



2014 Environmental Health Summit

Exposure Science in the 21st Century: Role of Citizens and Communities

Representing Expert Discussions/Recommendations

Executive Summary

In November 2014, the Research Triangle Environmental Health Collaborative (EHC) convened its seventh annual summit on environmental health issues. EHC invited stakeholders with wide-ranging expertise to consider the challenges and opportunities for exposure science and community-engaged research, and to identify recommendations for the environmental health community to move forward deliberately and collaboratively.

Participants represented diverse perspectives within the field of exposure science, including local, state, and federal government officials, nongovernmental and community health advocates, private sector public health consultants, and academic researchers. Participants divided into working groups to delve further into the fields of data, technology, and risk communication. Five prominent recommendations emerged:

1 Academic institutions and government agencies have an opportunity to facilitate, strengthen, and build off of relationships with community stakeholders and industry representatives in order to share information and create innovative new technologies to assess existing and emerging threats and environmental justice issues.

2 Expedited assessment and mitigation of exposures could be addressed with web-based portals created and managed by data experts, where communities could contribute to data collection, learn about existing exposure data in clear terms,

and engage with researchers and engineers around study ideas and technologies.

3 Researchers and community members should work closely with industry and private companies to funnel ideas for technology development to the open market.

4 New technology for exposure science should be flexible and, at times, untargeted, in order to respond to changing knowledge about environmental stressors and risks. To respond to this, researchers should use a combination of approaches and analytical tools that offer a broad cover of analytical space rather than a few chemicals.

5 Academic and government researchers experienced in community-engaged research and citizen science should promote their experiences within the research community and build greater understanding of and support for such approaches. Such efforts would bring environmental justice issues into greater focus in exposure science.

Overview: Exposure Science in the 21st Century

Exposure Science

Exposure science represents a shift in paradigm of our understanding of how to measure exposures. Traditionally, “exposure” has been viewed as when a person has contact with a stressor. Scientists now view exposure as more complex and dynamic, influenced by factors such as genetics, lifestyle, and place. With this nuanced understanding emerges the need to assess multiple exposures integrated across scales of time, space, and biological organization.

The National Research Council (2012) report, *Exposure Science in the 21st Century: A Vision and a Strategy* provides a comprehensive review of exposure science and how the field proposes addressing human health and ecologic challenges. The report provides four key recommendations to the build capacity of 21st century exposure science.

1. Assess and mitigate exposures quickly in the face of emerging environmental health threats and natural and human caused disasters.
2. Predict and anticipate human and ecologic

exposures related to existing and emerging threats.

3. Customized solutions that are scaled to identified problems.

4. Engage stakeholders associated with the development, review, and use of exposure-science information, including regulatory and health agencies and groups that might be disproportionately affected by exposures.

The field of exposure science has greatly advanced due to paradigm changes concerning the nature of exposure; novel technologies to measure dynamic multiple exposures; an onslaught of data from public health and medical research, as well as from non-traditional sources; new and emerging methods to integrate data; increased support for the role of non-scientist communities in data collection; and greater emphasis on translation and communication of environmental health data for use at community, local, and state levels.

Community Engagement and Citizen Science

Engaging community members in the development of research questions, monitoring and data collection, and development of tools for risk communication and decision-making has been an important dimension of exposure science, especially in the context of environmental justice and health disparities. Both the process of investigating exposures and the research results can empower individuals, communities, researchers, healthcare professionals, and agencies to prevent and reduce exposures.

Community-engaged research is able to meet the rigors of science and advance environmental health and exposure science efforts by contributing real-time measurements over long periods of exposure across numerous locations, which researchers are limited in their ability to do alone.

Citizen science, while not a new concept, is gaining renewed interest in the federal government

as a way to involve the public in research as collaborators and contributors to scientific advancement and discovery. It is also seen as a way to “transform the way local knowledge is created, understood, and used.” Organized citizen scientists may work independently, or in partnership with a researcher or institution. Their motivations for being involved in the science may differ from those of the academic researchers.

In the context of environmental health sciences, environmental justice, and health disparities, community residents want to understand what they are exposed to, if the exposures pose a risk, and what can be done personally – as well as by society – to reduce, mitigate, or prevent continued exposure. The exposure science field welcomes this form of research and understands how mutually-beneficial partnerships can be established and strengthened.

