BOSC

BOARD OF SCIENTIFIC COUNSELORS

January 18, 2022

Wayne E. Cascio, MD
Acting Principal Deputy Assistant Administrator for Science
Office of Research and Development
U.S. Environmental Protection Agency

Dear Dr. Cascio:

On behalf of the Board of Scientific Counselors (BOSC), I am pleased to provide you a review report addressing charge questions posed by the Office of Research and Development (ORD) for the review of the PFAS research program.

The BOSC was reconstituted in 2017 with an Executive Committee and five subcommittees aligned with each of the National Research Programs (part of the Health and Environmental Risk Assessment program is reviewed in conjunction with the Chemical Safety for Sustainability program). The Executive Committee met in September–November 2021 to discuss the PFAS research program, and this report represents the response of the Executive Committee to the provided charge questions. In addition to responses to the three sets of charge questions, the full committee felt that two issues warranted a special response: public engagement and program integration. To that end, the review committee has provided specific comments and recommendations that we feel will increase the effectiveness of the PFAS research program as well as the outreach to communities.

We anticipate that this report will assist ORD in evaluating the strength and relevance of the PFAS research program and aid in guiding further course adjustments to the research within. We will be happy to provide any additional information concerning the review or answers to any questions you may have, and we look forward to working with you in the future on this program.

Sincerely,

Paul Gilman

Paul Gilman, Ph.D.
Chair, BOSC

Lucinda Johnson

Lucinda Johnson, Ph.D.
Vice Chair, BOSC

Cc: Bruce Rodan, Associate Director for Science

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REVIEW OF U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT'S IMPLEMENTATION OF PFAS RESEARCH AND DEVELOPMENT

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January 18, 2022

A Federal Advisory Committee for the U.S. Environmental Protection Agency's Office of Research and Development

Contents

LIST OF ACRONYMS

AOF	Adsorbable Organic Fluorine
BOSC	EPA Board of Scientific Counselors
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIC	Combustion Ion Chromatography
CPHEA	EPA's Center for Public Health and Environmental Assessment
DoD	U.S. Department of Defense
EC	EPA BOSC Executive Committee
EPA	U.S. Environmental Protection Agency
HCFC	Hydrochlorofluorocarbon
MM	Modified Method
NADP	National Atmospheric Deposition Program
NAMs	New Approach Methods
NEJAC	National Environmental Justice Advisory Council
NTA	Non-targeted Analysis
ODS	Ozone-depleting substance
ORD	EPA Office of Research and Development
OTM	Other Test Method
PCB	Polychlorinated biphenyl
PFAA	Perfluoroalkyl acids
PFAS	Per- and polyfluoroalkyl substances
PFC	Perfluorinated compound
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonate
POD	Point of departure
QSAR	Quantitative structure-activity relationship
RCRA	Resource Conservation and Recovery Act
SEM	Systematic evidence map
SSA	Suspect Screening Analysis
SWDA	Safe Water Drinking Act
TOF	Total Organic Fluorine
VOC	Volatile organic compound

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) made a strong commitment to address the unique challenge of addressing per- and polyfluoroalkyl substance (PFAS) contamination through a multi-prong strategy released in October 2021, "PFAS Strategic Roadmap: EPA's Commitments to Action, 2021–2024". This strategy document highlighted the importance of grounding decisions in sound science, citing a need to better measure and understand the exposure pathways, toxicities, and potential health impacts of less-studied PFAS; identify strategies for addressing multiple chemicals at once; and developing tools to remove and remediate PFAS from the environment. These research priorities are well aligned with the EPA Office of Research and Development (ORD) programs that were reviewed by the Executive Committee (the Committee or EC).

The EPA Board of Scientific Counselors (BOSC) EC met and deliberated on the three aspects of ORD's PFAS research program: (1) issues associated with testing and analytical issues associated with quantifying PFAS in the environment; (2) approaches for classifying PFAS to more effectively inform the human health assessment and risk mitigation programs; and (3) research addressing PFAS mitigation and treatment, with special consideration of the Agency's work within communities. The ecotoxicology component of the PFAS research program was not covered in this review, although it is itself informed by the empirical data collected in the field and helps inform the priorities for human and mammalian studies.

Following the initial presentations by ORD staff, the Agency released two reports: "PFAS Strategic Roadmap: EPA's Commitments to Action 2021–2021" and "National PFAS Testing Strategy: Identification of Candidate Per- and Poly-fluoroalkyl Substances (PFAS) for Testing". The EC read and considered these reports during the charge question deliberations.

The complexity of the research program was recognized and discussed at length, along with consideration of the important role that communities play in deployment of place-based research activities. As a result of these discussions, the Executive Committee addressed two issues in addition to the formal charge questions: (1) strategies for optimizing integration of PFAS research activities across ORD, and (2) strategies for enhancing community engagement. Recommendations were proposed for each of these two areas.

CHARGE QUESTIONS AND CONTEXT

The EC was charged with addressing a series of questions about ORD's implementation of PFAS research and development. Charge questions were as follows:

> Q.1. Many stakeholders have identified a need for validated "total PFAS" methods, such as total organic fluorine (TOF) or total oxidizable precursor (TOP) methods, to quantitatively measure a non-compound specific amount of PFAS in environmental samples. EPA has expanded the scientific foundation for identifying and quantifying PFAS in the environment through the development of validated analytical methods for specific PFAS and the use of non-targeted analysis methods. ORD researchers are working to develop validated TOF methods for wastewater and air emissions.
>
> Please comment on the implementation of ORD's PFAS methods research. In addition, what suggestions and recommendations can the Executive Committee offer on the utility of "total PFAS" methods and other analytical approaches for identifying "total PFAS" in environmental samples?

Q.2. Due to the large number of PFAS in commerce and the environment, there is an emerging consensus on the need to use grouping- or category-based approaches to assess and address potential PFAS toxicity. While structure-based categories are most common, there is no clear consensus method for categorizing PFAS, and ORD researchers are evaluating other features (e.g., chemical and physical properties, toxicokinetic properties, toxicity mechanisms) for use in categorizing PFAS for human health risk assessment and risk mitigation purposes.

Please comment on the implementation of ORD's research on the human health effects from PFAS. In addition, what suggestions and recommendations can the Executive Committee offer on common category characteristics that would maximize the utility of the resulting PFAS groupings for the broadest set of decision contexts?

Q.3. Data on the efficacy and costs of different approaches for removing PFAS from the environment and managing PFAS and PFAS-containing materials are needed to inform federal, state, tribal, and local decisions on drinking water and wastewater treatment, contaminated site clean-up and remediation, and end-of-life materials management. ORD is working to increase our understanding of approaches for addressing PFAS in the environment through analytical method development, laboratory-based studies, pilot-scale studies, and field studies.

