, members, and goals. The NC PFAST Network is a statewide research collaboration comprised of principal investigators from NCSU, DU, UNC-CH, UNC-Wilmington, UNC-Charlotte, ECU, and NC Agriculture and Technical University. This research network arose from a NC General Assembly mandate and funding to answer questions regarding exposure to PFAS compounds within the state. The network also received support from the NC Policy Collaboratory.

The NC PFAST Network is organized into five research teams interested in water testing, private well contamination, PFAS removal, air and atmospheric deposition, and applied research. They are supported by the project management, risk assessment, and data management teams. The goals of the NC PFAST Network are to measure the current levels of PFAS chemicals in public drinking water sources across the state, develop quantitative models to predict which private wells are most at risk of PFAS contamination, test the performance of removal technologies, study the air and atmospheric deposition of PFAS, evaluate other research to inform water quality sampling techniques, data interpretation, and mitigation of PFAS, and finally, research to understand the adverse effects of PFAS on human health, wildlife and the environment. The NC PFAST Network has a newsletter to help keep the public informed of its activities, and more information can be found at their website, ncpfastnetwork.com.

Water Sampling & and Analysis
Lee Ferguson, Ph.D., Associate Professor, Civil and Environmental Engineering, Duke University

Lee Ferguson detailed the methods used by his lab and Detlef Knappe's at North Carolina State University to measure and determine the levels of different PFAS present in public drinking water across the state of NC. He also provided an update on the current status of the water sampling process and an overview of the communication schema used to disseminate the results coming out of the study to the parties that need to be informed. The water sampling analysis is being conducted at 405 sites across the state, including 190 surface water samples, 158 well water samples, and 57 county-owned groundwater samples.

Ferguson shared that the samples are analyzed with both targeted (shows known PFAS compounds) and non-targeted (allows for detection of unknown PFAS compounds) analysis. They compared levels in the water samples against the EPA standards for PFAS, and these metrics are shared with the stakeholders so they could take action in the event the levels were higher than the safety limit. For example, the town of Maysville was informed and able to switch their water supply to Jones County.

He also explained that while the sources of PFAS contamination are well understood for some cases, that is not always the case. Understanding the source is an important part of understanding and remediating PFAS contamination. He also noted that all the necessary stakeholders need to be informed at once, from the public and the regulatory agencies to the municipalities. The lessons learned from water testing highlight the need for communication strategies to connect the different communities polluted by PFAS.

Air Emissions and Atmospheric Deposition
Barbara Turpin, Ph.D., Professor and Chair, Environmental Sciences and Engineering, UNC-CH

Barbara Turpin provided a discussion of the research measuring the PFAS in the air across North Carolina. The main goal in researching air emissions and atmospheric deposition of PFAS is to determine where the PFAS contamination comes from. There are few measurements of how much PFAS are present in the atmosphere, so there is a pressing need to answer this question.

Turpin stated that potential sources for air contamination with PFAS could include contamination from industrial manufacturing emissions, fire-fighting foam, or compounds released by waste streams. The research team working on atmospheric deposition is sampling air in Research Triangle Park, Appalachian State University, Wilmington, Charlotte, and East Carolina University.

Collectively, the NC PFAST Network is working to better understand and address PFAS contamination in the state.

PANEL I: PERSPECTIVES FROM ACROSS THE STATE

The first panel of the Summit examined how regulatory agencies and impacted communities respond to PFAS contamination. The panel was moderated by Katy May, Co-Director for the Community Engagement Core at the Center for Human Health and Environment at NCSU.

Panelists included:

- Schumata Brown, Town Manager for the Town of Maysville, NC
- Linda Culpepper, Director of the Division of Water Resources for the NC Department of Environmental Quality

- Zack Moore, Section Chief, Epidemiology, Division of Public Health, NC Department of Health and Human Services

- Emily Sutton, Haw River Keeper, Haw River Assembly

- Emily Donovan, co-Founder, Clean Cape Fear

In introducing themselves, the panelists shared their perspectives on PFAS contamination. For Schumata Brown, he has lived in Maysville his entire life, and has become an expert in PFAS since hearing his town's water supply had elevated levels of a specific PFAS. He is passionate about this issue and being a part of the discussion was a chance to give back to his community what PFAS has taken away. This highlights the importance of improving communication between the public and researchers investigating PFAS.