Summit Findings and Recommendations

Cross-Cutting Issues

While each working group (Technology, Data, and Risk Communication) discussed issues specific to their area within exposure science, certain themes emerged in all three discussions, with each working group lending their perspectives.

Fit-for-Purpose Research

All working groups discussed the application of the fit-for-purpose principle in their respective fields. In technology, this means that a tool or platform is not only effective at measuring the data of interest, but that it is also appropriate for the context in which it will be used. For example, engineers may make a less complex technology in order to increase ease-of-use or decrease cost, allowing it to be used more often by citizen scientists over a longer term to collect rich, long-term data on chronic exposure. In data collection, fit-for-purpose could mean designing a data storage platform that offers simplified, non-technical explanations in order for non-scientists to understand the data presented. In risk communication, a fit-for-purpose strategy means working with key informants from a community of interest to design an outreach and education campaign that is tailored to the community's knowledge and information needs and available outlets.

Developing Web-Based Platforms for Community Involvement

All working groups discussed ideas for web-based portals for communities to contribute to data collection, to learn about existing exposure data in clear terms, and to engage with researchers and engineers around study ideas and technology. The working groups acknowledged the advancements in technology that have contributed to furthering the role of community-engaged research in

exposure science. All working groups agreed that further web-based data collection and data-sharing portals have the potential to increase public understanding of exposure and further community-researcher partnerships.

Inclusion of Community Stakeholders

Community participation in exposure science is more valuable than ever, yet there is the need to learn from the 20 years of community-engaged and community-led environmental health research efforts in North Carolina and across the United States. The working groups discussed way in which community-engaged research and citizen science enable individual community members to contribute to data collection, technology development, and risk communication. Additionally, the working groups emphasized the need for community stakeholders to participate in exposure science as partners rather than as subjects. Plus, communities and tribal groups seek "citizen science" that support legal assurance, compliance, and enforcement.

Timely and Clear Exposure Data Communication

All working groups agreed on the important ability of community stakeholders to access exposure science data quickly (this includes both existing data and data generated by citizen science projects). They also underscored the importance of clear language in data reporting. Timely data access will enable communities to better respond to exposures without needing to wait for publications. The working groups also agreed that in new studies, the anticipated uses of data by scientists and community stakeholders should be outlined clearly at the outset, and that such uses should contribute to the methods of data collection, the technology that will be used, and the plan for dissemination.

Technology Working Group

The purpose of this working group was to explore technologies to assess exposure in communities, as well as discuss possible

technology that could be developed in the future, and to develop a census of useful tools currently available.

Barriers and Recommendations

Information Exchange

Citizens have concerns about their exposures, researchers have exposure data, and engineers have measurement technology. Yet researchers, engineers, and community stakeholders have limited opportunities to communicate and collaborate on environmental health exposure data and measurement tools. While many communities would like to learn more about an exposure, or engage in their own citizen science work, it's often unclear where they should begin. Likewise, researchers often do not know how to approach communities to engage in community-based exposure science research.

The working group discussed the need for a venue to drive communication between researchers and communities about technologies to assess exposure. In library sciences, information is stored in clearinghouses, put into web portals, and organized for different interests. A similar system for data and data collection technology would be useful. In this system, community members could express their concern about an exposure, reach a researcher or engineer, and find existing data to address their concerns, or find appropriate technology to embark on citizen science research. This information exchange would build necessary relationships between stakeholders, engineers, and researchers in order to strengthen the field of exposure science and support community-engaged research.

This process should match the fit-for-purpose to identify gaps in existing technologies suggested by community stakeholders and researchers, to develop innovative new tools, deploying them in exposure studies, and preparing future responses.

Recommendations

- The creation of a new clearinghouse of data measurement and analysis tools that could be accessible to communities. Community stakeholders could visit this venue (which would likely take the form of a website) and request data or ideas for measurement tools based on an exposure that causes a public health concern. This clearinghouse would be a source of

information for new technological developments as well as existing technologies.

