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Exposures that Impact Health in Vulnerable Populations

# Symposium Book

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## A Canadian Perspective on the Intersection between Environmental Chemical Exposures and Vulnerability Factors [32]

This symposium will encompass numerous research initiatives dedicated to evaluating the extent of exposure to various chemicals within Canadian populations. Grasping the health implications associated with exposure to toxic substances is crucial for promoting robust growth, development, and sustaining overall well-being throughout one's life. A more profound comprehension of exposure levels and the pathways of exposure is imperative for appraising the risks of adverse health effects. The symposium will feature insights on exposure determinants to multiple chemicals in the Canadian population, across the life course including pregnancy, adolescence, and perimenopause. We will highlight findings from population subgroups who may experience unique exposure scenarios including indigenous communities and women with occupational exposure to chemicals. The analyses will underscore vulnerability factors and contextual elements that could contribute to disproportionate exposure and/or adverse health consequences.

## Accountability Research: Evaluating the Community Impact of Policy Interventions [15]

Do laws requiring seat belt use save lives? Do regulations aimed at reducing air emissions decrease asthma incidence in vulnerable communities? How do we know? Questions like these can be evaluated empirically, using “accountability research” methods. Accountability studies are specifically designed to examine the relationship(s) between an intervention, regulation, or event and the resulting downstream impacts on emissions or exposure, and subsequently, health - providing critical feedback for policymakers.

A challenge for researchers conducting accountability studies is that it often takes time for an intervention to be fully implemented and for its effects to be realized. During that time a “web” of factors can make it difficult to isolate the impacts of a particular intervention. These can include concurrent local and/or regional actions; behavior changes within a population impacting exposure or health, which may or may not be related to the intervention; and broader socioeconomic shifts inducing differential population migration.

This symposium welcomes speakers to address the complex nature of this area of research, including the “web” of factors to consider when conducting accountability studies, and approaches researchers and regulators can use to define and study populations considered to be vulnerable. Also encouraged are recommendations for planning and completing a robust accountability study, including novel and innovative air pollution and exposure data, and methods for distinguishing effects of simultaneous policy interventions.

## Addressing climate change and Impacts to exposures across different environments [83]

Over 20% of the earth's land mass is set to cross one or more temperature thresholds by 2100. Even small shifts in the climate can produce abrupt and highly consequential changes. The implications on the health and well-being of populations living in these regions are poorly understood, though it is anticipated that there will be severe impacts on food security, heat stress, air quality, infectious disease hosts and vectors and other health outcomes. The pathways of increased exposure are varied, but many are related to differences in the built environment, including housing structure, power and electrical grid reliability, reliable access to water and food, and characteristics of surrounding greenspaces. Approaches to further define direct and indirect health from climate change must be coupled with adaptation strategies and solutions to curb known health. This symposium aims to convene research related to the themes of 1) measuring and predicting climate change related exposures; 2) methods for integrating climate, exposure and/or health data; 3) incorporating climatic factors into exposure and risk models; and 4) approaches for engaging the research community in transdisciplinary efforts to address exposure arising from climate change impacts. We anticipate broad interest for the exposure science, environmental health, and biomedical research community as the session themes are cross cutting and applicable to many areas globally.



## Advancements in characterizing exposure to air pollutants from residential wood burning [31]

Residential wood burning is a major source of air pollution in cold regions and has been linked to adverse health effects and extreme air quality episodes. Several governments have implemented regulations to limit the use of wood burning or to replace older appliances with cleaner less polluting ones. Contrastingly, the use of wood for residential heating has been increasing in some regions due to the rising cost of other heating fuels or to incentives to switch to renewable energy sources in some cases. Wood burning also remains an important heating source in remote areas and under severe winter climatic events.

Nonetheless, limited information exists on the exposure of populations to pollutants from wood burning emissions, partly due to imperfect data on emissions from wood burning appliances and to a lack of information on their spatial distribution and intensity of their use. This limits the ability to accurately quantify the impact of wood burning on exposure to air pollution and assess the impact of different policy interventions or changes in wood burning usage.

This symposium will highlight recent advancements in estimating and controlling residential wood burning emissions as well as assessing their impacts on exposure to air pollution. This will include measurements or modeling of air pollutants and specific compounds such as levoglucosan in indoor or outdoor environments impacted by wood burning. This session will also cover new approaches to develop spatially resolved wood burning emission inventories and improvements in estimating and characterizing emissions from wood burning appliances.

## Advances in Exposure Science to Support Consideration of Vulnerable and Sensitive Subpopulations in Chemical Safety Decision Making [68]

As the field of exposure science has advanced, we have improved our understanding of the potential exposures of vulnerable and sensitive subpopulations. These populations may be disproportionately exposed to chemical and non-chemical stressors, and consideration of this potential for differential exposures is needed in the development of models and tools to support chemical safety decision making. Further, regulatory agencies may require special consideration of these subpopulations. The expansion of databases on chemical use, occurrence, and toxicokinetics has informed exposure modeling efforts, allowing for the prediction of chemical exposures at refined geographic scales and for defined demographic groups. The development of models and tools has further advanced efforts to evaluate chemical safety, including in a real-world context where mixtures (as opposed to single chemicals) are the norm. Decision makers, risk assessors, and regulators at the community, state, regional, and federal levels have unique and varied needs related to chemical safety decisions, in particular when considering vulnerable and sensitive subpopulations. This symposium aims to showcase data and models that may support chemical safety decision makers in considering vulnerable and sensitive subpopulations in a chemical safety evaluation or risk assessment. Special emphasis will be placed on applied case studies showing application of data or models to support consideration of vulnerable and sensitive subpopulations in a decision-making context, or operationalized models or tools currently providing utility in a chemical safety evaluation or risk assessment context.

## Advances in the determination of chemical components and exposure potential in recycled tire crumb rubber used on synthetic turf fields [48]

Over the last two decades, the public has raised concerns about the use of recycled tire crumb rubber on synthetic turf playing fields and playgrounds. Previous studies that examined chemical constituents were limited and did not comprehensively evaluate all aspects of potential exposure. In order to address the concerns and the limitations of previous studies, a variety of entities around the globe undertook efforts to more comprehensively evaluate potential exposures during use of recycled tire crumb rubber on synthetic turf playing fields. Significant efforts have been made to identify and quantify a wide range of chemical constituents in the recycled tire crumb rubber. Specific research activities include determining the bioaccessibility of chemical compounds in the recycled tire crumb rubber and chemical emissions from crumb rubber. Research activities to evaluate exposure potential (particularly to vulnerable populations) include evaluation of activity parameters, field and personal exposure measurements, exposure modeling, and biomonitoring. In addition, efforts have been made to assess the toxicity of materials and constituents and, in some cases, to evaluate potential risks to field users.

The recent activities undertaken provide a more comprehensive picture of potential exposure to chemical compounds in recycled tire crumb rubber and can be used to inform policy and regulatory actions.

## Advancing Chemical Evaluations with Toxicokinetics Models and Data [76]

Toxicokinetics (TK) is “what the body does to a chemical” and includes chemical absorption through various portals of entry (e.g., dermal, inhalation, oral), distribution in the body after absorption, possible biotransformation in the liver and other tissues, and possible excretion (e.g., renal clearance, exhalation). TK plays a critically important aspect of chemical evaluations for human and ecological health. Thousands of new and existing organic chemicals require assessment for their potential impact on human and ecological health. Most of these chemicals have limited measured information necessitating the use of computational models to address data gaps and interpret testing data. For example, TK models facilitate the understanding of the relationships between external exposures and internal exposures for humans and ecological receptors in the “real world” as well as for in vivo test systems (e.g., rodent and fish). TK also informs the assessment of bioaccumulation in aquatic and air-breathing organisms. Chemical-specific TK models and data are also needed to extrapolate in vitro testing data (e.g., New Approach Methods) to in vivo conditions (e.g., steady-state blood concentrations, intake rates). Reliable TK model predictions require reliable model input parameters, particularly for partitioning in different biological matrices (i.e., biopartitioning) and biotransformation. This symposium aims to communicate existing and emerging TK data and models to support chemical evaluations for human (occupational, consumer, general population) and ecological health. This includes in vivo, in vitro, and in silico methods for parameterizing and applying TK models. Presentations that incorporate case studies of TK model application and evaluation are encouraged.

## Assessing Micro- and Nano-Plastics: From Measurement and Characterization to Environmental Impacts and Effects on Organisms [65]

This session aims to bridge the knowledge gap regarding the impacts of micro- and nano-plastics on human health and the environment. Plastic production during WWII marked the beginning of plastics being pervasive in the environment. Their continued proliferation correlates with increases in plastic production, urbanization, and pollution. Since the 1940s, all habitats and organisms have been exposed to micro- and nano- plastics. Micro- and nano-plastics are ubiquitous in the environment, come directly from sources, such as microbeads in toothpaste or cosmetics, or indirectly from the biological, physical, or chemical breakdown of products. They can be found in water sources, soil, plants, air, and animals. These plastic particles accumulate and persist in the environment and may contain harmful chemical additives. This session's aim is to highlight exposure scenarios, toxicology studies, and risk assessment cases of micro- and nano- plastics. How has your research contributed to the understanding of micro- and/or nano-plastics' adverse effects on human health and the environment; uptake by plant and aquatic species and further movement up the food chain? We seek contributions to enhance our knowledge of applications to stormwater runoff, wastewater release, atmospheric deposition, and what happens once chemical additives in plastics such as colorants, stabilizers, p-Phenylenediamines, bisphenol A, sulfonyl bisphenol, flame retardants, heavy metals, and phthalates are released.

## Assessing Pesticide Safety: Unveiling Exposures That Impact Health in Agricultural Communities and Risk Assessment Approaches to Address Them [44]

Join us for an insightful symposium focused on assessing pesticide safety and exposures in agricultural communities. Our symposium aims to shed light on critical topics surrounding the safety assessment of pesticides for agricultural workers, bystanders, and the general population, particularly in vulnerable and underserved populations.

Throughout the event, speakers will delve into various aspects, including the application of epidemiological studies in pesticide safety assessments, existing methodologies in exposure and risk assessment, and new approach methods to support safety risk assessment. We'll also explore existing gaps in exposure and risk assessment and discuss strategies to address them effectively, including compounding conservatism and cumulative assessments.

Furthermore, we'll highlight efforts and initiatives aimed at protecting vulnerable populations from pesticide exposures, emphasizing the importance of risk assessment, environmental justice and sustainability across industries. From regulatory compliance to innovative research endeavors, our symposium aims to showcase diverse initiatives contributing to human safety.

Particularly, we invite presentations focused on the development of exposure or risk assessment tools tailored for less developed regions, ongoing exposure assessments in agricultural communities, and evaluations of human exposure from new technologies. Topics such as dietary and non-dietary exposure will be explored to provide a comprehensive understanding of the complexities involved in pesticide human safety assessments.

## Assessment of Occupational Exposure to Chemical and Mineral Mixtures: Challenges and Advances [26]

The assessment of concurrent exposure to mixtures has been a concern for decades. Considerable advances in toxicology, epidemiology, computer science, omics technology and other fields now allow a more precise exposure reconstruction. Occupational exposure to chemical and mineral mixtures generally occurs at higher levels than environmental exposure, albeit for shorter durations. Assessing both occupational and environmental exposures to mixtures is necessary to get a more accurate reflection of risk factors contributing to health over a lifetime. To date, very few studies have reported on concurrent exposures to mixtures of pollutants and contaminants in both environmental and occupational settings. Some studies have focused on specific industries or have neglected exposures of subgroups of the population such as women or seasonal workers. Challenges in characterizing exposures to mixtures in large populations also contribute to these gaps in knowledge. Sophisticated techniques are emerging to measure combined exposures of small populations in the workplace. Advances in job coding techniques (e.g. based on artificial intelligence algorithms) and with job exposure matrices are also offering new opportunities to characterize exposures of large and vulnerable populations to chemical and mineral mixtures.