Please comment on the implementation of ORD's PFAS treatment research. In addition, what suggestions and recommendations can the Executive Committee offer for working and communicating with communities in potential field study locations?

The responses of the EC to the charge questions are provided in the following section.

SUBCOMMITTEE RESPONSES TO CHARGE QUESTIONS

Charge Question 1

Q.1. Many stakeholders have identified a need for validated "total PFAS" methods, such as total organic fluorine (TOF) or total oxidizable precursor (TOP) methods, to quantitatively measure a non-compound specific amount of PFAS in environmental samples. EPA has expanded the scientific foundation for identifying and quantifying PFAS in the environment through the development of validated analytical methods for specific PFAS and the use of non-targeted analysis methods. ORD researchers are working to develop validated TOF methods for wastewater and air emissions.

Please comment on the implementation of ORD's PFAS methods research. In addition, what suggestions and recommendations can the Executive Committee offer on the utility of "total PFAS" methods and other analytical approaches for identifying "total PFAS" in environmental samples?

Narrative

The Committee commends EPA for remarkable progress on advancing methods for the detection of PFAS in environmental media. The challenge is significant, as it involves working in different media to identify a broad class of chemicals with a variety of physical-chemical properties that are mobile in the environment and that react and transform in poorly understood ways.

The Committee is pleased that EPA is continuing to advance methods for targeted testing of longer lists of PFAS in more complex media (e.g., solid phase extraction-isotope dilution). At the same time, it is appropriate for EPA to advance methods for screening multiple environmental media for "total PFAS". Failure to screen this chemical space broadly would risk missing "hotspots" or widespread chemicals, and could thereby risk harm to human health and the environment. Testing for PFAS as a class is also an appropriate approach for such a large group of chemicals that are mobile and transform into other PFAS, are persistent, and cannot realistically be regulated individually due to their sheer numbers. For this reason, the Committee strongly encourages continuing priority research into "total PFAS" methods.

Measuring "total PFAS" is important for screening and for mass-balance (to not miss anything) but measuring meaningful categories (or subgroups) of PFAS is a slightly different challenge that aligns well with the needs of toxicity assessments. We commend EPA for also developing methods for groups or categories of PFAS compounds when such methods provide more specific information that aligns with other parts of the program (toxicology, exposure, or risk assessment).

The Committee noted the development of Other Test Method (OTM)-45 for polar PFAS compounds, and the ongoing development of Modified Method (MM)5 for non-polar PFAS compounds. With further development, it is anticipated that analytical approaches focusing on structural categories of PFAS, in addition to total PFAS, could identify and quantify PFAS categories that are informative for specific EPA research and regulatory needs.

Basic questions remain unanswered in air, including whether PFAS are in the vapor phase, or are bound to particles (or all the above). Dispersion and potential exposure from this pathway are also unclear. A greater focus on deploying "total PFAS" methods in the context of airborne emissions would be valuable. The Committee is encouraged by the work presented on Combustion Ion Chromatography (CIC) for airborne emissions, as well as the multiple innovative approaches for air monitoring, but all the air-related work is still at an early stage and requires significant development and ongoing resources from EPA to ensure that it becomes usable in the field.

The Committee was particularly impressed with the progress made in suspect screening analysis (SSA) and non-targeted analysis (NTA). The methods presented can be deployed in multiple media and decision contexts and appear to have progressed greatly in terms of accuracy, sensitivity, reproducibility, and comprehensiveness. The low levels of detection are especially impressive, compared to Adsorbable/Total Organic Fluorine (AOF/TOF) methods. The continued growth of the chemical library of PFAS makes this method especially promising, and the Committee wonders what it would take to bring SSA/NTA methods to the scale needed to explore the wide range of potential sources and media that might require analysis. Research into increasing the throughput, reducing the cost, and increasing access for stakeholders and partners to SSA/NTA methods would be especially valuable.

Strengths

- ORD should be commended for leveraging partnerships with government entities (e.g., the U.S. Department of Defense [DoD]) and businesses (e.g., SGS Axys) to accelerate scientific progress.
- ORD has made good progress on methods for drinking water analysis, including two validated methods, EPA 537.1 and EPA 533.
- We commend EPA for developing methods for total PFAS, as well as for groups or categories of PFAS compounds when such methods provide more specific information that aligns with other parts of the program (toxicology, exposure, or risk assessment).
- ORD should be commended for their ongoing leading-edge work on SSA/NTA of PFAS.
- ORD's collection of 400+ PFAS standards is impressive.

Suggestions

- Consider developing a reference and decision guide that organizes methods by program application area (Clean Air Act [CAA], Safe Water Drinking Act [SDWA], Resource Conservation and Recovery Act [RCRA]/Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA], etc.) and provides essential information (detection limits and key strengths and limitations) for users making decisions (e.g., investigation for presence, screening, mass balance, permit compliance, risk assessment, etc.) related to the use of the methods.
- Consider developing an approach or framework for determining which PFAS compounds are the priority for developing methods and monitoring in air. The approach should be used to guide a research program that addresses important open questions about PFAS in air. For example, are small, volatile perfluorinated compound (PFC)-like compounds of concern? Or do we need to worry about neutral perfluoroalkyl acids (PFAA) precursor compounds, or ionic PFAS in the air? Another example, are the National Atmospheric Deposition Program (NADP) National Atmospheric Deposition Network samplers effective for capturing PFAS in air? Can PFAS be measured in air in real time? In what phase? Particles? Volatile organic compounds (VOCs)? How effective are canisters for integrated air measurements? What are the most important PFAS to measure in air? Does PFAS in air get deposited into rainwater?

Recommendations

The Committee offers these recommendations to support the relevant Agency priorities:

Recommendation 1.1: Continue to increase the applicability and value of NTA and SSA across EPA programs, increase efforts to expand throughput, and lower cost while maintaining data quality and the quality of the resulting information.

EPA Response: ORD agrees with the recommendation. ORD plans to pursue opportunities with EPA Regional and Program office partners to expand EPA's NTA capabilities while maintaining data quality and the quality of the resulting information.

Recommendation 1.2: Increase focus on methods development for measuring PFAS in air and strengthening of links between research groups developing methods across environmental media.

EPA Response: ORD agrees with the identified need to develop methods for measuring PFAS in air and will engage with EPA's Office of Air and Radiation to prioritize this need across the full set of air-related PFAS research needs. ORD is continuously working to improve integration and coordination across its PFAS research efforts.

Charge Question 2

Q.2. Due to the large number of PFAS in commerce and the environment, there is an emerging consensus on the need to use grouping- or category-based approaches to assess and address potential PFAS toxicity. While structure-based categories are most common, there is no clear consensus method for categorizing PFAS, and ORD researchers are evaluating other features (e.g., chemical and physical properties, toxicokinetic properties, toxicity mechanisms) for use in categorizing PFAS for human health risk assessment and risk mitigation purposes.