Furthermore, Zack Moore commented that there is a need to help people understand the health and environmental impacts of PFAS contamination, and that the newness of the research means there will be knowledge gaps, so guidance from researchers and policy makers is needed.

Other points made during the panel discussion included:

- The significance of the Riverkeepers and other community groups as connections between agencies/researchers and the public.

- The importance of clear and constant communication.

- The challenge of uncertainty: "we aren't able to answer all questions, but we can help people know what information we do have to help navigate the complexity and unknowns and reduce fears."

- The NC PFAST Network is invaluable. It was developed to help impacted communities, and they offered their expertise in helping communities navigate reports of elevated PFAS exposures. They also shared techniques and knowledge with local research agencies.

In addition to these points, there was lengthy discussion about the cost of remediating PFAS contamination; who would pay for remediation (whether that is removal/changing water supply/in-home treatment options/etc.). It does pose a financial burden on impacted communities and highlights economic disparities. Because of this, there is a need to control PFAS at the source.

In closing the panel, each panelist was asked to say one thing they wanted. They answered as follows:

1) to know where the contamination was coming from

2) to have continued dialogue with communities and work together on getting answers

3) to advocate for regulations and collaboration between regulatory agencies and researchers to get the evidence needed to enforce regulations

4) to develop an understanding for how to move away from using PFAS

5) to explore the potential to regulate PFAS as a class instead of as individual PFAS discharged into the environment.

An integral part in solving issues around PFAS contamination is rebuilding public trust. The comments from panelists and the stakeholder communities they represent, provided a wealth of insight for moving forward.

PANEL II: PERSPECTIVES FROM NORTH CAROLINA POLICYMAKERS

The second panel of the Summit focused on legislative actions to address PFAS contamination in the state. The panel was moderated by Jeff Warren, Research Director of the NC Policy Collaboratory. The panelists were:

- Senator Rick Gunn, N.C. District 24
- Representative Pricey Harrison, N.C. District 51
- Representative John Szoka, N.C. District 45
- Senator Mike Woodard, N.C. District 22
- Senator Harper Peterson, N.C. District 9

The NC policymakers present at the panel discussed a variety of issues regarding PFAS contamination in the state, and there was bipartisan support that these issues need solutions. A main question is how to ensure that North Carolinians are getting clean water—particularly rural communities that are difficult to reach and schools. Similar to the prior panel, comments included:

- issues of equity and cost to address PFAS contamination
- how this issue rests at the intersection of science, public works, and community needs
- the role of interaction between regulatory agencies and socially-responsive research networks
- adoption of rules that will help prevent discharge of chemicals into our water or air when potential health effects are unclear.

The policymakers also discussed how industry partners have an important part in this conversation. Initially, the human health effects of replacement PFAS were poorly understood and companies were discharging what they were legally allowed to discharge. New research will play a role in creating better ways of regulating PFAS, and policymakers and industry need to work together.

Comprehensively, a framework that allows for the study of PFAS, removal of PFAS from the environment, protective regulations for PFAS, and enforcement of those regulations is needed to ensure that communities are safe. The panelists discussed the need for a proactive approach, shifting the burden of proof to showing chemicals are safe to use, and investing in the appropriate people to tackle the issues that PFAS contamination has created. They closed by stating that citizens in NC should talk to their representatives and senators so they know of their needs and can factor those concerns into future legislation and funding.

LEGAL PERSPECTIVE

Controlling PFAS at the Source: The Legal Obligations and Liability

Geoff Gisler, J.D., Senior Attorney and Leader, Clean Water Program, Southern Environmental Law Center

Geoff Gisler provided a detailed overview of the laws that are relevant for addressing PFAS in the environment. He examined the question of PFAS being unregulated (not controlled by law) and reviewed the different legal frameworks that provide insight into how PFAS could be legally managed in our environment at the federal, state and industry levels.

This included the Clean Water Act, which governs the direct discharge of PFAS compounds from industrial sites, the North Carolina groundwater standards, and common law, which currently is addressing concerns from public utilities and property owners. Each has some layer of protection or means of recourse regarding PFAS contamination.