## Atmospheric Micro and Nanoplastics: Environmental and Human Health Considerations to Assess Exposure [42]

Atmospheric micro and nanoplastics (MNP) are small plastic particles suspended in the air. While still not extensively studied, various sources of MNP have been identified, including the breakdown of plastic debris, industrial processes, tire abrasion, incineration of plastic waste, and the degradation of synthetic materials like textiles. Weather conditions such as temperature, wind force, and precipitation strongly influence the atmospheric emission and distribution of MNP.

MNP have emerged as a significant concern due to their widespread presence and persistence in the environment, and potential impacts on ecosystems and human health. They can enter the human body through respiratory, oral, or dermal routes, accumulating in various organs. However, their toxicological properties, including absorption routes, distribution and dose-response relationships remain poorly understood. MNP are suspected to impact immune response, apoptosis, and oxidative stress, potentially leading to health issues such as cardiovascular, reproductive, and developmental disorders.

Exposure assessment of atmospheric MNP, both in the environment and within the human body, is in its nascent stage. Thorough characterization of airborne MNP is essential to determine source contributions and temporal and geographical variations in concentrations. This involves identifying the chemical composition, particulate size distribution, and shape. Standardizing methods for sampling and analyzing MNP is critical. While various biological matrices like blood, urine, and stool have been utilized for MNP human biomonitoring to assess internal exposure, no guidelines or reference values exist yet.

This symposium aims to comprehensively address exposure assessment of MNP, encompassing environmental and human health perspectives, and discuss recent advancements in the field.



## Beyond Legacy PFAS: Human Exposure to Novel PFAS and PFAS Mixtures [45]

Per- and polyfluoroalkyl substances (PFAS) are a class of highly persistent chemicals comprised of thousands of fluorinated organic molecules. They are used extensively in various industrial and consumer products including water-, grease-, and stain-repellents, surfactants, lubricants, cosmetics, and aqueous film-forming foams (AFFFs). Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS), commonly referred to as legacy PFAS, have been regulated over the last two decades due to their persistence, bioaccumulation, and toxicity to wildlife and humans. As a result of these restrictions, the production and use of other PFAS has grown. Recently, these novel PFAS have begun to be identified and measured in environmental samples and human tissues due to advances in analytical chemistry. Legacy PFAS are known to be widespread in human blood but accumulation of novel PFAS in human fluids and tissues is only just beginning to be investigated, and much remains to be learned about sources of exposure, toxicokinetics, and health effects of these novel compounds. This symposium focuses on human exposure to PFAS of emerging and immediate concern and progress towards a comprehensive understanding of total PFAS body burden. We will highlight recent work identifying novel PFAS and PFAS mixtures in the context of exposure assessment and biomonitoring, as well as studies investigating the toxicokinetics of emerging PFAS, PFAS precursors, and other often-overlooked PFAS sub-classes. Research exploring innovative approaches to characterize the broader PFAS exposome and understand associated human health outcomes is also of interest.

## Biomonitoring for environmental metal exposures [49]

Biomonitoring remains an indispensable and informative tool for assessing environmental exposure to chemicals, including toxic metals. Metal exposure can be evaluated in biospecimens that are either invasive (i.e., blood) or non-invasive (i.e., urine, saliva, and toenails). As technological advances have made it increasingly possible to analyze biospecimens for a variety of chemical exposures, there is growing need to make thoughtful decisions when considering which chemicals are appropriately measured to answer the study question of interest. This symposium will examine methods, issues, and applications of metal biomonitoring for environmental health studies. As certain exposures are complex and co-occurring, this symposium is also open to studies that look at metal mixtures. We encourage participation from studies that highlight exposure timing, biological relevance, and implications of biomarker findings for public health. We will discuss important considerations when choosing appropriate matrices for metal exposure assessment and focus on how findings from biomonitoring data can inform public health intervention.

## Biomonitoring of vulnerable communities: translating biomarker findings to individual and collective public health actions [87]

Biomonitoring of environmental chemicals, or their metabolites, in a person's body fluids or tissues is an important part of health effects research, as well as exposure screening and surveillance programs. These measurements can identify at risk individuals, characterize disproportionately exposed communities, and characterize trends in these disparities over time. In vulnerable communities, biomonitoring paired with questionnaires customized to specific cultural or community behaviors can reveal contributing exposures and systemic biases that may not be readily identifiable elsewhere. These insights can point to opportunities where public health action may be impactful. Customized guidance and interventions as well as broader policy changes can ultimately create meaningful strategies to reduce disparities and move towards environmental health equity. Partnerships with communities have been invaluable in both developing, conducting, and reporting results of biomonitoring projects. Opportunities remain in developing communication to inform individual action and collaborating with stakeholders to facilitate coordinated change. In this symposium, we will examine how environmental chemical biomonitoring is being used to understand exposures in vulnerable communities and how this information is being translated into public health action.

## Causal Methods for “Exposure Epidemiology” [66]

An increasing number of exposure studies examine associations between a biomarker of exposure and external measures of exposure, in addition to demographic and behavioral factors. Such studies often have the goal of investigating the importance of an exposure route or relative importance of different routes. For example, in a cohort one might regress PFOA serum concentrations against PFOA water concentrations as well as data obtained from a food frequency questionnaire. Such studies can be considered a type of epidemiologic study where the outcome is the exposure biomarker rather than a health outcome. The investigator might consider two different analytic approaches to such “exposure epidemiology”. Descriptive approaches such as stepwise regression yield the most “important” variables predicting serum concentrations as well as overall goodness of fit. While such approaches are useful, they are not designed to answer a different question: if we were to intervene on an exposure (e.g., by filtering water to remove PFOA), how much would serum PFOA change? Causal inference methods, commonly employed in epidemiology can yield different results when exposure predictors confound each other or lie on the causal pathway. To aid the investigator in the design and analysis of such studies, we recommend the use of directed acyclic graphs (DAGs) as well as consideration of other sources of potential bias such as exposure measurement error. Exposure scientists typically know much about the system under investigation, which can be incorporated into DAGs and model specification in order to improve causal inference. For example, external routes of exposure should typically have additive effects on the exposure biomarker. This session will discuss causal methods in exposure epidemiology using practical examples. It will be of interest to exposure scientists conducting such studies, risk assessors, and regulators who want to understand how to best use the scientific literature.

## Challenges and Opportunities in the Use of Wearable Technologies to Improve Exposure-Health Outcome Models in Exposure Science and Environmental Epidemiology [69]

Personal air pollution monitors combined with wearable physiology sensors are increasingly used in epidemiologic studies to elucidate the intricate relationship between exposure and health outcomes in individuals. The use of these devices, however, presents significant challenges including participant burden, data management, and statistical analyses. In this context, we encourage presentations from interdisciplinary perspectives for a symposium dedicated to exploring the multifaceted applications of wearable sensors. The symposium aims to delve into methodologies and approaches to the use of wearable sensors to measure both exposure data and physiological responses in individuals, thereby yielding high-resolution datasets capable of discerning fluctuations in air pollution exposure and associated health changes. Presenters will share insights gleaned from their research endeavors, including lessons learned and study limitations, to foster a deeper understanding of the challenges and opportunities inherent in this field. Additionally, discussions will encompass the utilization of wearable sensor technologies across various settings, both current and potential future applications. Presentations and discussions will also encourage participants to consider next steps to advance translation into clinical or public health practice, particularly in the realm of health outcome management, by prognosticating exposures and subsequent health episodes.

## Challenges Beyond Limits: Occupational Exposures to Unregulated Chemicals [85]

Many potentially toxic chemicals do not have regulatory limits for workplace exposures, and their number is growing with the constant influx of chemicals of emerging concern and with advances in non-targeted analytical screening. Unregulated chemicals are often novel substances for which exposure levels or health effects are not documented enough for the establishment of regulatory limit values, or for which exposure assessment methods, if any exists, are not yet adapted to the complexity of occupational contexts. Nevertheless, it is known that some of the highest exposures to chemicals such as per- and polyfluoroalkyls, brominated flame retardants, quaternary ammoniums or manufactured nanomaterials have been measured in occupational environments. Exposure assessment in workplaces is challenging because each workplace, job, or even task can represent its own microenvironment with specific contaminant generation processes, environmental conditions, and protective measures. Furthermore, the absence of regulatory values hinders occupational risk assessment and impairs levers for action. This poses challenges for the prevention of potential adverse effects on workers' health in many industries, which may be exacerbated in small or very small workplaces.

In this symposium, we aim to highlight research that contributes to the body of knowledge on occupational exposures to unregulated chemicals. Topics of interest include, but are not limited to, levels of occupational exposure to novel chemicals, risk assessment approaches in the absence of regulatory values, and occupational exposure assessment methods for unregulated substances.

## Characterizing Harmful and Addictive Exposures Related to New and Emerging Tobacco and Cannabis Products in Vulnerable Groups and the General Population [74]

In many parts of the globe changes in policies toward tobacco and cannabis lead to markedly increased exposures to harmful and addictive chemicals. Tobacco products are changing as people seek potentially less harmful sources of nicotine, including heated tobacco products (HTPs) and e-cigarettes. Furthermore, the prevalence and magnitude of cannabis use is increasing for both medical and non-medical applications. In North America, adult use of non-medical cannabis is legal in 22 states. Furthermore, Canada legalized adult use cannabis in 2018. The primary use modality for both tobacco and cannabis is smoking, and thus product use leads to significant exposure to harmful smoke chemicals such as benzene (carcinogen), acrolein (respiratory irritant), and cyanide (cardiotoxicant). Furthermore, tobacco and cannabis are often used concurrently in ways that potentiate addiction and continued smoke exposure. Increased prevalence of cannabis smoking decreases efficacy of “Smoke Free” policies designed to reduce secondhand smoke exposure (SHS). SHS from tobacco and cannabis is disproportionately found in vulnerable populations (e.g., children and impoverished people). Recurring exposure to harmful smoke chemicals is associated with an increased risk of cancer, respiratory disease, and cardiovascular disease. Additionally, the widespread availability of e-cigarette/vape products and different liquids/oils/substances to put into these inhalational drug delivery devices led to the EVALI outbreak in the U.S. in 2019-2020 Exposure assessment is crucial for understanding potential harms associated with emerging tobacco and cannabis products.

The proposed symposium will focus on topics such as device engineering/emissions, topography, and biomarkers of exposure (active and passive).

## Climate Change and Wildfire Outbreaks Scenario, Do We Need to Worry about Wildland Firefighters? [70]

Climate change is causing substantial damage and losses, with wildfire outbreaks in many countries. In this exposure scenario, the wildland firefighters are a group made up of formal, informal, and voluntary workers, who are exposed to chemical, physical, and biological risks. The complexity of forest fire smoke indicates the need for more in-depth studies to fully understand the impacts on workers' health. This symposium will meet speakers discussing occupational exposures associated with forest fire fighting and the cutting-edge recommendations available to protect those workers' health. Development of methodologies to reduce occupational exposure and studies on the effects of forest fires on atmospheric chemistry, beyond their impacts on human health, and risk assessment are very welcoming topics as well.