Please comment on the implementation of ORD's research on the human health effects from PFAS. In addition, what suggestions and recommendations can the Executive Committee offer on common category characteristics that would maximize the utility of the resulting PFAS groupings for the broadest set of decision contexts?

Narrative

In its opening presentation to the BOSC Executive Committee, ORD outlined the critical need for a categorization strategy to support the assessment of the large number of PFAS without human health or toxicity data. ORD then presented a tiered toxicity testing strategy for PFAS that will: (1) use chemical curation to establish initial structure-based PFAS categories; (2) curate existing in vivo toxicity data to identify PFAS categories with data gaps; and (3) fill data gaps and refine PFAS categories using "mechanistic, toxicokinetic and in vivo testing data." Subsequent presentations provided additional details on each aspect of ORD's strategy using New Approach Methods (NAMs) for in vitro toxicity and toxicokinetics to be supplemented with in vivo toxicity studies. The tiered testing strategy discussion was complemented with a summary of ORD's efforts to estimate human health effects of PFAS using electronic health records, existing and draft human health toxicity assessment for selected PFAS, and a strategy to develop systematic evidence maps (SEMs) for around 9,000 PFAS compounds.

Given the large number of PFAS and the many data gaps, the Committee agrees that a single substance assessment approach is not feasible. In contrast, a categorization approach is expected to streamline ORD's research efforts. The use of chemical categories, based on commonality in structure, toxicity, and/or other relevant properties, is also not a new approach to chemical assessment (e.g., coplanar vs. non-coplanar polychlorinated biphenyls [PCBs]) providing further support for its proposed use.

The EC was impressed with the ambitious research and categorization efforts outlined by ORD under Charge Question 2, activities that are critical given the number and complexity of PFAS structures, widespread contamination, and potential for human health effects. ORD has substantial expertise in all the research areas described. ORD's categorization strategy will help identify, and start to address, critical data gaps necessary for characterizing PFAS groupings for which categorization in terms of toxicity and/or chemical structure is challenging. ORD's strategy will also help identify and categorize the adverse human health impacts of PFAS. It is anticipated that as the data accumulate and is further curated, patterns correlating categories of PFAS with recognized health impacts will improve understanding of the human health risks associated with PFAS exposure. Ultimately, the Committee believes that ORD's strategy is sensible, and that ORD has the expertise for successful execution.

The exploration of the relationship between PFAS exposures and adverse health outcomes is a rich and realistic opportunity for greater research investment. To take full advantage of this opportunity, ORD will have to strengthen and integrate its PFAS research programs, with a focus on health outcomes. A key question ORD must address is, *"What are common category characteristics that would maximize the utility of the resulting PFAS groupings for the broadest set of decision contexts relevant to human health concerns?*" To accomplish this, ORD is taking a multi-pronged strategy which was supported by the Committee. Nonetheless, there were areas of the plan that were not clear, perhaps due in part to the complexity of the material presented and the magnitude of the PFAS problem itself:

- It was sometimes unclear how research efforts covered under Charge Question 2 will be coordinated and integrated with other research efforts to understand exposure (e.g., develop methods for measuring PFAS) and health effects of PFAS, and how the information will be used to support risk assessment and risk mitigation. For example, does the subset of 150 PFAS selected for mechanistic and toxicokinetic testing (as discussed in EPA's presentation "ORD's Tiered Toxicity Testing Strategy for PFAS") include sufficient diversity to cover: (1) PFAS with known exposure and/or human health outcome concerns; (2) PFAS for which current analytical methods exist or are under development; and (3) PFAS with high priority for hazard/risk assessment and/or risk mitigation?

- There was also considerable discussion within the BOSC regarding how existing exposure data, and, most importantly, the vast amount of biomonitoring data that now exists can inform and focus the ORD's toxicity testing strategy. There is a wealth of information available on exposure to certain PFAS in the general population and in various subpopulation (e.g., NHANES, various state agencies, and other research organizations), as well as past analyses of sentinel PFAS in water, food, air, and consumer products. Greater focus on identifying PFAS that contribute most to human exposures could increase the efficiency and relevance of ORD research on health effects. Exposure data can never be complete and will not always relate to current exposures, but there is likely much to be gained by placing greater emphasis on actual human exposure patterns.

- Another area that generated discussion within the BOSC was the likelihood that "real world exposure" to PFAS will occur as chemical mixtures in conjunction with non-chemical stressors and in communities with environmental justice concerns. Furthermore, in recognizing some of the health outcomes pointed out in the presentations by Owens and Kraft, it appears that children and pregnant women are particularly vulnerable to the adverse health impacts of some identified PFAS chemicals. Although ORD acknowledged that mixtures and "real world" exposure (that disproportionately affect certain vulnerable populations based on socioeconomic status, which determines geographic location, as well as African American communities that suffer the legacy of redlining that affects their residential location) must be addressed at some point, and how these problems will be addressed was not presented. Children as well as pregnant persons and the developing fetus are uniquely sensitive and susceptible to chemical disruption. Children and pregnant persons from disadvantaged communities are more vulnerable because of the cumulative impact of chemical and non-chemical stressors. The Committee readily acknowledges the challenges associated with addressing the combined impacts of chemical mixture exposures and non-chemical impacts to human health in vulnerable communities but nonetheless felt the topic was important and should be addressed.

- The Committee was encouraged by the intention of ORD to place some emphasis on NAMs, not only to reduce the need for animal testing, but also to increase substantially the pace of testing and perhaps to increase the relevancy of test results to human health risk assessment. ORD has stated that information from the applications of NAMs will be used to "refine" results obtained from prioritization efforts based on chemical and physical properties, but the objective of using NAMs to achieve more definitive evaluations of toxicities also seems important to pursue. The BOSC believes that the success of the PFAS program depends heavily on having in place a suite of standardized, or ideally validated, NAMs. However, it is not clear how standardization/validation will be achieved as part of the strategy. In addition, it seems likely that the NAMs comprising the current tiered testing strategy will evolve as new data are generated. It was not clear how the evolution of NAM testing in the tiered testing framework will be managed in real time as new data emerge.

- Although the meeting presentation focused on human health, the ecological impact of PFAS contamination, as well as any impact on the livelihood of those depending on the services provided by a healthy and diverse environment, are important concerns. Moreover, ecological health can inform human health. However, given the complexity of the problem and the focus of the charge question on human health, the Committee chose not to delve into ecological implications despite the importance of the topic for our overall understanding of PFAS exposure risks.