A main thrust of his talk focused on the need for source control of these compounds. This helps prevent public health threats, removes the need for in-depth analysis of every chemical, and allows for alternatives to be considered. Overall, he emphasized that this is not about these chemicals being unregulated; they are regulated and there are rules to use to help control their discharge into communities' drinking water.

INDUSTRY PERSPECTIVE

The final talk of the Summit included two speakers from Chemours Fluoroproducts, Sean Uhl and Amber Wellman. They focused on the use of PFAS in industry and consumer products, their utility, and the diverse nature of this large family of compounds. They emphasized that because of the inherent differences between members of the PFAS family, these compounds should not be regulated or referred to as one class.

They championed for the phase out of the more toxic PFAS compounds. Additionally, they discussed about their efforts to promote specific analytical methods with reliable standards (that they will share with others to use) to make evidence-based decisions about PFAS. This is an area where interactions between regulatory agencies, research networks, and industry can be productive in helping inform communities on how to proceed and handle PFAS contamination responsibly.

As a company, Chemours has made a corporate commitment to have a 99% reduction in their air and water emissions of all fluorinated compounds by 2030. To achieve this goal, they have been working to improve their analyses of PFAS remediation technologies. This includes better sampling methods, reclaiming of waste streams, improved detection limits, and the installation of a thermal oxidizer to destroy PFAS before releasing waste streams into the environment.

Chemours is working to address their role in contaminating the environment with PFAS, while balancing the use of these chemicals in their industrial processes. As communities and the state move forward in plans to manage and remove PFAS from our environment, Chemours will be an important partner.

Working Group Sessions

The working group sessions were an integral part of the Summit to foster small group discussion of the different facets of PFAS research. The group discussion topics were chosen by the Summit Organizing Committee and focused on:


Fate and Transport


Treatment and Disposal


Risk Assessment

Participants at the Summit selected which working group they attended based on their interests. Each group had representatives from the various stakeholder communities, including scientists conducting research on PFAS, state and federal public health and environmental agencies, and representatives of advocacy organizations and communities impacted by PFAS presence.

The two working group sessions (2-3 hours each) were facilitated by members of the Summit Organizing Committee with relevant expertise. The sessions began with short presentations from stakeholders, followed by guided discussion and time for open dialogue and brainstorming. Together, lists of questions and actionable recommendations were developed within each group to highlight challenges within the PFAS research landscape that need to be addressed.

Collectively, the three working groups settled on several common main themes as the predominant guiding principles for PFAS work. These themes will be summarized below in the Central Themes, but a brief outline of each breakout group is provided here.

FATE AND TRANSPORT

The Fate and Transport working group was facilitated by Bryan Luukinen from the Duke University (DU) Superfund Research Center, and Sarah Yelton from University of North Carolina (UNC) Institute for the Environment. The three speakers that provided the foundation for discussion were:

1) **Scott Belcher, Ph.D., Research Professor at North Carolina State University (NCSU)**
Bioaccumulation and Impacts of Novel and Legacy PFAS in Wildlife of Coastal North Carolina

2) **Dave Genereux, Ph.D., Professor of Marine, Earth, and Atmospheric Sciences at NCSU**
Discharge of PFAS from groundwater to surface water near the Fayetteville Works, North Carolina

3) **Jennifer Redmon, Senior Environmental Health Scientist and Chemical Risk Assessment Specialist at Research Triangle Institute (RTI) International**
A Hydrogeological Modeling Approach to Understanding the Fate and Transport of PFAS in the Cape Fear Watershed

The main question this group discussed was:

What are the missing links in our understanding of fate and transport of PFAS?

Other questions that arose during the discussion to guide future research:

- What information is needed to understand how PFAS compounds move through the environment?

- How can available data and information help reconstruct historical fate and transport?

- What new data, information, or approaches are needed to improve modeling estimates?

The group centered their discussion around challenges that need to be overcome to fill in the gaps in our understanding of the migration of PFAS in the environment. These included accurate measurement of the fluorine content in the environment, research in fundamental chemistry to understand these compounds, investigation of PFAS sources, and modeling the distribution of PFAS in the environment. These will be discussed further in the Central Themes section.