## Collection and Dissemination of Workplace Monitoring Data to Support Occupational Exposure Assessment [63]

Chemical exposures in occupational settings can be vastly different than exposures in home environments. However, the chemicals used and the tasks performed in different workplaces vary greatly, resulting in a wide range of potential exposures to thousands of chemicals in commerce. Under the Frank R. Lautenberg Chemical Safety in the 21st Century Act, the United States Environmental Protection Agency must consider “highly exposed and susceptible sub-populations” in their risk evaluation of chemicals. While workers do fall under this umbrella, the lack of data can make this specific consideration challenging for risk evaluators.

Harmonized repositories of workplace monitoring data can support assessment of occupational exposures. Aside from merely evaluating worker health, the acquisition and availability of these data would be a boon to environmental justice research efforts as it has been documented that some socioeconomic groups may be disproportionately exposed to chemicals not only due to their housing/school locations but also due to their occupations. For example, minority female groups working in home care and beauty industries who are exposed to larger quantities specific chemicals.

The focus of this symposium is to provide a space for researchers to share knowledge of existing repositories of workplace monitoring data, existing or new efforts for obtaining these data, or efforts to apply this type of data for rapid evaluation of worker exposure evaluations.

## Communicating Environmental Inequity Through Data: Emerging Tools and Methods [77]

Recognizing the inequitable health impacts of environmental exposures on vulnerable populations, national and regional governments around the world are adopting legislation and developing strategies to advance environmental justice and equity. Local decision-makers are also increasingly integrating environmental equity into urban planning practices to improve the health and resilience of communities. However, planning and advocating for equitable healthy urban environments requires systematic analysis of reliable spatial data to identify where vulnerable populations intersect with positive or negative urban/environmental characteristics. Public access to such data is lacking. To fill this gap, new tools are increasingly becoming available to empower communities and local stakeholders to inform and motivate action on environmental inequities by facilitating access to data.

This symposium will feature data-driven tools and environmental equity indicators that support decision-makers, urban planners, public health professionals, advocacy groups and engaged citizens in assessing and addressing issues of environmental equity in urban settings. The symposium will promote the exchange of knowledge about these tools and methods by highlighting key features, environmental and demographic data sources, types of users and examples of impact, showing how they contribute to community empowerment, equity and resilient public health. The goal of the symposium presentations will be to capture how environmental indicators and tools can help advance the implementation and evaluation of equitable public health interventions in cities. Finally, opportunities and barriers for incorporating and visualizing environmental exposure and demographic data in public tools will be addressed.

## Communication of environmental health data to environmental (in)justice communities [46]

Environmental justice (EJ), or environmental injustice, has received renewed attention and funding in the past several years, both in the United States and globally. A frequently cited definition of EJ comes from the US Environmental Protection Agency, which has defined EJ as the right of all people to receive fair treatment and meaningful involvement in issues related to human health and the environment. Most research on EJ has focused on documenting the existence and extent of hazards; however, aspects related to promoting meaningful involvement are also important. One critical element of meaningful involvement is communication of environmental health data. There are many challenges in communicating environmental health data such as translating scientific jargon into more accessible language, communicating across language or cultural barriers, reaching the target audience, addressing misinformation or confirmation bias, and more. Workable approaches to communication are also likely to vary across the world, or even within a single region. Thus, the goal for this symposium is to share research and experiences related to communication of environmental health data with communities affected by environmental injustice around the globe, as a small step towards enabling meaningful involvement and progress towards achieving true EJ for all communities.

## Community Health Impacts of Noise Exposure [82]

Environmental noise – intrusive, unwanted sounds that disturb our ongoing activities – is a ubiquitous exposure that impacts millions worldwide. It is estimated that noise exposure may cause a loss of 1 million disability-adjusted life years due to a range of diseases. Excessive noise exposure from sources such as traffic and aircrafts can cause significant annoyance and stress, which can ultimately increase risk of physical and mental health concerns. Although the field of occupational health has measured and researched associations between noise and several health outcomes, effects from environmental noise within population health studies are less frequently reported. This may be partially due to the lack of accurate exposure data. Recent advancements in sensor technologies and spatial modeling approaches have allowed researchers to capture more accurate noise estimates for large geographic areas and populations. There are additionally environmental justice concerns with noise exposure, particularly in large cities, given the high correlation between noise levels and higher neighborhood deprivation, violence, and social stress. Because of these concerns it is additionally important to capture aspects of subjective noise annoyance along with measured sound levels. Using citizen science approaches may help to achieve these aims by involving community members in the process and capturing both objective and subjective measures of noise exposure. This symposium will address areas of innovation in noise exposure assessment and health impacts on vulnerable communities. Topics of interest include citizen science approaches for noise assessment, innovative methods in noise exposure assessment, and health impacts of noise exposure in vulnerable communities.

## Community-informed approaches and real-time exposure data collection in indoor environments [58]

As individuals move through their daily routines, they encounter a variety of indoor chemical exposures that can impact health. Whether it's the use of multiple personal care products, household cleaning products/practices, or air fresheners that impact indoor air quality, individuals have unique health patterns shaped by family/community culture and resource access. Vulnerable and underserved populations, including pregnant women, children, older adults, and those with chronic respiratory and allergic conditions, are particularly at risk to chemicals in their environments. Research involving real-time exposure data collection enhanced by community input provides important insight into exposure levels and their health impacts.

Use of technology can aid in the real-time capture and reporting back of data to individuals and communities. These data collection and report-back approaches can be better tailored to individual and community needs by meaningful community input/interactions. Community-informed approaches can occur at different stages of the research process (planning, data analysis, and dissemination) and can utilize different communication structures including report-back of research results with community advisory boards and during town halls.

This symposium invites presentations that illustrate real-time collection of indoor environmental exposures and their health impacts, particularly studies involving community input. Exposures of interest include but are not limited to particulate matter, wood smoke, cook stove emissions, ultrafine particles, volatile organic compounds, pesticides, chemicals related to plastics pollution, disinfectants, personal care products, household cleaning products, and indoor occupational exposures. We encourage presentations that discuss logistics and process elements of real-time data capture and/or community-informed approaches.

## Contending with Cumulative Impacts in Rural Communities [90]

“Rural” (inclusive of black, brown, indigenous, traditional, mixed heritage, and some settler) communities worldwide report deep connections to the environment that extend beyond mere reliance on “natural resources”. Human-environment relations yield material and spiritual “benefits” (those that are economic and those that matter far more than that) to health and well-being, past, present and future. Globalized capitalism’s pursuit of raw materials generates impacts and exposures in rural regions that differ from urban contexts. It’s not just because of their proximity to large spans of “undeveloped” land that landfills, agricultural operations, mines, and other extractive industries are more likely to be sited in and near rural communities. Lax environmental regulations and other economic incentives combine with inequities in decision-making power and a lack of recognition for Indigenous sovereignty to create the perception that rural regions are “open for investment” from polluting industries. The potential for exposure to emissions from nearby facilities increases with more frequent and longer duration of time spent outdoors for labor, subsistence, worship, and leisure. Also, rural communities often earn lower wages than their urban counterparts, have limited access to basic public health infrastructure (e.g., water and sewer), and travel farther for healthcare services. This symposium invites presentations on the intersecting and compounding socio-economic, cultural, environmental, and health impacts experienced in rural communities. In assessing cumulative impacts, we encourage the use of collaborative socio-ecological frameworks and the integration of asset-based perspectives that highlight aspects of rural life worth protecting and reproducing as communities contend with structural harm.

## Cooperate, Coordinate, Collaborate: Reducing Barriers to Cross-Governmental Collaborations for Key Environmental Challenges [56]

Society is at a critical juncture. Increasing challenges with climate change, pandemics, shifting supply chain considerations, and growing energy concerns in the face of international conflicts are some of the issues that are impacting environments, ecosystems, and individuals. Overcoming these challenges will require ground-breaking approaches to cutting edge science across sectors and historic boundaries. Governmental research needs to be faster, more responsive, and collaborative. An approach is needed that addresses decision making in the face of uncertainty, enables rapid incorporation of new findings into decisions, and advances knowledge in key areas. This balancing act is particularly challenging for high-profile topics that have significant human impacts and a high degree of uncertainty. In December 2021, a new U.S. interagency enterprise called the Joint Subcommittee on Environment, Innovation, and Public Health (AKA the JEEP) was initiated to foster coordination, cooperation, and collaboration to address key environmental issues. The JEEP seeks creative approaches to identifying and responding to emerging challenges at the interface of the environment and health. The JEEP explicitly coordinates action across governmental entities and, as needed and appropriate, through coordination with international, NGO, industry, academic, state, and Tribal partners. This symposium seeks presentations that would help develop or refine our model of collaboration for challenges that include this year's theme of exposures that impact health in vulnerable populations.

## Cyanobacteria Harmful Algal Blooms: Exposure Assessment for Protecting the Public's Health [23]

Reports over the past several decades of cyanobacteria harmful algal blooms (cyanoHABs) associated with human and animal illnesses and deaths have been increasing and are anticipated to continue to be of significant concern due to development, nutrient pollution, and climate change. CyanoHABs can range vastly in size (shoreline accumulations to areas covering several kilometers), location (planktonic and benthic), and temporality (duration of hours to weeks). CyanoHABs, even in the absence of detectable cyanotoxins, have been associated with a variety of health effects primarily during exposure to ambient surface waters during recreational activities. But concerns about health effects associated with cyanoHAB or cyanotoxin exposure due to cultural activities, subsistence fishing, aerosolization, and consumption of inadequately treated drinking water persist. While cyanoHABs are recognized as a growing public health concern, there are substantial challenges in characterizing ambient cyanoHAB exposure. Variable bloom formation and dissolution, toxin production, aquatic community composition, and weather events contribute to the challenges of exposure attribution. Simulation models and satellite remote sensing have been used to overcome some of these challenges, but their utility for exposure assessment at the individual or community level is poorly characterized. This symposium aims to highlight studies which dive into the complexities of cyanoHAB exposure assessment and the challenges in assessing associations between cyanoHABs in water and air with biologically relevant exposure metrics and/or adverse health effects.



## Effect of Environmental Exposure on Indigenous Population and Health [14]

Investigating the effect of environmental extremes on human health has received global attention, particularly in the context of climate change. Such extremes disproportionately affect at-risk populations, including children, elderly and Indigenous populations. Despite the significance and critical nature of this issue, studies on the effects of environmental exposures on indigenous populations and health remain under-researched. Indigenous peoples often reside in remote or rural areas, constitute less than 5% of the global population, and are custodians of 80% of the world's biodiversity. This stewardship places them at the forefront of environmental extremes due to climate change. Some of the issues with conducting research in remote Indigenous contexts are– logistical challenges to reach rural and remote locations, cultural and local knowledge, small sample sizes, and mobility of Indigenous people– which makes it hard to link exposure to a health outcome. By bringing studies conducted in these populations, this symposium will provide valuable insights into challenges in these communities to ensure that the health impacts of environmental exposure on at-risk populations are not overlooked and that policies are informed by comprehensive, culturally sensitive research.

## Effects of Historical Redlining on Multiple Environmental Exposures and Health Disparities [55]

Historical housing policies (i.e., redlining) and their impacts on environmental and health disparities in the US have been increasingly examined over the past decade in public health research. In particular, the maps generated by the Home Owner's Loan Corporation (HOLC) in the practice of redlining has contributed to examine persistent environmental disparities. However, it remains elusive how these past practices of mortgage are linked to health, particularly mental health outcomes, of present-day residents in historically redlined neighborhoods.