- Community stakeholders should be involved in the creation and operations of this clearinghouse to ensure its accessibility and ability to meet the needs of diverse communities, health issues, and exposure pathways. The clearinghouse would be the product of multi-directional communication and information from communities, researchers, and engineers.
- The funding for this endeavor could come from federal agencies, foundations committed to supporting citizen science and public health research innovation, grassroots supporters, and/or companies (in particular, large corporations with interests in data innovation, public health, and community-engaged research).
- The infrastructure for this clearing house to respond to users' research needs should not be too limiting or specific, as responses are often situational-dependent (disaster response, in particular, is dictated by the specific situation). This center should be able to suggest recommendations for different exposure issues.
 - When creating a platform for response infrastructure, developers must consider the input process (when users want to find technology, they enter what they want to understand as well as the intended purpose of the data) the output process (considering not only what technology is available, but which tools are fit for purpose and cost-appropriate, and explaining sensitivity and specificity of different tools).
 - Within the clearinghouse, establish a center for prototype devices for use when necessary. This will allow researchers and citizen scientists to use up-and-coming technologies and contribute to their evidence-base and value.
- Measure the value of this infrastructure by communities' use of it, and continue to involve

stakeholders in the process of developing and revising this platform.

- Community stakeholders and citizen scientists should receive thorough training in how to use research technology to ensure their safety as well as the quality and consistency of the data.

Technology Development

Technology will continue to evolve to meet the needs of the scientific community, but it must also be responsive to the needs of community stakeholders and citizen scientists. The group proposed a framework for this procedure, called the sensor technology paradigm, wherein sensor technology development is an iterative collaboration between community members (who express a need, as well as validate and use the tool) and researchers (who work with community members to create the tool).

Technology development in this arena requires the engineering community to identify current exposure and citizen science needs (responsive approach) and future needs (proactive approach). Some examples of current and future needs in technology for community-engaged research and citizen science include low-volume or non-invasive measurements for biological analysis; tools that allow for analysis of multiple exposure; higher sensitivity; lower costs; and tools have increased usability for a citizen scientist; and tools that can measure chronic exposures over longer periods of time.

Recommendations

- Researchers' should seek input from communities to identify issues and gaps in technology. Working closely with industry and private companies can serve to funnel ideas to the open market. When developing exposure assessment tools for researchers and citizen scientists, technology engineers must consider the principle of fit-for-purpose to create technology that is able to address a need. Engineers should continue integrating advanced sensors into research grade exposure assessment devices. Engineers must also consider the ease of use for the citizen scientist,

as well as the cost and value of the data for their purpose.

- In considering fit-for-purpose, engineers should design technology where data collection meets the need of the user (informative data for a citizen scientist or defensible data for a researcher maintains privacy of participants), produces valuable data that can be shared, and uses a common data model.
- Engineers should design technology so that the cost is accessible to community groups. Cost is affected by the ease of manufacturing and use (to save costs of training) while still producing high-quality data. The instrument could be a simplified version of a research grade technology or an independently designed instrument.
- Engineers should consider the following issues in a new technology's functionality: the ability to collect multiple-exposure data in real time; sensitivity and reliability of data; use in real-world situations; sensors for broad chemicals; results that are high-quality and can be validated; and the distance at which the tool must be from the source of the chemical (to protect the safety of its users).
- Engineers should consider the following aspects of ensuring a technology is easy to use: level of maintenance and protection from adulteration; calibration of results; safety of use; warning signals; the flexibility and transferability of its data; and any necessary training procedures.
- New technology should be flexible and, at times, untargeted, as researchers may be mistaken in their original hypothesis on stressors of concern. To respond to this, researchers should use a combination of approaches, such as integrated biomonitoring and physiological monitoring (e.g. spirometry), or tools that offer a broad cover of analytical space rather than a few chemicals.

The group discussed the landscape of data collection strategies that can be used for understanding and communicating risk, including sensors, direct surveys, repurposing existing data for multiple uses, probabilistic sampling and convenience sampling methods, and predictive modeling. Concerns about these methods include feasibility of costs, technology, and utility for public health protection. The group considered new ways to look at data management and sharing for engaging communities in exposure science. The group recommends that scientists shift their philosophy from managing risks to managing for sustainability (environmental, but also social and economic), as well as from disease prevention to health management.