In summary, the Committee felt that a "means to an end" analogy holds particular relevance for the categorization research efforts. While ORD presented its categorization approach as an appropriate "means" to a categorization "end," the ultimate "end" must include meaningful research outputs that can support PFAS assessment, mitigation, and regulation, and complement other "means" being pursued at the same time. To illustrate this, consider the following: Development of reliable and accurate quantitative structure-activity relationships (QSARs) for a specific PFAS category (a foreseeable "end" from ORD's tiered toxicity testing strategy as a "means") would not hold much value if that PFAS category has little commercial relevance, is not an exposure concern, and/or cannot be measured given a lack of analytical methods.

Strengths

- A **broad and ambitious research agenda** that will maximize opportunities to bring new data to light to inform PFAS management efforts.
- A **categorization approach instead of a single substance approach** to address the complexity of PFAS toxicity testing and assessment. Recognizing the large number of PFAS that lack data and the likelihood that new PFAS chemistries will continue to develop, ORD's use of a categorization approach for predicting effects is imperative.
- Research on curating existing data and generating new data using a battery of **toxicity and toxicokinetic NAMs to support PFAS categorization** based on structural, toxicological, and toxicokinetic similarity.
- An **integrated plan that includes exposure** estimates linked to a NAM testing plan to fill data gaps and a stated goal to "calibrate" NAMs against in vivo PFAS toxicology data.
- An ambitious goal to establish **Systematic Evidence Maps (SEMs)** with preliminary evidence that this can be accomplished using existing automation tools.
- The inclusion of **"real world" health outcomes** research from EPA's Center for Public Health and Environmental Assessment (CPHEA) to identify human health risks.
- Although released after the meeting, the Committee commends EPA on the **PFAS Roadmap and National Testing Strategy** illustrating its commitment to action, which includes consideration of environmental justice, an aggressive timeframe for carrying out their comprehensive strategy to address PFAS exposures, establishing a voluntary stewardship program (which does not supplant industry's regulatory or compliance requirements), and communicating PFAS risk to the public to provide understandable and actionable information.
- **Use of environmental transport, fate, and human exposure** to guide PFAS research needs in sampling and analytical methods, human health effects, and treatment technologies.
- The initial data presented on human health impact of PFAS exposure suggests that ORD has a **clear focus on gathering more health impact data**.

Suggestions

- Real world exposures occur to **PFAS mixtures**, along with other chemical contaminants as well as **non-chemical stressors**. The Committee suggests that ORD summarize how its toxicity testing strategy will help address the challenge of assessing health impacts of PFAS mixtures under real world exposure conditions, particularly for vulnerable populations who disproportionally experience non-chemical stressors and cumulative exposures.
- The **EPA PFAS Roadmap and National PFAS Testing Strategy** documents were provided to the Committee following the September 29–30 BOSC Executive Committee Meeting. Review of the document and the meeting materials left gaps in the Committee's understanding of the relationships between the ORD category-based prioritization approach, including the 75 compounds selected for tiered toxicity and toxicokinetic testing (Patlewicz et al. Environmental Health Perspectives, 2021), and the PFAS categories defined in the EPA PFAS National Testing Strategy document, including the 24 PFAS

candidates for testing. The Committee suggests that ORD clarify how the categorization and testing strategy presented during the Executive Meeting will be harmonized with the National PFAS Testing Strategy. The Committee also suggests that connections between the internal ORD research strategy and the aspirational goals of the PFAS Roadmap be clarified as complementary research that can advance Roadmap goals significantly.

- ORD should make every effort to link the **NAM-based tiered toxicity testing strategy** to risk-based decision-making relevant to human health outcomes. The Committee suggests that ORD further consider how the real-world evidence data (e.g., from the CPHEA presentation) will be integrated into the testing strategy and compound grouping strategy. ORD noted that NAMs data will be used to "refine" the use of chemical structures for toxicity prediction, but with little description of what such refinements might entail and about how the results of such refinements will be used for regrouping. The Committee suggests that ORD clarify how NAM-based testing will be linked to human toxicity. As data is emerging from ORD and in the broader research community, there is a need for **greater collaboration and coordination**. Data from research outside of EPA and ORD can supplement the ORD data and should be closely monitored and integrated into the emerging data bank on PFAS and its adverse human health effects. The Committee believes that ORD is in a unique position to establish an enhanced line of communication with the broader PFAS research community. The Committee suggests ORD consider playing a leading role in coordinating and facilitating opportunities for the exchange of research ideas through conferences, webinars, etc.
- In recognition of the **adverse health impacts of the PFAS as a family** and emerging data on the relationship between specific PFAS and specific health outcomes, including cancer, reproductive and developmental effects and immune system suppression, the Committee suggests that ORD inform and adapt its human health outcome research with a strategy to support expedited regulatory decisions with a strong focus on **communities with environmental justice concerns, as well as pregnant persons, infants, and children**.
- The Committee suggests that it might be useful to include **biostatistical expertise in pattern recognition and other approaches** to develop more generalized hypotheses regarding structure-response relationships to focus the strategic approaches for in vivo and in vitro testing.
- The Committee suggests that ORD develop a plan to test the **validity of the categorization-based groupings** used to predict toxicity, and more specifically to predict quantitative dose-response relationships and identification of appropriate points of departure (PODs).

Recommendations

The Committee offers these recommendations to support the relevant Agency priorities:

Recommendation 2.1: Better formulate how the outcomes of its PFAS categorization research strategy will support end users and how the approach will be informed as new information emerges. For example, by collecting, analyzing, and integrating available information on human exposures to PFAS compounds and by addressing developments in analytical methods, exposure (e.g., biomonitoring data), adverse health outcomes research results, and hazard identification and risk assessment of PFAS. The integrated information (e.g., using a conceptual model or roadmap) can be used to guide and communicate research results and is likely to increase the efficiency and relevance of ORD research for risk-based decisions.

EPA Response: ORD appreciates this feedback and will consider it while working across EPA to accelerate public health protections by identifying PFAS categories. In particular, ORD recognizes the importance of considering the multiple inputs contributing to the integrated picture necessary to address risk-based decision needs.

Recommendation 2.2: Maintain a high priority on the validation / standardization of NAM tests to be used for PFAS risk-based decisions and also make clear the processes to be used to achieve standardization/validation. The application of the standardized/validated NAM-based tests in a tiered testing strategy is critical for an effective PFAS data gap filling strategy and to support the evolution of NAM testing into a valid approach that can be used by ORD or external entities for PFAS hazard identification and characterization and human health outcomes.

EPA Response: ORD appreciates this feedback. As part of the 2021 updated NAMs Workplan, EPA continues to foster efforts to develop NAMs that fill critical information needs and establish scientific confidence in NAMs. Activities under the workplan are also meant to demonstrate application to regulatory decisions, such as would be expected under a tiered testing approach relevant for PFAS risk-based decisions (e.g., National PFAS Test Strategy 2021).