In the present session, we are interested in the effects of environmental exposures, including the joint effects of multiple types of exposures to extreme heat, air pollution, noise, and a lack of greenspace, and how they are linked to worsened mental and physical health outcomes of residents and communities. Furthermore, we welcome studies that examine how exposure to multiple environmental risk factors independently and jointly affects health outcomes among subgroups defined by personal characteristics, such as age, sex, and race/ethnicity, pre-existing conditions, and socioeconomic status. Lastly, we are interested in studies that explore methodological challenges and potential solutions associated with the spatial and temporal resolution of analysis.

## Efforts to Empower Data Collection and Applied Research for Climate-Related Disasters [20]

Robust, impactful, and timely climate-related disaster research is incumbent on accurate characterization of exposures and health conditions. In order to grow and advance the field of climate-related disaster and human health research, innovative equipment and tools, comprehensive data resources, and sound methodological best practices are needed. Additionally, a number of academic researchers from the climate change and disaster research communities of practice are in the field utilizing new technical equipment and exposure assessment methodologies to conduct timely, ethical, and novel studies.

This symposium will highlight efforts by agencies, academia, and NGO's that are working to develop and improve these types of resources including: funding and research infrastructure support; technical resources and instrumentation for exposure and health data collection in disaster settings; and initiatives related to building and strengthening data infrastructure (exposure, climate, and health data integration, harmonization, and accessibility) for research on climate-related disasters.

This symposium will involve a series of short overviews and a panel discussion to highlight high-visibility work in these areas, as well as key research studies showcasing innovative data collection and data integration strategies employed to support exposure assessment in studies of health-related impacts from disaster events.

## Elevating the Role of Microbes in the Exposome for Unraveling Society's Biggest Environmental Challenges [33]

Despite an ever-present push for cumulative impacts and systems thinking in the exposure community, there is a relative lack of emphasis on the contributions of microbes to the exposome. Efforts to characterize the dynamic nature of the gut microbiome in response to environmental factors are bringing together biologists, toxicologists, exposure scientists, and health professionals. Antimicrobial resistance (AMR) has emerged as an area of focus that threatens Western approaches to treating human disease and illness as microbes evolve over time. Another example that provides further evidence that a holistic approach is necessary is enhanced treatment of pathogens in drinking water that may result in elevated chemical exposures. With climate change being felt worldwide, additional individual and community-level stressors can increase the occasions for human interactions with a variety of agents that are normally controlled or prevented. From changes in microbial biodiversity and redistribution of pathogens due to shifting weather patterns to greater numbers of indoor microbes under post-flooding conditions, there is an opportunity to not only consider the chemical consequences of such events, but also the changes in microbial exposures that will impact human health. Furthermore, it has been shown that socially vulnerable groups may be more likely to shoulder the burden of health effects from changing climate. The purpose of this session is to highlight current exposure science research that is tackling microbial exposure in the context of broader environmental challenges and provide a forum for enhanced understanding of the most appropriate ways for considering microbes in exposomics.

## Environmental Justice Tools and Policies and Addressing Disproportionate Health Outcomes [38]

Some communities have a higher potential for facing elevated health risks and have historically borne a disproportionate burden of adverse health conditions compared with others. The term “Environmental Justice” (EJ) has been coined to reflect current and historical health, economic, and social disparities that are due to the accumulated effects of harmful environmental exposures. This symposium will provide an overview of EJ regulations and emerging regulatory and policy drivers that are shaping the EJ scoring and analysis methods used to measure and rank communities. Speakers will discuss the intended purposes of established federal and state EJ tools and highlight their strengths and limitations, focusing on their relevance to health disparity and disproportionate exposure to environmental pollutants.

By developing insights into environmental justice measurement tools, we can expand our understanding of what they measure and how those measures relate to a community’s actual health and exposure status. The general body of knowledge shared in this symposium can benefit various groups including community activists, government agencies, and academic researchers.

## Errors Exposed: Characterizing Exposure Measurement Error in Environmental Epidemiological Studies [29]

Much of our understanding of the health risks of environmental exposures comes from observational epidemiology studies, which depend on reliable exposure measurements in the study population. Characterizing exposure measurement error can enable researchers to take steps that minimize bias in epidemiology studies. It provides a means to understand the likelihood, direction, and magnitude of bias in epidemiology studies for better interpretation of the findings.

Presentations in this symposium will describe research that characterizes or accounts for exposure measurement error in epidemiology studies either qualitatively or quantitatively.

Examples that will be presented include a novel tool to incorporate chemical-specific information into assessments of bias from of exposure measurement error when conducting systematic reviews of epidemiology evidence, as well as examples from the U.S. EPA's IRIS assessments of methylmercury, hexavalent chromium, and ethylbenzene.

## Establishing a Global Community of Practice to Advance Exposome Research [93]

The exposome concept has been increasingly embraced by the biomedical research community and an expanding body of exposome research initiatives is rapidly forming. Yet, coordination and cooperation between initiatives are sporadic and scattered at both the national and international levels. There is a critical need to build a global Community of Practice (CoP) to guide more impactful future exposome studies and foster national and international collaborations. To address this critical gap, the National Institutes of Health (NIH) and the European Commission each announced a funding opportunity recently, calling for global coordination in exposome research. As a result, the International Human Exposome Network (IHEN) Project was funded by the European Commission in early 2024, and the Center for Exposome Research Coordination to Accelerate Precision Environmental Health (RFA-ES-23-010 [<https://grants.nih.gov/grants/guide/rfa-files/RFA-ES-23-010.html>]), is expected to be established by the NIH in the summer of 2024. Both projects, while independent of each other, share an overarching goal of building a global network through a commonly agreed upon framework and shared resources and tools for exposome research. This symposium, sponsored by leaders of the US Center for Exposome Research Coordination and the IHEN Project, will present an opportunity for connecting exposome initiatives and researchers around the world to discuss how to advance exposome research through global coordination and cooperation. The session will consist of presentations of representative international exposome efforts, followed by a panel discussion on opportunities for future collaboration and cooperation.

## Estimating dietary and non-dietary exposure to pesticides and how to translate them into risk [50]

The transition to more sustainable agricultural practices with much less impact on health and the environment requires input from exposure science. Policymakers need support to make better informed decisions on regulatory action in line with strategic programs such as integrated pest management (IPM) initiatives. Substantial reduction of the use of pesticides is a corner stone in IPM. Most current use pesticides accumulate less but both parent and their metabolites may still have a significant impact on human health. A main issue in the health risk assessment of pesticide exposure is the characterization of dietary and non-dietary exposure. To what extent can uptake from food and beverages be estimated from residues in food products? What is the role of procedures such as food frequency questionnaires, market based analysis and duplicate portion analysis? To what extent do we expect contributions from non-dietary sources and routes of exposure? There is much interest in accumulating pesticides in indoor dust in homes. To what extent does this explain internal exposure reported from biomonitoring and last but not least: What are the most abundant pesticide mixtures for farmers, neighbors and consumers in real life? What are good approaches to predict the health risk for these pesticide mixtures?



## Exposed and vulnerable: chemical exposures in hospital settings [62]

There is a wealth of data and research on the sources and health implications of human exposure to various chemicals, including endocrine disruptors. Yet, studies characterizing exposures to endocrine disruptors and other chemicals in hospital settings, such as intensive care units, are scarce. This is despite the fact that individuals in such settings are more vulnerable, often critically ill, and may have greater susceptibility to chemical exposures. Recent studies have shown that commonplace medical supplies, equipment, and devices (e.g., IV tubing, respirators, catheters, cardiopulmonary bypass circuit) serve as major sources of chemical exposures, particularly phthalates, alternative plasticizers (e.g., DINCH), and bisphenols, with estimated intakes or quantified biospecimen concentrations often exceeding those observed in comparable general population samples (e.g., NHANES).

## Exposure Assessment and Health Impacts of Agriculture: What does this Mean for Your Community and Neighborhood Farmer? [88]

With increased demands on food systems from population growth, climate change and other factors, agriculture world wide has continued to evolve. Food animal production has transitioned towards large-scale, densely stocked operations with broadly ranging impacts on air, soil and water quality. Industrialized agricultural and animal production operations can negatively impact the health and well being of already vulnerable neighboring communities. Adverse health effects range from increased asthma rates and infection and colonization with antimicrobial resistant bacteria, to quality-of-life impacts and psychosocial impacts. Crop production is increasingly impacted by extreme heat, drought, and other extreme weather events. Agricultural workers, many who are migrants to the US, are often on the frontlines of these challenges.

As demands on the food system continue to increase, there is a need to understand and investigate the impacts of agriculture on the environment, communities, and workers of the agriculture industry. The proposed symposium will be an opportunity for researchers, clinicians and other investigators to discuss their efforts in exposure and health assessment in various aspects of the agriculture industry. Talks in this symposium will be on a broad range of topics, from exposure assessment in vulnerable agricultural worker populations to community impacts of living in proximity to agricultural operations. This symposium has relevance for a broad audience of environmental and occupational epidemiologists, exposure scientists, environmental scientists and other researchers who focus on the impact of environmental and occupational exposures among vulnerable populations and environmental justice issues surrounding agriculture.

## Exposure Research and Surveillance at the State Level: Challenges, Opportunities, Findings, and Lessons Learned [73]

State health departments in the United States engage in chemical exposure research and surveillance to fulfill public health obligations, such as addressing community questions, and to contribute to scientific knowledge around chemical exposures and related health effects. State health departments conduct a variety of projects, including descriptive projects to characterize chemical exposures in general or in high-risk populations, analytic studies that measure the association between chemical exposures and health, and evaluative studies to measure the impact of public health programs. This symposium focuses on state health departments' efforts to better understand novel and legacy contaminants through projects in each of these domains. Projects to be discussed include NHANES-like state-level biomonitoring surveillance, exposure investigations in vulnerable populations (e.g., community and occupational populations), and studies measuring the relationship between PFAS exposure and biomarkers for health outcomes. We will discuss study methods, results report-back, and public health interventions facilitated by exposure research and surveillance projects. This symposium offers a platform to share perspectives, challenges, and capabilities unique to state governments and how partnerships with state governments can lead to innovation and increased capacity for exposure research and environmental health practice.

## Exposure Science & Engagement in K-12 Schools and Communities [22]

Worldwide millions of students spend 6-10 hours a day inside kindergarten to 12th grade (K-12) school buildings, where they can be exposed to elevated levels of ambient pollutants such as wildfire smoke and indoor generated pollutants such as carbon dioxide and respiratory infectious viruses. Since the Covid-19 pandemic, schools have invested millions of dollars in low-cost sensors to monitor indoor air quality as well as HVAC and room based interventions intended to reduce exposures to pollutants and viruses. The advent and increasing availability of these low-cost sensors and public environmental data enables novel partnerships between exposure scientists, educators, school staff, and community members to inform action and policy in schools. Additionally, exposure science methods and tools are being used in the classroom and out-of-school programs to provide K-12 and undergraduate students with inquiry-based learning experiences.

This symposium provides evaluation of indoor environmental quality sensors and interventions in K-12 schools, and discusses emerging issues including school community engagement and education, researcher-school partnerships, environmental justice, climate resilience, and sustainability. Participants in this session will also learn to identify challenges and innovative methods for linking exposure science and STEM education.

## Exposure, Risks and Health Outcomes in Workers due to Climate Change [64]

Climate change can exert a direct impact on the overall health of the population, particularly affecting vulnerable groups such as workers. Health and safety repercussions are emerging from various hazards, including chemical, physical, biological, and psychosocial factors. For instance, chemical hazards may manifest when employing pesticides to combat new crop pests, while physical hazards could arise from direct exposure to extreme heat, leading to diverse health issues stemming from thermal dysregulation. Biological hazards emerge from conducive environments for zoonotic diseases like Lyme disease. Moreover, psychological hazards may appear during flooding events, especially among public safety and healthcare workers.