TREATMENT AND DISPOSAL

The Treatment and Disposal working group was facilitated by Neasha Graves from the UNC Center for Environmental Health and Susceptibility and Andrew George from the UNC Institute for the Environment. The three leading speakers were:

1) **Michael Borchers, Assistant Director, Water Resources Department, City of Greensboro**
Greensboro's Response to PFAS in its Watershed and Drinking Water

2) **Orlando Coronell, Ph.D., Associate Professor, Environmental Sciences and Engineering, UNC-Chapel Hill**
Removal of PFAS from drinking water by reverse osmosis membranes, residential filters, and a novel resin

3) **Mei Sun, Ph.D., Assistant Professor, Civil and Environmental Engineering, UNC-Charlotte**
Removal of PFAS from drinking water by activated carbon, ion exchange resin, and electrochemical oxidation

The main discussion question for this group was:

Which alternative treatment and disposal options offer the most promise?

Other questions that arose during the discussion to guide future research:

- What influences municipalities' decisions to address PFAS in drinking water?

- How do you equitably share the burden and responsibility for addressing contaminants?

- Since research on health effects and remediation will always be slower than production and discharge, what is the best solution to protect public health?

This group concentrated on how to clean up and remove PFAS in our environment, including the issues of source control, cost, the relationship with industry, differences in how quickly PFAS is put into the environment/being removed, and how to prepare communities for the long-term removal of PFAS. These will be discussed further in the Central Themes section.

RISK ASSESSMENT

The Risk Assessment working group was facilitated by Kathleen Gray from the UNC Center for Environmental Health and Susceptibility and Ariana Eily from DU Initiative for Science and Society. The three leading speakers were:

1) **Jamie DeWitt, Ph.D., Associate Professor, Pharmacology and Toxicology, East Carolina University**
Descriptive toxicological approaches to understand health risks of understudied PFAS

2) **Sue Fenton, Ph.D., Group Leader, Reproductive Endocrinology Group, National Institute of Environmental Health Sciences (NIEHS)**
Comparison of health effects following oral exposures to PFOA and GenX in pregnant mice

3) **Rebecca Fry, Ph.D., Professor and Associate Chair, Environmental Sciences and Engineering, UNC-CH**
PFAS and Placental Toxicity

The main discussion question for this group was:

How can emerging knowledge about PFAS be factored into risk assessment?

Other questions that arose during the discussion for guide future work:

- How to best design PFAS studies?
- What toxicological data are most critical for decision makers about PFAS?
- Who needs to know about this research, and how should it be shared across sectors?

The discussion of this group centered around the communication landscape between stakeholders about PFAS research, coordinating efforts across sectors to address PFAS contamination, and how to further PFAS research into the future. These will be discussed further in the Central Themes section.

Overall, the discussions of the working groups were incredibly dynamic. These conversations highlighted important aspects regarding PFAS that researchers, regulatory agencies, policymakers, and communities need to consider as work continues to address PFAS in the environment.

Table 1 provides insight into the thinking processes that took place in each working group, and questions that need to be addressed moving forward in PFAS research.

QUESTIONS FOR FURTHER RESEARCH

WORKING GROUP 1	WORKING GROUP 2	WORKING GROUP 3
What information do we need to understand how PFAS compounds move through the environment? How can available data and information help reconstruct historical fate and transport? What role do lab, field, modeling studies play? What new data, information or approaches do we need to improve modeling estimates? (current distribution, predicting future fate and transport) How much is directly from manufacturing and how much through consumer product use? 1. Chemical manufacturing 2. Byproducts 3. Consumer products Need a better understanding of consumer products on PFAS presence and intersection with social justice. Multi-site studies: historical reconstruction and broader health studies to link fate and transport. What does it take to make modifications to the sludge application permits?	Who should bear the burden of cost? To what extent are downstream municipalities putting pressure on upstream municipalities to address PFAS sources? How can the public be educated about PFAS issue without causing mass hysteria and losing public trust? Are outlying communities well informed about PFAS issues? What are manufacturers required to show and tell? How can manufacturers be transparent about chemicals when they have a trade secret formula? How can utilities, consumers, advocates put pressure on industry to make changes? Should manufacturers fully test and measure the implications of their products before it can be used in consumer products and educate consumer? What can be done to empower an entity to take the lead and make a roadmap to address PFAS?	How do we best design studies that will protect communities? How do research questions answer regulatory needs? What do regulators need to take action? What is the burden of proof to take someone to court? What is different regarding what is objective in court vs. what is objective to scientists? How do we measure outcomes around prenatal exposures? How can research studies be designed to study mixtures? What is important information for clinicians to know? Which chemicals are priority to regulate? How can we make the current research more accessible? How do we get trained researchers into the field to properly address the issue in communities?