Charge Question 3

Q.3. Data on the efficacy and costs of different approaches for removing PFAS from the environment and managing PFAS and PFAS-containing materials are needed to inform federal, state, tribal, and local decisions on drinking water and wastewater treatment, contaminated site clean-up and remediation, and end-of-life materials management. ORD is working to increase our understanding of approaches for addressing PFAS in the environment through analytical method development, laboratory-based studies, pilot-scale studies, and field studies.

Please comment on the implementation of ORD's PFAS treatment research. In addition, what suggestions and recommendations can the Executive Committee offer for working and communicating with communities in potential field study locations?

Narrative

The Committee commends EPA for its excellent progress in advancing methods for the treatment and remediation of PFAS in drinking water, wastewater, and contaminated sites, and waste disposal and destruction. The challenges EPA faces are enormous as PFAS are ubiquitous in these media with a large range of concentrations, and difficult to isolate and destroy in a cost-effective manner. Andrews and Naidenko (2020) estimate that 18 to 80 million people in the United States receive tap water with 10 ng/L or greater concentration of perfluorooctanoic acid (PFOA) and perfluorooctanesulfonate (PFOS) combined, and over 200 million people likely receive water with a PFOA and PFOS concentration at or above 1 ng/L. Short and long-chain PFAAs were widely detected in both the influents (up to 1,000 ng/L) and effluents (15 to >1,500 ng/L) of wastewater treatment plants worldwide (Lenka, et al., 2021). Despite these challenges, EPA has been able to: (1) take a systemic approach to evaluating treatment technologies; (2) conduct remediation studies ranging from laboratory scale to full field demonstrations; (3) perform a modeling study of the transport and deposition of a chemically resolved suite of PFAS air emissions from a major manufacturing source; and (4) update their Drinking Water Treatability Database to include PFAS treatment options (https://tdb.epa.gov/tdb/contaminant?id=11020) for users (e.g., drinking water utilities, first responders to spills).

EPA recognizes that formulations continue to change to meet consumer needs and regulatory drivers, and is taking a "total PFAS" approach to mitigation that aligns with their approach for Charge Questions 1 and 2. In addition, EPA recognizes that the applicability of such treatments to a wide range of real-world facilities faces scaling-up challenges, including mass-transfer limitations, the need to address treatment by-products, an understanding of long-term costs and energy use, and the need to overcome a lack of community acceptance and trust. Therefore, the Committee encourages EPA to also focus on source reduction research and evaluating options to treat drinking water at the service connection or tap (see for example, Herkert et al., 2020). In addition, the lack of information on production volumes of PFAS, where they are used, and the location of environmental hotspots makes it impossible to understand the scale of remediation needed (Ng, et al., 2021). Therefore, the Committee encourages making studies in these areas part of EPA's research portfolio.

The Committee noted that ORD scientists and community outreach staff have sought and received some help from regional offices to work and engage with communities at potential field study locations. The Committee appreciates EPA's willingness to listen and learn from the experience in a community where there was inadequate engagement and apply this learning toward engaging other communities. It is also encouraging to know that ORD scientists have previously conducted community listening sessions on PFAS in North Carolina, Colorado, Kansas, New Hampshire, and Pennsylvania. These types of community contacts will ultimately help build trust between communities and EPA.

Strengths

- Pathways: The Committee appreciates EPA's focused approach on the primary PFAS human exposure pathways – drinking water, food consumption, land application of biosolids, wastewater discharges, and landfill leachate.
- Technologies: EPA examined a host of technologies for mitigating PFAS in the environment, and narrowed down 14 potential non-combustion technologies to four innovative technologies for further development and testing based on technology readiness, applicability, cost, and other factors. The Committee appreciates the technology readiness level scale presented by EPA.
- Methods: The Committee appreciates the variety of method platforms used by EPA – comprehensive literature reviews, modeling, benchtop and other laboratory studies, pilot demonstrations, and field testing. Preliminary results in laboratory and pilot-scale treatment systems demonstrate up to 99% loss of the initial PFAS compounds in the contaminated waste. A major caveat is that it is still unknown whether 99% loss is adequate, what PFAS byproducts, if any, are formed, and not enough is known about the transfer of PFAS from leachates, waste streams, and groundwater to air.
- Engagement: The Committee appreciates EPA's willingness to listen and learn from the experience in a community where there was inadequate engagement and apply this learning toward engaging other communities.
- Communication: The Committee appreciates EPA's efforts to share research results through a variety of venues, such as the research briefs on the four innovative technologies, the update to the Drinking Water Treatability Database, and peer-reviewed publications.
- Collaboration: The Committee appreciates the cross-agency collaborations, including using DoD chemical warfare destruction models and applying that to EPA's PFAS work, and additional work with universities and private sector partners. EPA is also aware of thermal destruction research and field demonstrations in Europe and Australia, and sorbent studies in Asia, although all of these focus on only a few waste constituents and do not measure PFAS byproducts.

Suggestions

- Source Reduction: While the Committee agrees with EPA's prioritization of research on the primary PFAS human exposure pathways – especially treatment technologies for drinking water and wastewater – the ultimate burden for large-scale remediation will fall on local water utilities and waste treatment operators with likely constraints in funding, expertise, and treatment equipment. Therefore, the Committee suggests that EPA consider source reduction research needs (e.g., non-fluorinated packaging and fire-fighting foams, preventing industrial discharges) as this approach could potentially be more effective and less costly in reducing and preventing future environmental exposures. This approach would also support states (e.g., California, Maine, Washington) that have banned, or are considering bans on use of all PFAS in food contact materials, fire-fighting foams, carpets and rugs, and other consumer products. To support these efforts, the Committee suggests that EPA quantify/estimate how much PFAS has been produced, where it is used and emitted, and how much PFAS will need to be remediated and managed. A recently identified issue is that hydrochlorofluorocarbon (HCFC)-22, a now-banned ozone-depleting substance (ODS) (for new production under the Montreal Protocol) and potent greenhouse gas is released in significant quantities during PFAS production. The Committee recommends that EPA consider research to evaluate whether these releases could be reduced or eliminated.