These hazards pose multiple risks and consequential health outcomes, encompassing physical health conditions such as heatstroke, syncope, edema, exacerbation of cardiovascular, digestive, or renal diseases, as well as chemical poisoning. Additionally, they impact psychosocial and mental health, leading to income loss, post-traumatic stress syndrome, anxiety, and depression.

This symposium aims to delve into various facets of this emerging topic, where research is rapidly expanding. It will explore the most recent knowledge of worker exposure to different risks (chemical, physical, and biological), including the nature and quantification of these exposures. It also will address the evidence-based health outcomes and potential prevention and adaptation strategies. Original research, knowledge synthesis, and promising intervention projects conducted globally are encouraged for presentation and discussion at the symposium.

## Exposures to Endocrine Disrupting Chemicals and Women’s Health: Addressing Current Gaps to Eliminate Health Inequities and Environmental Injustice [24]

Endocrine disrupting chemicals (EDCs) can interfere with the normal endocrine system function, which regulates various physiological processes, including reproduction. Exposure to EDCs is ubiquitous and racial/ethnic disparities are reported with women of color suffering an elevated exposure burden, potentially contributing to a higher incidence of hormone-dependent diseases and other health inequities. These exposure disparities may stem from structural racism, personal care product use, and occupation. To date, there is limited evidence to conclude how exposure to EDCs affects women’s reproductive health and further studies focusing on exposure to mixtures of EDCs are needed. Addressing these gaps is crucial for identifying modifiable risk factors and developing interventions to reduce EDC exposures and their impact on women’s health disparities.

This symposium is relevant to exposure scientists, environmental epidemiologists, physicians, policymakers, and biomedical researchers with an interest on exposures to legacy and emerging endocrine disrupting chemicals and their impact on women’s health inequities and environmental injustice. The proposed symposium will provide a forum for investigators to share developing research on the intersection between EDC exposures and women’s health endpoints. Health outcomes of focus include but are not limited to endometriosis, uterine fibroids, polycystic ovary syndrome, infertility, pregnancy complications, and autoimmune disorders. The symposium will showcase factors that impact exposure and health risks, efforts to promote community resilience, and strategies to conduct successful community engagement. The session seeks to highlight community involved research addressing exposure disparities and health inequities among women in underserved and under-resourced communities.

## Exposures to Legacy and Emerging Contaminants in the United States and Associated Determinants and Developmental Outcomes in the Environmental Influences on Child Health Outcomes Cohort [25]

The Environmental influences on Child Health Outcomes (ECHO) Cohort initiated in 2016 and funded by the United States National Institutes of Health, aims to advance understanding of effects of early environmental exposures on children's development and health outcomes with high public health impact. ECHO Cohort has simultaneously measured over 100 legacy and emerging chemicals in the urine of over 6600 pregnant participants, including bactericides, benzophenones, bisphenols, fungicides and herbicides, insecticides, organophosphate esters, parabens, phthalates/alternative plasticizers, polycyclic aromatic hydrocarbons, melamine, and aromatic amines. Two pilot studies conducted among 171 pregnant participants within the ECHO Cohort reveal frequent detection of these chemicals in urine biospecimens. This finding is of great public health significance as many of these chemicals are known or suspected endocrine disrupting chemicals and limited research suggests that some of these chemicals may be associated with adverse birth and developmental outcomes. Given the widespread exposure of these contaminants during a critical window of development for children's health, identification of exposure determinants and examination of their associations with developmental outcomes is critical.

The proposed symposium will provide a platform for investigators to discuss ongoing efforts in identifying exposure characteristics in pregnant individuals and exploring the developmental effects of these chemicals on children. This symposium is relevant to exposure scientists, environmental epidemiologists, physicians, policymakers, and biomedical researchers with an interest in legacy and emerging chemical exposures and their impact on pediatric health outcomes. The session will foster discussions on future research directions aimed at protecting the health of vulnerable pediatric populations.

## Firefighter's Exposure to Mixtures of Hazardous Chemicals and Assessment of Health Impacts [54]

Firefighting is a dangerous occupation involving intense physical demands. Firefighters also have higher exposure to chemicals formed during combustion and are routinely exposed to synthetic chemicals during a fire. For example, flame retardants are commonly used in insulation, furniture, electronics and vehicles, and per- and polyfluoroalkyl substances (PFAS) are used in fabrics, carpeting, firefighter turnout gear and firefighting foams. In addition, the increased use of lithium-ion batteries in electronics and electric vehicles has raised battery-related fire risks, potentially exposing firefighters to an increasing range of chemicals.

Growing epidemiological research has correlated firefighting exposures with immediate health effects like reduced lung function and cardiovascular issues, as well as long-term health implications like cardiovascular disease. However, these findings, while suggestive of causal links, are frequently derived from cross-sectional studies and are often limited by inadequate hazard characterization.

Assessing exposure to environmental mixtures is a challenge within the general population, and this complexity is magnified among firefighters. Their working environment constantly changes, with chemical exposures varying significantly over time. Moreover, many conventional exposure assessment tools, such as wearable air samplers, are impractical in firefighting scenarios as they can compromise firefighters' effectiveness and safety. Passive silicone samplers (e.g., wristbands and dog tags) and skin and gear wipes have been proposed as alternative exposure assessment tools. Understanding exposure patterns and sources of exposure is necessary for protecting firefighters' health and exploring methods to mitigate occupational risks. This symposium will highlight new research assessing firefighters' exposure to chemical mixtures and new firefighter health research.



## Frontline Exposures of Agricultural Workers: Connections Across Fields to Improve Health [71]

Agricultural workers experience a heavy burden of disease related to environmental and occupational exposures. These exposures emanate from various sources and practices in livestock operations and/or crop production. For example, farm workers are at increased risk for thermal stress and/or aerosol exposures containing infectious pathogens or silica and other inorganic constituents. Respiratory allergy and disease have been widely recognized among dairy workers while an epidemic of chronic kidney disease of unknown origin (CKDu) has been particularly devastating in Central America. Reducing the risk of illness among agricultural workers remains a high priority across occupational health agencies and organizations, including the National Occupational Agriculture, Forestry and Fishing Sector Council that identified 13 research objectives for 2016-2026. However, etiologic and surveillance research encounter an array of technical challenges during sampling, analysis, detection, identification and assessment of risk, health impacts, and exposure-response relationships.

The goal of this symposium is to connect scientific communities that engage in state-of-the art research, discuss new research directions, and promote advances in the frontiers of exposure science to address existential health challenges in agricultural workers and communities impacted by environmental and occupational diseases (e.g., fixed airways disease and CKDu). We believe this symposium reflects the theme for our 2024 meeting.

## Gap-filling Methods to Assist Risk Characterization of Data Poor Chemicals [67]

Gap-filling methods, including those that predict exposure “endpoints” based on chemical structure, can assist in exposure screening of candidates for risk prioritization. Specifically, chemical use and release information, media concentrations (for example, air, dust, food, water, etc.), and human and ecological exposure data are unavailable for the vast majority of new and existing chemicals. Data informatics tools are also needed to link chemical information, model predictions, and available data repositories in reproducible workflows that provide transparent and actionable information to risk assessors. Many regulatory bodies, including the US Environmental Protection Agency and Health Canada, are tasked with evaluating potential risks (hazards and exposures) of data-poor chemicals. Programs to perform these tasks, while also providing approval for manufacture and use, exist for both existing chemicals and for new chemicals. While read-across approaches and New Approach Method (NAM) data for hazard (toxicity/bioactivity) are being considered to support hazard characterization for data-poor chemicals, similar methods are also needed for exposure information. The focus of this symposium is to provide an overview of existing modeling methods and operationalized workflows that can be used by decision-makers in the process of screening, prioritization, and exposure evaluation of chemicals. Best practices will be shared, and research needs will be discussed.

## Harmonizing Wearable Passive Samplers for Operationalizing Exposomic Measurements [89]

Exposomics aims to comprehensively characterize environmental influences from social, physical, chemical, and biological factors. Comprehensive assessment of the chemical features of the exposome is challenging given their structural diversity, wide range of physical-chemical properties, and dynamic range of these factors. Traditional exposure assessment approaches using active sampling tools have limited wearability due to their power requirements and cost. Wearable passive samplers offer a more assessable approach to evaluating the chemical space of the exposome in diverse populations.

As wearable passive samplers gain popularity in measuring personal exposures, harmonizing measurements is critical for reporting meaningful exposure results and enabling comparisons among studies to advance exposomics. Standardizing analyses can be achieved by characterizing the sampling behavior, artifacts, sample extraction procedures, and the analytical and computational protocols used with these tools.

This symposium will feature abstracts characterizing the performance of wearable passive samplers for assessing chemical exposures. Topics will include the calibration of passive samplers against gold-standard or commonly used methodologies, as well as the identification of major contributing factors to variations in exposure measurements resulting from sample and data analysis approaches. Wearable passive samplers present opportunities for overcoming key barriers to analyzing chemical exposures in population studies and will serve as the basis for 'sequencing' the human exposome. These discussions aim to foster the development of a robust, reliable, and rigorous framework that maximizes exposure measurement coverage.

## Health-based interpretation and communication of human biomonitoring data [78]

Human biomonitoring – the direct measurement of how much of a chemical or its metabolites or breakdown products is present in a person – is one of the most important instruments in exposure science. The health-based interpretation and communication of human biomonitoring data is paramount for its effective use in risk assessment, risk management, and public health policy, and to advance research on the associations between environmental chemical exposures and adverse health outcomes. The development of human biomonitoring health-based guidance values (HB2GVs) by regulatory agencies and researchers has facilitated the use of human biomonitoring data to understand the potential impacts of chemicals on human health. HB2GVs allow for more direct comparisons between environmental chemical levels measured in people and exposure thresholds derived from toxicological studies, such as Tolerable Daily Intakes (TDIs) and Reference Doses (RfDs).

Given the value of HB2GVs as a tool to assist with the health-based interpretation and communication of human biomonitoring data, the International Society of Exposure Science (ISES) International Human Biomonitoring Guidance Value (i-HBM) Working Group developed the Human Biomonitoring Health-Based Guidance Value (HB2GV) Dashboard (<https://www.intlexposurescience.org/i-hbm/> [<https://www.intlexposurescience.org/i-hbm/>]) as a platform to easily access available HB2GVs. The dashboard contains pertinent information for over 500 HB2GVs derived by regulatory agencies and researchers. In this symposium hosted by the i-HBM Working Group, we aim to highlight recent studies and work that involves the derivation and/or use of HB2GVs, as well as featuring new and alternate approaches to the health-based interpretation and communication of human biomonitoring data.

## How nicotine and toxicant exposure change across user behaviors and e-cigarette device characteristics [21]

Electronic cigarettes (e-cigarettes) are used by millions of people globally. While controversial, some in public health have promoted the use of e-cigarettes for tobacco harm reduction. However, to truly reduce harm to smokers and to not pose significant harm to nonsmokers who use them, it is important to understand user behaviors and device characteristics that may influence nicotine intake, exposure to toxicants, and ultimately, health risk. This symposium will present the state-of-the-science on differences in exposure across puffing behaviors (topography), vaping patterns, electrical power, e-liquid pH, nicotine salts, and the latest iteration of e-cigarettes compared to older models. Studies range from lab-based vaping machine studies to clinical pharmacology studies.