Table 1

Central Themes Regarding PFAS

Following the working group sessions, participants at the Summit reconvened to report back the discussions that occurred in each of the three groups. The diverse perspectives converged on several key themes. The nature of the discussions was complex and examined the many ways PFAS interact with the connection between science and society. That these themes were found independently, and echoed throughout the other sessions at the Summit, highlights their importance in how to think about PFAS and work toward solutions.

The themes are as follows:

 Piecemeal Progression versus Class Designation

 Source Control to Limit Exposure

 Interaction of Stakeholders to Holistically Address PFAS

 Integration of a Society-focused Research Network

 Precautionary Principle to Reduce Presence of PFAS

The questions, challenges, and recommendations shared throughout the duration of the Summit will be summarized below by theme.

PIECEMEAL PROGRESS VERSUS CLASS DESIGNATION

One of the main themes that emerged during the discussion in the Summit centered on whether PFAS should be considered as a family of compounds for regulation instead of trying to understand their health risks and pursue regulations in a piecemeal fashion. There are several reasons why this distinction is important, particularly with regards to the timeline it takes to understand their health effects and get regulatory action versus the timeline of PFAS compounds being released into the environment. To address this concern, both long- and short-term recommendations were made to support current research about PFAS and efforts to push for re-classification. These recommendations are below, starting with short-term solutions.

▶**Prioritize which PFAS should be addressed first while working in a piecemeal fashion. To do this, start with a targeted health analysis on those that are found in the blood of exposed populations, grouping PFAS compounds based on regulatory-focused research, and using 150 representative compounds from different sub-classes of PFAS in those studies.**

▶**Use computational toxicology to drive understanding of which compounds to focus on as well and use chemical structures to predict toxicity, which may help leveraging regulatory action.**

- **Generate a reference dose for legacy PFAS and their byproducts as well as for the 4-5 PFAS that have been identified in blood of Eastern NC residents so that their health effects are understood and safe water limits may be set.**

- Explore other examples for class regulation in the US as well as in other countries, such as the Madrid Statement, the Washington State – CF2 regulation, regulations on dioxins and PCBs, OECD efforts, and encourage the adoption of the precautionary principle (discussed below).

- Create a PFAS taskforce made up of stakeholders from across the state (EPA, DEQ, research and industry, politicians, communities, clinicians). Building trust among these groups and sharing perspectives and information, will support the best outcome for NC environmental and public health.

SOURCE CONTROL TO LIMIT EXPOSURE

While work is underway to understand the effects of PFAS exposure, where PFAS are in the environment, how they are getting there, and ways to decrease exposures, a key part of limiting exposure is to pursue source control. This is especially important given how large the family of PFAS is, the high persistence of some PFAS in our environment, and the lag between their discharge and society's ability to respond. The concept of managing PFAS at the source so they are not being discharged into the environment was discussed constantly during the Summit. Source control will allow grappling with the PFAS communities are currently exposed to, and create a future in which PFAS are not a pressing concern because they were to be removed and there are no more PFAS being released. It is important to note that this isn't a matter of these chemicals being unique, there are regulations that may be used to control their discharge into the environment. Actionable recommendations that address this topic of source control were:

- **Enforce the Clean Water Act, Administrative letters, special orders of consent as they pertain to PFAS discharge in the state. To this end, state agencies need to work together and leverage their powers to enforce these provisions.**

- **Explore low-tech solutions to source control such as hydraulic control at the source, adopting alternatives to PFAS-containing compounds (like the case of fire-fighting foams), and informing secondary parties that they may be releasing PFAS chemicals so they can control their waste streams.**

- Require industry to disclose the chemical compounds they are creating, and treat their waste streams before they make their way out into the environment, to consumers and water treatment plants.

- Support small studies that discover or implement new technology to advance methods for practical management of PFAS discharge.