- Pathways: The Committee suggests that EPA consider literature reviews, modeling, or other research to examine the potential for PFAS atmospheric exposures (i.e., breathing, dermal, deposition) and opportunities for reduction/destruction in air. Another area that could be explored is whether PFAS is present in municipal compost and its possible exposure pathways (e.g., composting of food packaging or food scraps that might contain PFAS). Because of their persistence, PFAS compounds that transfer from contaminated materials to the air can be distributed over long distances and potentially bioaccumulate. The potential of low-level, long-term exposure both indoors and outdoors could be factored into assessing potential risks.
- Technologies: Because large-scale remediation could potentially take many years, the Committee suggests that EPA consider research to evaluate options to cost-effectively treat drinking water at the service connection or tap. Both existing commercially available products and promising technologies could be evaluated for efficacy.
- Methods: The Committee suggests that EPA consider collecting more information on potential unintended consequences of otherwise successful PFAS treatment systems. These could include what PFAS byproducts, if any, are formed, and potential transfer of PFAS from leachates, waste streams, and groundwater to air.
- Communication: The Committee sees the need for a well-defined process to communicate across research programs to ensure that results (e.g., detection, ecotoxicology, human toxicity testing, remediation) inform priorities for other efforts. EPA could articulate the process (and identify barriers) for how work at each level informs the priorities of other programs.
- Engagement: Since the effort to identify communities contaminated with PFAS has been ad hoc rather the systematic, the Committee suggests that EPA engage with state and local governments to help them address "non-CERCLA" sites, and specifically reach out to communities with environmental justice concerns that might not be sampling for and/or aware of the PFAS contamination in their communities and the ramifications of this contamination. The Committee also suggests that EPA be more systematic in its strategies for community engagement and social science data gathering. In this vein, the Committee encourages EPA Headquarters and regional staff to become aware of efforts by local groups to support PFAS community engagement. For example, the Great Lakes PFAS Action Network (https://www.glpan.org/best-practices) warned that "Lack of transparency, disregard for health, and slowness to act are just some of the experiences communities have faced dealing with PFAS contamination over the last decade. These experiences underscore the need for government officials, the Department of Defense, and corporate polluters to better communicate with communities as they grapple with toxic PFAS contamination in their water." It is important that EPA take the time to build trust with stakeholders at each site (including the public, community groups, industry owners and operators), as this will contribute to social learning. In addition, it is not clear to the Committee that cross-site engagement is occurring. EPA can be a broker where community members at one remediation site can connect with community members at another site.

References

- Andrews and Naidenko (2020) Population-wide exposure to per- and polyfluoroalkyl substances from drinking water in the United States, *Environ. Sci. Technol. Lett.,* 7(12):931-936, https://pubs.acs.org/doi/10.1021/acs.estlett.0c00713.
- Herkert, Merrill, Peters, Bollinger, Zhang, Hoffman, Ferguson, Knappe, and Stapleton (2020) Assessing the Effectiveness of Point-of-Use Residential Drinking Water Filters for Perfluoroalkyl Substances (PFASs), *Environmental Science & Technology Letters*, 7(3), 178-184, https://pubs.acs.org/doi/10.1021/acs.estlett.0c00004.
- Lenka, Kah, and Padhye (2021) A review of the occurrence, transformation, and removal of poly- and perfluoroalkyl substances (PFAS) in wastewater treatment plants, *Water Research*, 199:117187, https://doi.org/10.1016/j.watres.2021.117187.
- Ng, Cousins, DeWitt, Glüge, Goldenman, Herzke, Lohmann, Miller, Patton, Scheringer, Trier, and Wang (2021) Addressing Urgent Questions for PFAS in the 21st Century, *Environmental Science & Technology*, 55:12755-12765, https://pubs.acs.org/doi/10.1021/acs.est.1c03386.

Recommendations

The Committee offers these recommendations to support the relevant Agency priorities:

Recommendation 3.1: Facilitate peer-to-peer exchanges between different PFAS field study sites so that there is collective learning and collective trust building between the communities and EPA. The lessons learned can then be applied to future field studies as well as for broader implementation of successful treatment and remediation programs.

EPA Response: ORD appreciates this feedback and is identifying opportunities to facilitate peer-to-peer exchanges between different PFAS field study sites. Understanding and optimizing means to foster community engagement with ORD research and in community science are also priorities to ORD, related to many environmental stressors, including PFAS.

Recommendation 3.2: Consider source reduction research needs (e.g., non-fluorinated packaging and fire-fighting foams, preventing industrial discharges) as these approaches could potentially be more effective and less costly in reducing and preventing future environmental exposures.

EPA Response: ORD appreciates this perspective. As part of ORD's PFAS research efforts, we are characterizing PFAS sources to the environment and evaluating technologies for removing PFAS from waste streams or environmental media. Evaluating source reduction approaches is generally done within EPA's Program offices.

Community Engagement

Narrative

As the ORD research agenda reflects, the nation has a strong interest in understanding PFAS, their disposition in the environment, the health impacts in communities, and effective mitigation/elimination methods. The BOSC was encouraged to read the EPA PFAS Strategic Roadmap (2021-2024) and applauds the Agency's commitment to "Engage directly with affected communities in every EPA Region." The Committee supports the recommendation of the National Environmental Justice Advisory Council (NEJAC) that EPA should meet with affected communities to hear how PFAS contamination impacts their lives and livelihoods.

At ORD field sites, involving local residents in PFAS research underway in their area can help foster a more knowledgeable citizenry, enable researchers' access to relevant local knowledge, extend the data collection/analysis infrastructure, and mobilize greater social interest in effective risk reduction. Community engagement and citizen science involve capacity-building processes that enable individuals without science and technology training to participate with confidence in technical discussions and activities, and at the same time to gather/generate rich information from the process that will advance the ORD research agenda.

The Committee was concerned that ORD has had difficulty conducting field research to validate new methods for PFAS detection and remediation, especially from potential air emissions sources. This challenge has the potential to significantly impede important research that needs to advance rapidly to protect public health and the environment. The Committee urges EPA to address this problem systematically at an Agency level, rather than leaving it to individual teams of scientists within ORD to try to solve. Agency public participation experts from headquarters and regional offices should redouble their efforts to support ORD engagement with local communities and the media to ensure that the science can be done to test new measurement methods under field conditions without unnecessary delays and with the willing cooperation and support of community leaders.

To date, ORD has operated with a community-of-place model – as most public involvement initiatives do – working to foster trust and mutual understanding at direct points of contact, in specific localities. These place-based, context-sensitive connections with residents remain critical to the successful conduct of PFAS field studies. At the same time, ORD scientists (and the Agency as a whole) could obtain further benefits from embedding this one-community-at-a-time approach within a centrally coordinated, multi-site model of community engagement. Doing so would likely entail the formulation of an overarching PFAS community engagement/citizen science strategy that includes ORD, program offices, and regional offices. This effort would likely include development of a community involvement and participation "best practices" portfolio that draws upon both external guidance, Agency-wide resources, and ongoing ORD experiences with PFAS-affected communities; and the facilitation of networked, peer-to-peer exchanges among the communities hosting PFAS field studies to provide greater opportunities for the capacity-building that underpins effective community engagement and citizen science.

It is not clear to the Committee that cross-site engagement is occurring. There is a need for a platform similar to EnviroAtlas to facilitate social learning on the technologies used at these sites, their community engagement techniques, and other best practices. EPA can be a broker where community members at one remediation site can connect with community members at another site. Furthermore, these processes need to be embedded in an infrastructure that needs to be established and that can then be deployed to deal with many other environmental challenges that currently exist or might be realized in the future. An infrastructure of this nature will not only yield the necessary information on pollutants and contaminants that affect environmental and human health, but it will lay the groundwork for effective and trusting community relationships that will ultimately benefit all of society.