## How to control new and emerging occupational health risks occurring in a circular economy? [51]

The transition to more sustainable practices requires new challenges to control exposure and health risk for workers. However, different solutions related to the circularity of chemicals and materials raise concerns for the health of involved worker populations. An example is the processing of waste resulting in exposure of an increasing number of workers to hazardous chemicals that are already phased out through regulation because of hazards for humans and the environment. E.g. during the large-scale pre-separation and processing of waste streams such as electronic waste (e-waste) and recycling of food packaging and plastic bottles from household waste. There, reuse may also lead to ‘recycling’ of hazardous chemicals like PCBs, plasticizers and flame retardants in the loop of recycled materials. This may lead to continued exposure to hazardous substance compared to the use of newly synthesized plastics of high purity. These challenges need to be taken into account in the protection of the health of involved workers. A similar situation occurs in agricultural practices where a reduction of the use of pesticides may lead to the introduction of alternative solutions relying on non-pesticide chemicals and biological crop protection as part of integrated pest management that may lead to new and emerging health risks e.g. related to biological agents and their metabolites. In this symposium the focus will be on chemical exposure, contributions on biological and physical exposures are welcome.

## Human exposure in the 'pyrocene': the rising health impacts of wildfires and other climate-driven events [30]

Anthropogenic climate change is bringing vast, unpredictable changes in human population exposures to a range of environmental agents. This causes health inequalities by disproportionately affecting vulnerable populations. Of particular concern is the rising intensity and distribution of wildland forest fires, which are impacting both local and distant ambient air pollution concentrations with the potential to massively increase the global burden of chronic diseases, such as cancer and cardiovascular disease. The 2023 Canadian wildfire season was the worst year on record for wildfire intensity, with more than double the number of hectares burned than the previous record, and more than four times that of a typical year. Large plumes of smoke also made their way south, affecting populations in the USA. The term 'pyrocene' has been coined to describe this new epoch of wildfire intensity humans are entering. This symposium will include a variety of presentations on human exposure to wildfire emissions worldwide, health endpoints of concern, predicted trends, assessment methods and mitigation measures to combat this growing public health problem, as well as other related exposures driven by human induced climate change. The symposium will be Co-chaired by Dr Dan Middleton and Dr Nathan DeBono, former Exposure Assessment Scientist and Epidemiologist, respectively on the Monographs Programme of the International Agency for Research on Cancer (IARC-WHO). Dr Middleton has expertise in a host of environmental exposures, and Dr DeBono brings unique expertise through serving as the Responsible Officer on the recent Monographs evaluation of firefighting - a recently upgraded Group 1 carcinogen.

## Improving Consumer Product Exposure Assessment: New Tools, Models, and Analyses to Better Estimate Exposures and Potential Health Risks [53]

As we continue to learn more about potentially harmful chemical ingredients in common consumer products, better exposure assessment tools and methods are needed to improve estimates of exposure and ultimately assess health risks. Through solicitation of interdisciplinary perspectives, this symposium will explore methods to better understand consumer product use patterns, routes of exposure, including inhalation, dermal contact, and ingestion, and the current state of research into the potential human health implications of exposure to chemicals in, and emissions from, common consumer products like household cleaners and personal care products. Presenters will share novel exposure assessment approaches that may include validated product surveys, new tools for collecting detailed product information, data collection with low-cost sensors, enhanced product use and risk models, or analyses that shed light on important predictors or potential outcomes of exposure to consumer products. Discussions will also encompass strategies for mitigating exposures, from product formulation and regulatory measures to consumer education and behavior change.



## Linking environmental exposure data to health outcomes post-climate disaster; emerging opportunities and challenges [91]

Research supporting and identifying key drivers of climate resilience is essential for the health and well-being of communities facing increased environmental and occupational stressors from these events. This session will explore successful case-examples and future opportunities collecting and linking perishable environmental health data to health outcomes after climate-related disasters. Barriers often limit post-event data collection, including rapid access to research funding, instrumentation and expertise availability, and infrastructure and community disruption. Identifying and facilitating these necessary elements for exposure assessment is crucial in advancing this research area. Representatives from the NIH Climate Change and Health Initiative, the NSF-funded Natural Hazards Engineering Research Infrastructure, and the Public Health Extreme Events Research network will share emerging opportunities and new research support tools, including the University of Washington RAPID Facility. This shared-use facility provides resources, software, and support for collecting, processing, and analyzing perishable data from natural hazard events. With research-based examples, this symposium aims to advance this field and drive change.

## Measuring Exposures that Impact Health in Vulnerable Populations: Trade-Offs Among Exposure Assessment Approaches [81]

Accurate and precise understanding of exposures that impact health in vulnerable populations is important for identifying and implementing worthwhile mitigation pathways. This symposium intends to engage discussion on benefits, burdens, and tradeoffs among field-based methods for exposure measurement. For example, while stationary and outdoor monitors for air pollution provide valuable large-scale data, limitations like spatial variability and lack of individual context remain. On the other hand, personal measures of air pollution exposure offer potentially higher-resolution data closer to the exposure source, or time-integrated samples that are collected over the course of a person's time-activity pattern(s), but such measures often suffer from short monitoring durations and potential user bias. Similar tradeoffs among measurement choices exist for ingestion, dermal, and inhalation exposure routes. While these tradeoffs are not new, the range and number of studies that have been able to employ more than one type of exposure measurement has grown. This symposium aims to attract researchers who want to present on, learn from, and discuss innovative approaches to exposure assessment. Research presentations are invited on: (1) selecting and optimizing exposure measurement strategies, considering data quality, cost-effectiveness, and ethical considerations of community engaged research; (2) communicating exposure data in light of uncertainty and measurement error; and (3) the application of knowledge on exposures measured using a range of techniques and methods for intervention and policy design and implementation.

## Micro- and Nanoplastics: Defining human exposure from the local to the global scale [80]

Micro- and nanoplastics (MNPs) have been identified in nearly every environmental compartment. They include intentionally-manufactured particles and fibers, plus fragments resulting from larger products (e.g., clothing, furnishings and tires) and discarded debris. The health impacts of these contaminants are unclear and complicated by their diverse morphology, composition (constituent polymers and associated chemicals), and biofilm. Human MNP exposure may occur by ingestion of contaminated food or beverages, ingestion of dust through hand-to-mouth activity (especially in young children), inhalation of airborne particles, and dermal contact. MNPs have been identified in a growing list of human-derived samples, including saliva, sputum, breast milk, lung and placenta tissue samples, and newborn meconium.

Exposure to MNPs is a nascent field of inquiry. Sampling methodologies, especially in the indoor environment where we spend ~90% of our time, are disparate, and analytical methodologies require improvement to enhance the rigour of scientific findings. Presently, a meta-analysis of our exposure to MNPs and associated chemicals is impossible. Concerted efforts are necessary to conceptualize common definitions of MNPs and operationalize these definitions by developing guidelines for how to approach MNP exposure assessment. The multinational nature of plastics manufacturing and differences in exposure and risk among diverse populations and regions underscore the urgency for global cooperation. This symposium will bring together experts in MNP research and exposure assessment to identify: (i) the central questions necessary to guide progress, and (ii) robust measurement methods and reporting that will optimize our individual and collective efforts.

## Multipollutant and Non-chemical Stressor Exposure Assessment Advances to Aid Public Health Decision-making [47]

A better understanding of the health effects of multipollutant mixtures as well as combined chemical and non-chemical stressor exposures can aid targeted interventions and inform future policy development and regulatory measures that involve assessment of multiple, overlapping exposures. Exciting novel approaches, including exposomics, non-targeted analyses, and new statistical methods for environmental mixtures, have pushed this area forward in recent years. However, data and analytical challenges, such as misalignment in precision, spatial scales, or temporal scales among data sources, identification, and prioritization of chemical and non-chemical stressors for specific decision contexts, public health interpretation of analytical approaches, and computational limitations of large datasets, have challenged advancements in this field and use in decision-making. Improving precision and accuracy of assessing exposure to chemical and non-chemical stressors particularly supports understudied, environmentally overburdened, and vulnerable populations, who may experience higher levels of exposure or stronger associations in relation to exposure to multiple stressors. This session will showcase recent advances in multipollutant and multi-stressor exposure methods, characterizations of multipollutant and multi-stressor exposure error, and public health decision-making applications.

We encourage abstracts from researchers that are using tested or novel methods to assess combined exposures to chemical and non-chemical stressors. We also encourage policymakers, community members, private sector representatives, and other decision-makers to submit abstracts demonstrating examples of where assessment of combined chemical and non-chemical stressors are being used in their own decision-contexts.

## New agricultural technologies for the management/mitigation of exposure to farming communities [17]

Various regional governmental policies, public interest, and machinery/engineering improvements in agricultural technologies are driving the change in agriculture aiming for more optimal performance (i.e., reduced, use of pesticides with more targeted decision-making and applications, e.g., digital tools, precision applications, unmanned aerial vehicles/spray systems, and countless application equipment technological improvements).

With improvements in available agricultural tools and technologies there is benefit not only to agricultural workers but also nearby residents of farming communities. A reduced risk of exposure for farming communities should be observable, thus justifying continued advancement/development of these tools as risk mitigation/management to further reduce exposure and improve overall safety.

Due to complex nature of variability of tools, market competition, costs of data generation, potential impact of the tools on farmers' financial viability, many stakeholders (governmental, academic, farming associations, machinery, chemical industry, etc.) are tackling the exposure management and general safety aspects separately and differently.

The aim is to bring the exposure community together, exchange ideas, and address and advance the management/mitigation of exposure to farming communities.

## New and Emerging Indoor Exposures in Children's Environmental Health [19]

Advancing children's environmental health requires a deeper understanding of the exposures that exist in key settings like homes, schools, and daycares. Many studies of indoor environmental hazards focus on exposures that occur in schools; there is a critical need to examine the breadth of exposures that occur other spaces where potentially vulnerable children spend their time, including homes and daycare facilities. Additionally, much of our understanding of indoor environmental exposures is limited to a relatively small set of exposures. For example, studies of air pollutants tend to focus on particulate matter exposures rather than the health-relevant constituents or properties of the PM (e.g., black carbon or oxidative potential). With the growing interest in the effects of multiple simultaneous exposures on health, there is a growing need to quantify exposures to new or emerging contaminants in these spaces and identify associated health impacts. Such data is necessary to better identify opportunities for intervention.

In this session, investigators will share their recent findings on exposures that may potentially impact the health and well-being of children in critical early life environments like homes, schools, and daycares. A goal of this session will be to explore challenges in data collection in these setting and identifying opportunities for advancing our understanding of exposures during a critical developmental window.

## Next generation approaches for advancing throughput and human relevance in the assessment of inhaled chemical exposures and health outcomes [61]

The high cost and low throughput of traditional approaches to inhaled chemical exposure modeling limits their ability to protect public health from exposures to air pollution. However, these challenges can be overcome through the development of new approach methodologies (NAMs) to increase throughput and human relevance. The effects of air pollutant exposures on human health varies widely due to composition and physico-chemical properties, frequency and duration of exposures, and underlying biological diversity of the exposed populations. In vitro models can mimic key features of the human respiratory tract and can be amenable to conducting repeated exposure studies. Primary cell-based models also allow for the consideration of age, sex, race, underlying disease, and other biological factors. Recent advances in multi-cellular systems and in vitro exposure apparatus have further improved in vivo relevance. In addition, high throughput exposure modeling can provide valuable insight for in vivo data-poor exposure scenarios. Dosimetry from inhalation exposures differs from other modalities in that deposition in the respiratory tract is driven more by mechanical and fluid dynamics than by chemical properties. Computational approaches are critical to characterize and rank chemicals on the basis of inhalation exposure potential. This session will highlight advancements in the use of NAMs to address the complex challenges of modeling inhaled chemical exposures and effects. Highlighting successes and challenges is critical for understanding how NAMs can be used to overcome key challenges to protecting public health from inhaled chemical and air pollutant exposures.