The importance of clear and transparent communication between all stakeholders involved in PFAS exposure was evident. Each stakeholder group has unique knowledge, abilities, and understanding that is highly relevant as solutions to limiting both environmental and human exposure to these chemicals are developed. There is a need for continued and thorough interaction between all parties to support the on-going work into the long-term. Recommendations to deepen the interaction of the stakeholders were:

- **Conduct conversations among researchers, regulatory agencies, and legal experts that inform data collection as PFAS research continues and share ideas on resolving their presence in our environment.**

- **Integrate clinicians in the conversation about PFAS exposure as they are a direct link between impacted communities and the effects of PFAS on human health.**

- **Start conversations about risk with how people are actually being impacted by PFAS. This will enable communities to help shape research questions as well as identifying vulnerable populations and, perhaps, guide research to look at specific health outcomes occurring in impacted communities.**

- **Industry and scientific communities need to share their developments of new technologies for treatment and disposal with public utilities and others such that they can use the best means to mitigate the presence of PFAS compounds.**

- **Ensure public education and communication about PFAS is from a collaborative effort so that key populations are reached and provide them with knowledge to reduce their household exposure, answer their questions, and listen to their needs. This communication should integrate organizations that interact with people in their daily lives, such as WIC, food pantries, and churches.**

- Develop partnerships with industry representatives, and share information about the PFAS used in commerce.

- Develop guidelines for the scientific community for working with PFAS, as well as a platform for sharing methodology to address which equipment is PFAS-free and which materials to use as solvents, as well as other experimental knowledge. This will promote consistency in how PFAS research is conducted and help eliminate potential problems.

- Broader communication about the funding mechanisms that can support research and community action in regards to PFAS are needed. This includes the NTP nomination process, rapid response grants from federal agencies, and communicating the findings of NTP or EPA PFAS prioritization documents with impacted communities and elected officials, so they have up to date information.

INTEGRATION OF A SOCIETY-FOCUSED RESEARCH NETWORK

Continually throughout the course of the Summit there was discussion of the role of a society-focused research network to help address issues caused by PFAS. There was widespread support of the efforts of the NC PFAST Network in its collaborative efforts at universities across the state, its interactions with officials and regulatory agencies, its connection to the public, and its ability to work with stakeholder groups as PFAS-related issues are faced. Particularly since this is a group of emerging contaminants, the scientific network is learning as the public is learning so having this network with so many interfaces helps everyone be involved and aware. There is still a major role for a society-focused research network to play in our continued understanding of these compounds. Recommendations for the continued integration of a society-focused research network are below.

- **Continue the NC PFAST Network to monitor and research PFAS in the state because it is integral in pulling together major stakeholders relevant to this issue. Explore funding to continue supporting it, so it can continue to share data and design societally-directed research.**

- **Focus on exposure data that align with existing regulatory frameworks help move the conversation forward toward action.**

- Conduct experiments to understand combinatorial effects of legacy PFAS compounds, as well as experiments that look for PFAS that are as of yet unknown.

- Continue research on disposal options to remove PFAS, since they are highly persistent in the environment.

- Explore the most sensitive exposure cases to help make policy decisions, and use in vitro studies to prioritize PFAS for animal studies and in the long-term, epidemiology studies.

- There is a responsibility to include in research studies the environmentally relevant doses of PFAS, as well as considering the levels measured in highly exposed populations.

- Research that aligns with and might better inform existing regulatory frameworks should be a focus, with the goal of helping regulators move the conversation forward toward action.

A closing note from the Summit was a promotion to adopt the Precautionary Principle as it applies to PFAS in NC communities. The Precautionary Principle states that the introduction of a new chemical whose effects are unknown into the environment should be avoided. Some opponents of the Precautionary Principle said that it may stifle innovation, but working collaboratively, pathways that support the principle and industry could be created.

Advocates stated that the use of this principle with regard to PFAS is necessary because research will always be slower than the production and discharge of these chemicals, so the best means of promoting public and environmental health is to limit their use until they are understood. It is also more equitable, because it shifts the burden from the public to the industries that profit from the use of these products. Recommendations to help adopt the Precautionary Principle are below.

- Conduct a cost/benefit analysis to identify the results of adopting the precautionary principle versus the status quo. Focus on the most susceptible exposed populations, such as children and first-responders.
- Work to rebuild and maintain public trust, since it has been broken in numerous communities by not knowing these chemicals were in the environment.
- Focus on having empathy for NC citizens, and develop an understanding that consumers should not be treated as test subjects for new chemicals.