Recommendations

The Committee offers these recommendations to support the relevant Agency priorities:

Recommendation 4.1: Agency public participation experts from program offices, regional offices, and ORD should support ORD scientists as they actively and interactively engage and partner with local communities to ensure that new measurement and remediation methods for PFAS can be quickly and effectively tested under field conditions.

EPA Response: ORD appreciates this perspective and is leveraging public participation experts from across EPA in field study efforts, including evaluation of factors that promote successful research engagement with local communities, such as continuity of relationships, commitment, and support mechanisms.

Recommendation 4.2: Develop the infrastructure for a community of practice to support peer-to-peer exchanges between different PFAS field study sites so that there is collective and cumulative learning, exchange of best practices, and ongoing trust building between the communities and EPA. This should include strategies not only to gain acquiescence of the community members and leaders, but to offer and encourage active partnership and participation in the research process and in the exploration of remediation measures. The outcome should be to engage, inform, and mobilize the community to be active participants in the process and equip and empower them to further explore remediation strategies. The lessons learned can then be applied to future field studies as well as for broader implementation of successful treatment and remediation programs.

EPA Response: ORD appreciates this feedback and is identifying opportunities to facilitate peer-to-peer exchanges between different PFAS field study sites. In addition, ORD will leverage Agency efforts outlined in the EPA PFAS Strategic Roadmap to engage directly with affected communities in every EPA Region through coordination with EPA Regional offices.

Integration

Narrative

The BOSC received briefings on three components of the PFAS program. The Committee believes that the programs are individually strong and, with better analytical methods and field-testing strategies, ORD will be able to enhance the ability to assess total PFAS contamination, identify the presence of PFAS compounds for which there are currently no analytical standards, and detect and quantify specific PFAS chemical species to help assess potential for human exposure through environmental media. EPA's categorization efforts are a logical approach to efficiently fill data gaps on toxicity, help identify hazards associated with compounds within the categories, calculate PODs relevant to human exposure, and, where sufficient data are available, assess the hazards of some PFAS categories based on data from other members of the categories.

The Committee feels that there are some missed opportunities and efficiencies from greater program coordination and integration that collectively could accelerate delivery of PFAS related solutions and the impact of those solutions. The Committee believes that a formal plan for coordinating and integrating the activities and efforts of the three major program thrusts (and the ecotoxicology program that was not included in this review) is necessary to realize the benefits of these opportunities. Successful integration and coordination would, for example, be evidenced by assignment of leaders accountable for the integration across both the research and regulatory programs, regular cross-program coordination meetings, and regular evaluation of the chemicals considered for testing, in response to either other parts of the research program, stakeholder feedback, or evidence from the field (e.g., accumulating information from the field on what compounds or categories are present in higher amounts/frequency; leveraging results of ecotoxicology testing to inform human health testing priorities).

Recommendations

The Committee offers this recommendation to support the relevant Agency priorities:

Recommendation 5.1: Articulate and implement a strategy and roadmap with goals for improved integration and coordination across the research programs elements (analytical methods, toxicity/hazard testing, environmental remediation) which assures that research products are used effectively to support regulatory decisions, and that each research area benefits from the findings in other research areas.

EPA Response: ORD appreciates this feedback and is continuously working to improve integration and coordination across our PFAS research efforts. Building off the EPA PFAS Strategic Roadmap, ORD conducts monthly coordination meetings where we track all our major PFAS deliverables. Newly identified priority StRAP 4 product deliverables have been developed through rigorous planning engagement with EPA Programs and Regions, and with state and Tribal partners, and will be incorporated into the tracking and monthly coordination meetings.

Summary List of Recommendations

Charge Question 1: Many stakeholders have identified a need for validated "total PFAS" methods, such as total organic fluorine (TOF) or total oxidizable precursor (TOP) methods, to quantitatively measure a non-compound specific amount of PFAS in environmental samples. EPA has expanded the scientific foundation for identifying and quantifying PFAS in the environment through the development of validated analytical methods for specific PFAS and the use of non-targeted analysis methods. ORD researchers are working to develop validated TOF methods for wastewater and air emissions.

Please comment on the implementation of ORD's PFAS methods research. In addition, what suggestions and recommendations can the Executive Committee offer on the utility of "total PFAS" methods and other analytical approaches for identifying "total PFAS" in environmental samples?

- **Recommendation 1.1:** Continue to increase the applicability and value of NTA and SSA across EPA programs, increase efforts to expand throughput, and lower cost while maintaining data quality and the quality of the resulting information.
- **Recommendation 1.2:** Increase focus on methods development for measuring PFAS in air and strengthening of links between research groups developing methods across environmental media.

Charge Question 2: Due to the large number of PFAS in commerce and the environment, there is an emerging consensus on the need to use grouping- or category-based approaches to assess and address potential PFAS toxicity. While structure-based categories are most common, there is no clear consensus method for categorizing PFAS, and ORD researchers are evaluating other features (e.g., chemical and physical properties, toxicokinetic properties, toxicity mechanisms) for use in categorizing PFAS for human health risk assessment and risk mitigation purposes.

Please comment on the implementation of ORD's research on the human health effects from PFAS. In addition, what suggestions and recommendations can the Executive Committee offer on common category characteristics that would maximize the utility of the resulting PFAS groupings for the broadest set of decision contexts?

- **Recommendation 2.1: Better formulate how the outcomes of its PFAS categorization research strategy will support end users** and how the approach will be informed as new information emerges. For example, by collecting, analyzing, and integrating available information on human exposures to PFAS compounds and by addressing developments in analytical methods, exposure (e.g., biomonitoring data), adverse health outcomes research results, and hazard identification and risk assessment of PFAS. The integrated information (e.g., using a conceptual model or roadmap) can be used to guide and communicate research results and is likely to increase the efficiency and relevance of ORD research for risk-based decisions.
- **Recommendation 2.2: Maintain a high priority on the validation and standardization of NAM tests** to be used for PFAS risk-based decisions and also make clear the processes to be used to achieve standardization/validation. The application of the standardized/validated NAM-based tests in a tiered testing strategy is critical for an effective PFAS data gap filling strategy and to support the evolution of NAM testing into a validated approach that can be used by ORD or external entities for PFAS hazard identification and characterization and human health outcomes.

Charge Question 3: Data on the efficacy and costs of different approaches for removing PFAS from the environment and managing PFAS and PFAS-containing materials are needed to inform federal, state, tribal, and local decisions on drinking water and wastewater treatment, contaminated site clean-up and remediation, and end-of-life materials management. ORD is working to increase our understanding of approaches for addressing PFAS in the environment through analytical method development, laboratory-based studies, pilot-scale studies, and field studies.