## Novel approaches to VOC exposure monitoring and assessment [41]

Daily exposure to reactive chemicals and air pollutants, including volatile organic compounds (VOCs), increases the risk of chronic inflammatory illnesses and cancers. Harmful effects of VOC exposures can disproportionately impact vulnerable populations, particularly those near sources of VOCs such as urban corridors or industrial sites. Adequate tools for assessing VOC exposures are essential in addressing health disparities across populations and communities.

Earlier, VOC biomonitoring was technologically limited to a few specific analytes. Now, with advanced instrumentation and innovative analytics, approaches for VOC biomonitoring in environmental chemistry and exposure science evolve rapidly. High-resolution mass spectrometry advances expanded exposure assessments to include hundreds of VOCs and other harmful environmental chemicals. Advanced technologies such as PTR-TOF-MS now enable ultra-sensitive real-time assessments of ultra-low levels of VOCs in breath. Others, like GC-MS/MS and LC-MS/MS aid high-throughput, quantitation of VOC exposure biomarkers. Measuring VOCs and metabolites in breath, biofluids (blood, urine, sweat, saliva), and wastewater provides a comprehensive exposure assessment, enabling tracking of the exposomic fate of these compounds.

This symposium will showcase novel approaches and technical developments for comprehensive assessment of VOC exposures at individual and community levels. This includes measurements in both biological and non-biological matrices associated with biofluids (e.g. wastewater) along with non-targeted and profiling approaches for examining environmental VOC sources, exposures, and metabolites, and linking these measures with adverse health outcomes. Insights shared at the symposium will broaden understanding of tools for assessing VOC exposures, and thereby address health inequities and disparities within our communities due to these exposures.



## Occupational and Environmental Risk Factors for Chronic Kidney Disease of Unknown Etiology (CKDu) in Vulnerable Agricultural Populations [18]

Large-scale changes in agricultural productivity and amplified global agrochemical dependence has coincided with an alarming and rising epidemic of chronic kidney disease of unknown etiology (CKDu), also known as chronic kidney disease of nontraditional cause. CKDu disproportionately afflicts agricultural communities and workers and is not associated with traditional risk factors. Studies of CKDu have investigated an array of environmental and occupational exposures, including heat stress and dehydration, heavy metals, pesticides, and infectious diseases, all hypothesized contributors to the global rise of CKDu. Still, limitations of existing exposure data, especially individual-level data, have hindered the ability to infer causal relationships between investigated risk factors and CKDu.

As our global dependence on agricultural production increases, it is imperative to encourage transdisciplinary and sustainable collaborations among researchers and with impacted communities, while improving exposure assessment methodologies for epidemiological investigations to address complex public health challenges in highly vulnerable populations. The proposed symposium will provide a platform for investigators to discuss ongoing efforts to evaluate CKDu risk factors in understudied agricultural communities and workers, focused on advancements in exposure assessment strategies. Talks will include innovative approaches to exposure assessment in resource-restricted settings, including those that address risk factors associated with climate change, or evaluations of the acceptance or implementation of novel methodologies among both researchers and target vulnerable populations. This symposium is of relevance to a broad audience of exposure scientists, environmental epidemiologists, physicians, policymakers, and other biomedical researchers examining the impact of environmental and occupational exposures on renal health disparities in vulnerable populations.

## Precision environmental health in exposure assessment and health effects research [35]

The impact of environmental exposures on human health differs among individuals and across populations and time, as well as across life stages. Some populations during specific time windows or life stages are more vulnerable to environmental exposures than other people or other times. Precision environmental health is an emerging field about understanding those differences to identify specifically susceptible individuals to environmental threats and enabling precise, targeted, and effective preventions.

Precision environmental health can be reflected in both exposure assessment as well as health effect estimate. Exposure assessment studies might use wearable sensors to map the whole picture of exposure for a person in real-world scenario and shed light on the impact of human activities on personal exposures to environmental stressors. It could also be “omics” studies of the totality of environmental exposures over the life course. Health effect research might involve collecting highly time and space resolved data to understand the causation of environmental exposure and health effects and to target individuals especially vulnerable to environmental exposures. It could also be leveraging multi-omics data to investigate the mechanisms of exposures on adverse health effects. All these studies contribute to the ultimate goal of precision environmental health of individualized risk assessment and interventions to prevent disease.

Oral and poster presentations in this symposium will share how they apply the concept of precision environmental health in their research, challenges they meet in precision environmental health, and effective interventions they applied to reduce the adverse health effects of exposures.

## Process Release Modeling for Occupational Exposures and Fenceline Analyses [75]

The chemical releases from processes that manufacture, process, use, dispose, reuse, and recycle chemicals are critical elements of exposure and risk assessments. Modeling can be improved to determine parameters and update release estimates that are fundamental to occupational exposure analyses. Newer methods describe fenceline analyses to gauge the toxic impact potentials in communities. The fenceline analyses can also reflect environmental justice concerns for specific population groups. Presentations are encouraged in various types of industries (chemicals, plastics, etc.) for modeled and measured exposures, and also in related areas such as non-routine process operation emissions, combined emissions of chemicals, monitoring, tools, etc.

## Qualitative Approaches to Investigating Environmental Exposure and Health Outcomes [84]

Environmental health issues are complex and often cross multiple sectors, requiring various perspectives to understand and address fully. In Exposure Science, we recognize that the social determinants of health play a significant role in shaping people's exposure to environmental hazards and their ability to mitigate those risks. Therefore, integrating multiple methods can lead to a more comprehensive understanding of environmental health issues and more effective interventions.

Qualitative and Mixed Methods provide valuable insights into the social and cultural factors that influence people's relationship with the environment and their behaviors regarding environmental health. Collaborative efforts between natural, physical, and social sciences can help to ensure that environmental health policies are just and equitable, considering community needs and addressing the root causes of environmental health problems. Effective communication and engagement with communities are also essential to successful environmental health interventions, and the social sciences can inform the development of culturally-sensitive education and report-back efforts.

## Quantifying the Relationships Between Exposures to Chemical and Non-chemical Stressors for Assessing Cumulative Impacts in Vulnerable Communities [37]

Cumulative impact assessment (CIA) attempts to incorporate and combine exposures to numerous chemical and non-chemical stressors from a wide array of sources through multiple pathways. One feature of CIA is the explicit incorporation of non-chemical stressors as contributors to cumulative impacts in vulnerable communities. There is significant evidence that exposures to elevated levels of non-chemical stressors have the potential to increase susceptibility to chemical exposures resulting in changes to an individual's biological response to the chemical exposure. These findings are applicable at the community level and contribute to their vulnerability. More research is needed to understand how the relationships between chemical and non-chemical stressors and health effects can best be incorporated into cumulative impact assessments, in particular quantitatively.

This symposium will present a range of available approaches for quantifying the relationship between exposures to chemical and non-chemical stressors when assessing cumulative impacts in vulnerable communities. Both the state-of-the-science and research needs will be presented. Examples of topics include:

1. How to combine exposures to both chemical and non-chemical stressors
2. Role of allostatic load (AL) and AL-based approaches
3. Biomarker approaches
4. Epidemiological approaches and needs
5. Incorporating critical life course windows of exposure to non-chemical stressors
6. Evaluating causal relationships – for example, influence diagrams and directed acyclic graphs

## Research ethics in exposure science: challenges and opportunities [34]

The International Society of Exposure Science (ISES) has recently established an Ethics Committee. The Committee aims to develop guidelines to assist members in understanding the ethical dimensions of their work and finding support from their ISES colleagues to address such issues. Leveraging the diverse, international membership of ISES, which includes scientists from academia, government, industry, consultancy, and non-governmental organizations, the Committee's first phase involves understanding the ethical challenges and experiences of members in their professional arenas. This symposium will be the first event where ethical challenges, whether real, perceived, or evolving, will be discussed in relation to exposure science topics, professional responsibilities, institutional motivation, potential strategies, and ethical dimensions.

## Symposium on Emerging Topics in Human Biomonitoring for Exposure Science [36]

Human biomonitoring (HBM) is a pivotal tool in exposure science, providing direct measurements of internal exposure to pollutants. This symposium will delve into the forefront of research and innovation in evaluating human exposure to contaminants through biomonitoring, covering diverse topics reflective of the multidisciplinary field and its crucial role in safeguarding public health.

The proliferation of HBM studies and national programs has generated numerous emerging topics and key advancements, including the development of analytical methods to evaluate exposures to chemicals of concern, including pesticides (i.e. neonicotinoid insecticides), plasticizers (i.e. Hexyl-Phthalate), and UV filters (i.e. 2-ethylhexyl salicylate) among vulnerable populations such as children, pregnant women, and occupational groups. These studies will elaborate on significant advancements made in the identification of novel, specific, and robust biomarkers for assessing contaminant exposures: providing insights into exposure levels and toxicokinetic factors. Presentations will also highlight the crucial elements in the development of HBM studies and national programmes to evaluate nationwide exposure to contaminants and its role in facilitating evidence-based risk assessment. Studies will also explore the differential exposure patterns and susceptibility among vulnerable populations.

Overall, these emerging topics underscore the dynamic nature of HBM in exposure science and its essential role in safeguarding public health. Researchers can enhance our understanding of environmental health risks through methodological advances, biomarker identification, and addressing exposure disparities. This symposium promises to be a platform for sharing cutting-edge research and influencing the future of HBM in exposure science.

## Teaching and Communicating Gene -Environment Interactions with a focus on Environmental Justice Communities and Various Education Levels [12]

This symposium will allow participants to present at several levels of educational courses and various teaching opportunities, experiences supporting vulnerable, EJ and minority communities struggling with toxicant exposures across the world. We invite a wide-range of participation as EJ and chemical exposure concerns continue to grow worldwide targeting more and more vulnerable communities.

The symposium participants will showcase many approaches ranging from traditional academic courses such as graduate or undergraduate courses through health professional training opportunities to general community outreach and exposure prevention educational efforts. The main thread of all of the presentations will follow the focus on various and different gene-environment exposure science research.



## The Air Quality & Health Impact of Wildland Fires [79]

In this symposium, we invite abstracts leveraging interdisciplinary methodologies to explore the relationship between wildland fires, air quality deterioration, and associated health impacts. We seek research that utilizes advancements in remote sensing technology, atmospheric science and environmental epidemiology with implications or applications in the assessments of the air quality and health impact of wildland fires. We also welcome studies focused on the engagement with community partners, various stakeholders and decision makers.

Topics could include, but not limited to:

Efforts to link environmental and health data to advance research on the health impact of wildfires, new studies of wildland fires air quality (PM, organic compounds and precursors) relevant to public health assessments: novel atmospheric chemistry mechanisms specific to wildland fires, novel exposure assessment methods (machine learning, dynamic exposures, hyperlocal data), integration of low-cost sensor technologies and other open-source datasets for enhanced monitoring and analysis of wildland fire events, developments of wildland fires alert systems, or exploration of climate change's impact on the frequency and intensity of wildland fires.