These recommendations are actionable, but the adoption of the Precautionary Principle largely rests on a serious consideration of our values and priorities as a society. Some participants at the Summit pointed out that it seems backwards to permit a chemical to be released into the environment until it is shown to be dangerous, as opposed to limiting it until research demonstrates its safe use. As put by one participant, “if we want to be protective, though we may be wrong some fraction of the time, that error should be in favor of protecting our communities and our environment.”

Conclusion

The 2019 Environmental Health Summit provided an in-depth examination of PFAS and its implications for environmental and public health. This comprehensive summit focused on PFAS research and recommendations to limit human and environmental exposure. It pulled together experts from the national and state-wide scientific communities, policymakers, lawyers, members of impacted communities, activists, and regulatory agencies to share their knowledge, experiences, questions, and concerns. The 12th Annual Summit provided each of these groups an opportunity to be heard and interact with each other while solutions to address PFAS contamination are developed. These discussions are crucial to ground our path forward for researching and removing PFAS from the environment.

The working groups focused on I) Fate and Transport, II) Treatment and Removal, and III) Risk Assessment and allowed for open discussion of each of these issues to create a list of pressing questions and recommendations to put into action immediately. The plenaries and panel sessions provided a suite of perspectives that also informed these discussions and represented the different stakeholder groups. Throughout the entire Summit, each session resonated on several key themes: Piecemeal Progress, Source Control, Interaction of Stakeholders, Integration of a Society-focused Research Network, and the Precautionary Principle. Guided by these themes, actionable recommendations were put forward to benefit the community around PFAS.

These recommendations range in how quickly they can be acted upon, with some being supported immediately following the Summit. For instance, the NC PFAST Network has received an extension to continue its work as a Society-focused Research Network, and a connector between different communities that need to be a part of the PFAS conversation. Similarly, better communication between all of the stakeholders, particularly researchers and the public, is being facilitated within the state as well.

The continuity of these actions to facilitate communication and coordinated research efforts around PFAS is instrumental in this issue being dealt with appropriately and thoroughly. However, these are just some of the pieces needed to truly address PFAS in our environment. The interplay between all of these themes sets the stage for how PFAS is removed from our environment, and exposure reduced. A collaborative system of dialogue with affected communities, research conducted by scientists that supports regulatory action and guides policy, transparency from industry & adoption of removal technologies, supportive policies by policymakers, and enforcement by regulatory agencies is needed. A diagram of how these themes interconnect and the dynamics that need to take place between the different stakeholders can be found in Figure 3.

Predominantly, the idea of adopting the precautionary principle seems of paramount importance for how PFAS-related issues are addressed moving forward. While research of PFAS environmental and human health effects are on-going, knowing that they have contaminated our water, easily traverse our environment, persist, and are found in humans and wildlife should be enough to shift us from reactive to protective. It seems that preventing PFAS from entering our environment before more fully understanding which of these compounds, if any, are safe is a critical step to protect us and the world we inhabit. The public also needs to continue being involved and informed on this issue. Advice for doing so can be found in Figure 4 below.