Please comment on the implementation of ORD's PFAS treatment research. In addition, what suggestions and recommendations can the Executive Committee offer for working and communicating with communities in potential field study locations?

- **Recommendation 3.1:** Facilitate peer-to-peer exchanges between different PFAS field study sites so that there is collective learning and collective trust building between the communities and EPA. The lessons learned can then be applied to future field studies as well as for broader implementation of successful treatment and remediation programs.
- **Recommendation 3.2:** Consider source reduction research needs (e.g., non-fluorinated packaging and fire-fighting foams, preventing industrial discharges) as these approaches could potentially be more effective and less costly in reducing and preventing future environmental exposures.

Community Engagement:

- **Recommendation 4.1:** Agency public participation experts from program offices, regional offices, and ORD should support ORD scientists as they actively and interactively engage and partner with local communities to ensure that new measurement and remediation methods for PFAS can be quickly and effectively tested under field conditions.
- **Recommendation 4.2:** Develop the infrastructure for a community of practice to support peer-to-peer exchanges between different PFAS field study sites so that there is collective and cumulative learning, exchange of best practices, and ongoing trust building between the communities and EPA. This should include strategies not only to gain acquiescence of the community members and leaders, but to offer and encourage active partnership and participation in the research process and in the exploration of remediation measures. The outcome should be to engage, inform, and mobilize the community to be active participants in the process and equip and empower them to further explore remediation strategies. The lessons learned can then be applied to future field studies as well as for broader implementation of successful treatment and remediation programs.

Integration:

- **Recommendation 5.1:** Articulate and implement a strategy and roadmap with goals for improved integration and coordination across the research programs elements (analytical methods, toxicity/hazard testing, environmental remediation) which assures that research products are used effectively to support regulatory decisions, and that each research area benefits from the findings in other research areas.

APPENDIX A: MEETING AGENDA

Wednesday, September 29, 2021

Time (EDT)	Topic	Speakers
11:30 – 12:00	Sign-on and Technology Check	
12:00 – 12:15	Welcome, Opening Remarks and Member Introductions	Tom Tracy (DFO), Lucinda Johnson (BOSC EC Vice Chair)
12:15 – 12:30	ORD Welcome	Chris Frey
12:30 – 12:45	Overview of Charge Questions and Meeting Format	Susan Burden
	PFAS Overview	
12:45 – 1:00	An Introduction to PFAS	Tim Watkins
1:00 – 1:15	ORD's PFAS Research and Development Portfolio	Susan Burden
	Charge Question 1 – Total PFAS Methods	
1:15 – 1:30	Analytical Methods Overview	Chris Impellitteri
1:30 – 1:45	"Total PFAS" Methods	Alice Gilliland
1:45 – 2:45	**Charge Question 1 – Breakout Rooms**	
	Breakout Room 1 – Water Methods	
	Analytical methods for PFAS measurement in environmental samples (aqueous)	Jim Voit
	Analytical method for PFAS in environmental media: CWA-1633	Marc Mills
	Non-targeted analysis of water	James McCord
	Development of adsorbable organic fluorine screening method with detection by combustion ion chromatography	Jody Shoemaker
	Breakout Room 2 – Air Methods	
	Other Test Method 45 (OTM-45)	Lara Phelps
	Additional source air methods under development	Lara Phelps
	Wet deposition of PFAS	John Offenberg
	Total organic fluorine analysis for PFAS in air	Hannah Liberatore
2:45 – 2:55	BREAK	
2:55 – 3:15	**Clarifying Questions on Charge Question 1 Content**	**Lucinda Johnson**
	Charge Question 2 – Human Health Effects	
3:15 – 3:30	Overview: Human Health Effects Research	Annette Guiseppi-Elie
3:30 – 3:45	ORD's Tiered Toxicity Testing Strategy for PFAS	Rusty Thomas

3:45 – 4:40	**Charge Question 2 – Breakout Rooms**	
	Breakout Room 1 – Toxicity Testing	
	New approach methods – toxicity	Richard Judson
	New approach methods – toxicokinetics	Barbara Wetmore
	In vivo toxicity testing	Justin Conley
	PFAS and multimorbidity: Using electronic health records to probe systemic effects	Cavin Ward-Caviness
	Breakout Room 2 – Assessments	
	Human health toxicity assessment for PFBS	Beth Owens
	Draft IRIS assessments for PFBA, PFHxA, PFDA, PFHxS, PFNA, and their related salts	Andrew Kraft
	Systematic evidence maps to characterize available evidence for 9000 PFAS	Kris Thayer
4:40 – 5:00	**Clarifying Questions on Charge Question 2 Content**	**Lucinda Johnson**
5:00 – 6:00	BOSC Executive Committee Deliberations	Lucinda Johnson
6:00	Adjourn	

Thursday, September 30, 2021

Time (EDT)	Topic	Speakers
11:30 – 12:00	Sign-on and Technology Check	
12:00 – 12:15	Welcome Back	Tom Tracy (DFO), Lucinda Johnson (BOSC EC Vice Chair)
	Charge Question 3 – Treatment Field Studies	
12:15 – 12:30	Overview: PFAS Treatment and Destruction Research	Greg Sayles
12:30 – 12:45	EPA PFAS Innovative Treatment Team Findings on PFAS Destruction Technologies	Tim Watkins
12:45 – 1:45	**Charge Question 3 – Breakout Rooms**	
	Breakout Room 1 – Bench- and Pilot-Scale Studies	
	Drinking water treatment	Tom Speth
	Thermal treatment of PFAS	Bill Linak
	Non-combustion technologies for PFAS destruction	Max Krause
	Mechanochemical destruction of PFAS	Erin Shields
	Breakout Room 2 – Field Studies	
	Waste management	Thabet Tolaymat
	Land application of biosolids	Kirk Scheckel
	Field-scale thermal treatment	Phillip Potter
	Source characterization	Marc Mills
1:45 – 2:05	**Clarifying Questions on Charge Question 3 Content**	**Lucinda Johnson**
2:05 – 2:20	**ORD Wrap-up Presentation**	**Susan Burden**
2:20 – 2:30	BREAK	
2:30 – 3:00	Public Comment	Tom Tracy
3:00 – 5:00	BOSC Executive Committee Deliberations	Lucinda Johnson
5:00	Adjourn	

APPENDIX B: MATERIALS

Material Provided in Advance of the Meeting

- Meeting Agenda
- Charge Questions
- EPA's PFAS Strategic Roadmap
- EPA's National PFAS Testing Strategy
- Primary Epidemiological and Animal Toxicology Studies of Developmental Effects Considered Across Five IRIS PFAS Assessments
- Zoom Virtual Participation Guide

Material Provided During or After the Meeting

- Final Presentations