## The Application of Big Data and Artificial Intelligence Technologies in Exposure Science [57]

The artificial intelligence (abbreviated as AI) technologies based on big data have provided a lot new thoughts for exposure science. By using these methods, the population-based refined exposure assessments can be realized, which contain general population and vulnerable population. In the various realm of exposure science, big data and AI have been widely applied, such as high-throughput omics technologies, exposome-wide association studies, machine learning and deep learning used in multiple exposure and interactions, exposure assessment of multiple emerging contaminants and computational toxicity. This symposium aims to discuss that how AI technologies promote the exposure science. Researchers who engage in interdisciplinary studies of artificial intelligence and environmental exposure and health are welcomed to participate, and submit presentations.

## The Cost of Beauty: Emerging Chemicals of Concern in Consumer Products and Their Health Effects [52]

Due to the success of scientific research, non-profit advocacy, and public health policy, many harmful chemicals are being phased out of consumer products, including some phthalates, sulfates, and parabens. Despite this marketplace progress, consumer products remain an important exposure source to hazardous chemicals. On average, a person uses between 12-25 personal care products alone per day, highlighting the importance of reducing chemical exposure from consumer products, particularly for people who identify as women. Further, products marketed to people of color contain a greater number of harmful chemicals and safer products are less available in low-income and minority communities. Many chemicals used in consumer products are established endocrine disruptors and have been associated with a wide range of hormonally dependent health endpoints, such as cancer, adverse pregnancy and birth outcomes, and decreased cognition in children. To protect susceptible populations, scientists, policymakers, and non-profit advocacy groups must work together to identify emerging hazardous chemicals in consumer products and potential health impacts.

This symposium will include abstracts that investigate emerging consumer product chemical exposures, including trends in chemical concentrations, biomarkers of consumer product chemicals, potential for disproportionate burden of consumer product exposure among individual groups, and/or the impact of these exposures on various health endpoints.

## The Great Indoors: Indoor Air Exposures and Impacts on Community Health [13]

Air quality insides homes, offices, and schools is an often overlooked issue for people all over the world, considering we spend an estimated 70% of our time indoors. While the COVID-19 pandemic has brought new public awareness to this issue with regards to infection, many may still be unaware of the health risks that arise from contaminant exposures in indoor spaces. Research in this area is vital to improving public health education and policy recommendations on these contaminants. The purpose of this symposium is to present current research on indoor air exposures, sources of contaminants, and associated health risks for communities.

## The Hidden Burden of Air Pollution Exposure: Investigating How PM2.5 and PM10 Shape Health in Urban and Rural Vulnerable groups [16]

**Objective:** To explore the hidden burden of air pollution exposure on the health of urban and rural vulnerable groups, especially those affected by PM2.5 and PM10 particulate matter. The symposium will facilitate a multidisciplinary dialogue and collaboration among researchers, practitioners, policymakers, and community stakeholders on the latest evidence, challenges, and opportunities in this critical area of public health and environmental justice.

**Format:** The symposium will consist of individual talks and a panel discussion, featuring prominent experts in the fields of environmental science, public health, medicine, and policy.

**Topics for discussion** will cover the origin and properties of PM2.5 and PM10, their health effects and mechanisms, their distribution and exposure patterns, their mitigation and prevention strategies, and their policy and ethical implications.

## The Impact of Chemical and Nonchemical Stressors on the Health of Vulnerable Populations [28]

Limited published data are currently available on the important chemical stressors (e.g., heavy metals, VOCs, and pesticides) and nonchemical stressors (e.g., sociodemographic and lifestyle) that can impact the health of vulnerable populations in their everyday environments. This symposium will feature research that improves our understanding of the important chemical and nonchemical stressors that substantially influence the health of vulnerable populations that have been historically under-represented (e.g., American Indian, Black, and Hispanic) or are currently under-represented (i.e., people with disabilities and LGBTQ+) in exposure sciences and environmental health. Examples include presentations on the potential health risks of school children with and without disabilities to air toxics from nearby potential pollution sources and estimated dietary intake rates among subsistence seafood consumers, an issue that impacts many indigenous communities.

## The road to the human exposome: Novel human biomonitoring markers, methods and metabolism data for determination of internal exposure [59]

To effectively monitor the exposure of the population to potentially harmful chemicals, human biomonitoring (HBM) needs to evolve constantly to keep up with the ever-changing chemicals market. New chemicals and substitutes appear rapidly in the environment and in humans after their introduction to the market. Hence, the HBM community is constantly challenged with finding novel biomarkers and developing methods for their detection. Methods have to be refined to cover a broader spectrum of analytes, lower concentrations or different matrices. Metabolism data have to be collected to correctly identify specific metabolites, pathways and excretion rates to enable the correct estimation and evaluation of the actual internal exposure of workers and the general population. For a comprehensive HBM system, new methods need to be implemented into existing HBM programs yielding data used by research, industry and authorities. Thus, current policy-relevant questions can be answered and potential health effects can be prevented.

In Germany, a cooperation between the German Environment Ministry (BMUV) and the German chemical industry association (VCI) was initiated to promote the development of new HBM methods and 33 new methods were developed so far.

The objectives of this symposium are to present i) the development of novel methods for biomarkers, for which no HBM method existed so far, ii) improvements of existing methods, e.g. inclusion of new biomarkers, determination of analytes in new matrices or with better sensitivity and selectivity, iii) novel biomarkers and metabolism data for current substances of concern and iv) application of new methods in HBM studies.

## The urban climate exposome: addressing the nexus between urban living, climate change and the human exposome [72]

The modern way of living related to urbanization results in complex exposures (including both chemical, physical, biological and psychological stressors) with cascade effects on public health. In order to capture exposures related to urban living, multiple activity sectors, such as industry and energy production, buildings & urban infrastructure, the food chain, waste management and transport, and their impact on the quality of the urban environment have to be considered. Human exposure to stressors linked to these activity sectors is influenced by the urban population activity and consumer patterns as well as socioeconomic status. Addressing these complex exposures and modifiers requires a broad array of technologies that involve advanced exposure modelling covering multiple pathways (indoor and outdoor air, diet and drinking water, use of consumer products), use of sensors, and methods to extrapolate individual exposure to the population scale, across the human life course. Behavioral aspects, which in turn are affected by the grey, green and blue infrastructure and sociodemographic characteristics, are equally important to both physical and mental health adversities and have always to be addressed in detail. In this sense, the following topics/presentations are proposed :

- Advances in urban exposome sensor technologies
- Dietary exposure related to the urban way of living
- Assessment of population complex exposures using agent-based modeling and machine learning
- Exposure to physical stressors (noise and artificial light) in urban environments
- Exposure to biological factors (allergens, viruses) and transmission dynamics in urban environments
- Citizen science and urban living labs in exploring the urban exposome for policy co-creation



## Unraveling the Complexity: Compound Climate Extremes in Vulnerable Populations [11]

In the dynamic landscape of climate change, vulnerable populations face an intricate web of challenges as various climate extremes converge, creating compound impacts that demand our urgent attention. This session aims to bridge the gap between climate science and public health by examining compound extremes through the lens of exposure science. From floods exacerbating contaminated sites to wildfires intensifying air quality risks, we will explore how vulnerable populations disproportionately bear the brunt of these compound events. Our focus extends to understanding exposure pathways, health impacts, and resilience-building strategies in the face of compound extremes. We invite researchers, practitioners, and advocates to submit abstracts exploring the diverse facets of compound extremes in vulnerable populations.

## Using Wastewater-based Epidemiology to Generate Inclusive Population-level Exposure Assessments to Inform Public Health Strategies in Support of Vulnerable Communities [60]

The field of wastewater-based epidemiology (WBE) is a rapidly evolving discipline that leverages community wastewater to generate population-level human health assessments indicative of behavior, activity, exposures, and health. This is accomplished by measuring excreted biomarkers in urine, feces, and other human fluids commonly found in wastewater. Given a collected sample typically represents a composited snapshot of community health that is anonymous, minimally invasive, and inclusive regardless of physical, social, or economic conditions, it has been proposed that WBE may be an important tool for reducing health disparities in vulnerable communities. WBE has historically been used to assess substance use, with a more recent focus on infectious diseases including COVID-19, influenza, mpox, and respiratory syncytial virus (RSV). The success of these applications illustrates a need to continue to diversify efforts to include: i) emerging and/or co-existing public health threats; ii) monitoring in low-resource settings; and iii) promoting interdisciplinary teams that honor community-engagement.

## Variation of Daily Lifestyle and Variation of Chemical/Biological Exposure in the Asian Countries/Region [27]

With regard to environmental issues and related exposure and health effects/risks to chemical and biological contaminants, etc., the substances to be evaluated, their concentrations and exposure levels, evaluation methods including feasibility, as well as daily lifestyle related to exposure, vary widely from country to country and region to region. However, the situation in each country and the challenges they face are not fully shared.

Focusing on the Asian region, this symposium aims to recognize the differences and diversity among countries and regions with regard to lifestyles, which are necessary when considering exposure assessment, and also with regard to exposure levels and exposure assessment methods. It also aims to obtain knowledge and basic information on how exposure assessment methods can be standardized and shared when countries and regions need to work together, mainly in addressing global issues related to these environmental problems.

## What's Missing from Pesticide Exposure Analysis? Capturing the Totality of Exposure and Effects of Emerging Pesticides [86]

Current national biomonitoring programs in the United States and the European Union typically evaluate exposure for approximately 30 pesticide analytes and parent compounds. Yet, the general population, as well as agricultural workers and communities, are exposed to far more pesticides than are currently monitored, depending on dietary, lifestyle and other factors. Hundreds of pesticides are approved for use internationally, and pesticide monitoring programs have detected hundreds of pesticides in the food supply that are not investigated in routine biomonitoring efforts. Use of non-targeted analytical methods in European populations has detected 40-70 different parent pesticides in human samples, the majority of which are excluded from national biomonitoring programs or rarely studied in epidemiological cohorts.

To fully capture the potential effects of pesticides on human health, comprehensive exposure assessment is needed, especially for vulnerable populations disproportionately exposed to environmental contaminants. This session will broadly explore emerging pesticides in the human population with a focus on characterizing the pesticide exposome through a variety of methods including non-targeted and suspect screening to address gaps in national biomonitoring programs. Other areas include targeted analysis of pesticides with insufficient exposure data, methods to prioritize pesticide exposure assessment based on emerging toxicological concerns, and efforts to estimate or predict exposure through additional pesticide data sources, such as food monitoring data coupled with dietary questionnaires, pesticide use information and residential proximity, as well as drinking water monitoring data. Investigations examining the associations of understudied pesticide exposures with adverse health effects are also welcome.

## Who is most vulnerable to air pollution-related COVID-19 outcomes? [39]

A growing body of evidence has reported associations between exposures to ambient air pollution and COVID-19-related outcomes. Most early studies on this topic were based on cross-sectional analyses or ecological study designs that were unable to describe individual-level risks. Moreover, their ability to identify people who were infected or seriously ill with COVID-19 was fraught with errors, such that the potential for biased results was high.

Knowledge gaps have remained due to heterogeneity in reported associations between exposure and outcomes, heterogeneity in exposure assessment, lack of results from multi-pollutant models, and limited reports seeking to identify the most vulnerable and susceptible populations using both multiplicative and additive scales for interaction.

Evidence is now available from large longitudinal studies, including some with rich, population-based, epidemiological datasets allowing for exploration of effect modification by sub-groups of the population. Recent studies have also included rigorous exposure models allowing for estimating short- and long-term exposures to multiple pollutants, and even biomarkers of air pollution exposure.