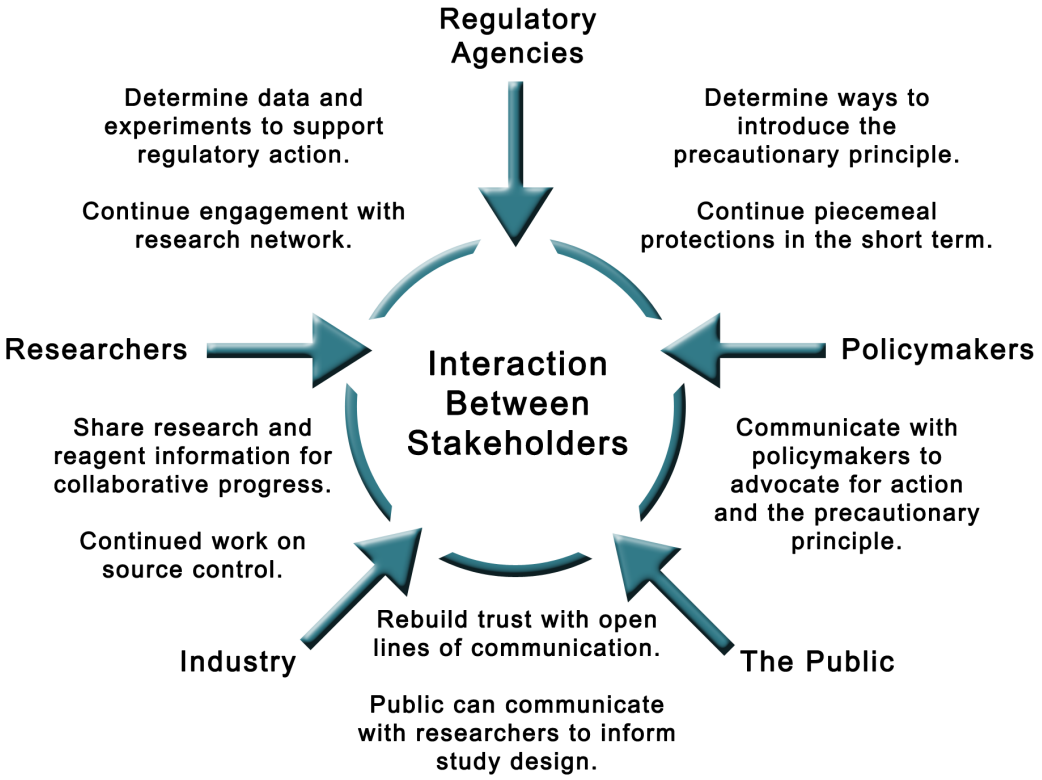

Figure 3: Interaction between stakeholders

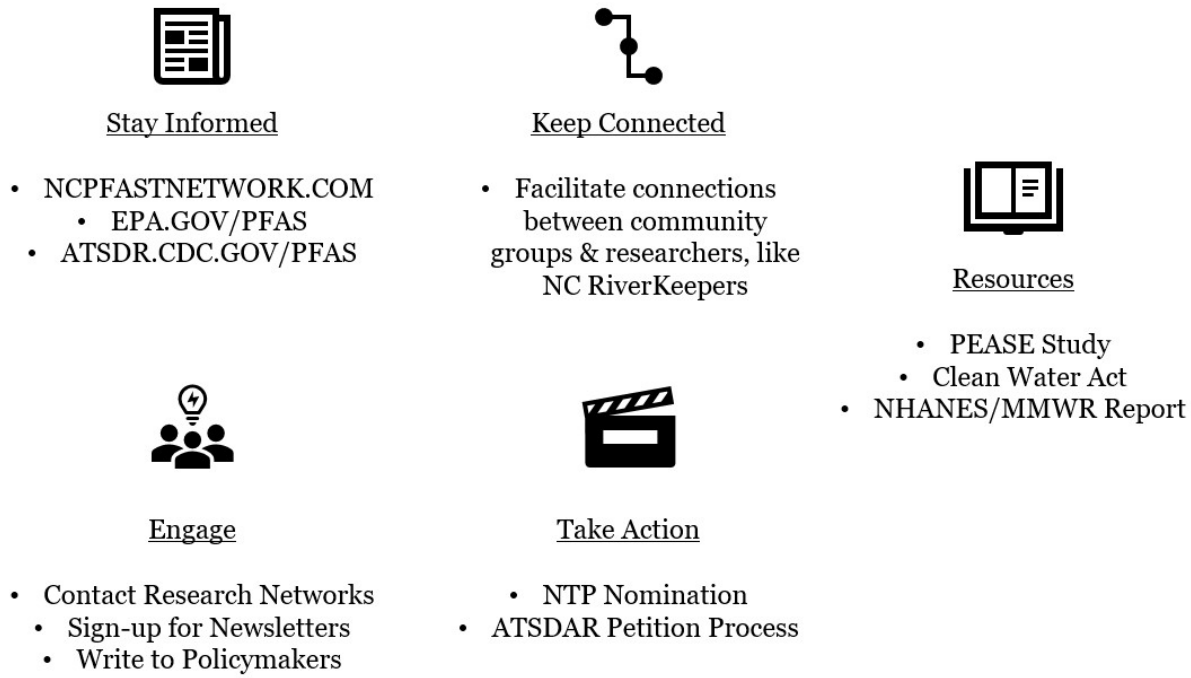

Figure 4: Public Awareness

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