Barriers and Recommendations *Researchers' Experiences*

The ultimate use and purpose of the data determine the structure of a study, but often the communities who serve as participants are not included in the study formulation. Researchers who have not been trained to involve communities often don't understand the value of their involvement or know how to work with them. Communities want to know about their potential exposure, and often they want to use study results to remediate the source of exposure. Community stakeholders and citizen scientists should be involved from the inception of a study: from defining the problem and scope, all the way throughout the process, providing expertise, collecting data, and offering feedback on the results.

Recommendations

- Scientists should be willing to share the power to create knowledge and address toxic exposure with the communities most affected. This means inviting community members to develop research questions, data collection strategies, and new technologies. It also means acknowledging the contribution of community members in publications and other outlets. Researchers should embrace power-sharing

with communities as a means of education and empowerment that furthers efforts to address environmental justice issues. Researchers should view community members as a vital part of their research process as partners rather than subjects.

- Researchers should reach all relevant community members, not only leaders or easy-to-reach groups. Collaboration only with prominent leaders or the most outspoken members may limit researchers' ability to connect and involve the rest of the community. However, well-trusted community leaders should be included in research-development process, especially when navigating different cultures, historic/social context, or ethical issues related to the research.
- In order to better understand a community's context, networks, and authority figures, researchers can invite community partners to map their community and train the researchers in important nuances. This can help identify power structures and leadership and eliminate redundancies in communication and outreach.
- Researchers and community partners and/or citizen scientists should create memorandums of agreements (MOAs) to outline roles and responsibilities before research begins. Clear and established roles and protocol can build trust and confidence among parties. MOAs can include a plan for sharing data among stakeholders.
- Researchers should identify and use technology that is fit-for-purpose, which can provide high usability and accurate data monitoring to ensure quality. Researchers should use this technology to convey their data to the community quickly and clearly (i.e. in common language, and with visual tools) in order to keep community members' trust and interest in the process.

Model for Data Integration Platform

The group identified the need for data integration from disparate sources. The current gaps in integration (particularly from different technologies across the sciences) stymie potential advancements in exposure science by limiting the ability of community-engaged research and citizen science studies to contribute to the broader field of knowledge. Integrated data streams can increase the utility of existing data to meet different needs.

Community members and citizen scientists should be able to access large, well-organized data to meet their interests and purposes through a new platform for data integration and exchange. This data integration model would take into account various types of studies, as well as non-traditional and alternative sources of data (e.g. data from social media, private companies, crowdsourcing, and qualitatively-derived information).

Recommendation

- A data integration platform should include information from sensors and other collection methods, as well as plain-language interpretation of the results and significance of the data.
 - This process should be standardized on one platform, transparent, highly visual, and written in common language accessible to non-scientists. Additionally, there should be some simple metric for understanding the quality of different data. This could, for example, be visual, numeric, color-coded in its description of the validity of the results and study design.
 - This data integration platform should take into account issues of privacy and ethics by not revealing personal data about study participants, as well as by revealing the financial interests of studies and data.
 - This platform should entail a set of standards that maximizes interoperability, i.e. a common language that allows data systems to communicate with each other, and allow for users to compare data across studies.

Multi-Lateral Partnerships

Exposure science data collection is limited by the perspectives and technology of the people who currently conduct it. In order to acquire, integrate, draw conclusions from exposure science data, researchers need to build partnerships across sectors. It is the belief of the working group that these partnerships can spur innovative new technologies, accumulate vast amounts of public health-related data, and provide new analytical tools for action.

Recommendations

- Develop strategic partnerships that seek mutual or multi-directional interests.
 - Researchers should investigate building relationships with groups such as AARP, and companies such as Amazon and Google.
 - Researchers should explore how to work with local and state divisions of public health to integrate exposure and citizen science information into community health assessments.
 - In order to identify potential partners in communities and community-based organizations, researchers should work with community leaders to map social and power structures to better understand the context.
 - Researchers and engineers should identify necessary agreements/contracts to cultivate positive, trusting, and fruitful relationships with partners. In particular, all parties must agree on expectations and procedures for data sharing from the onset of the research.
 - Researchers, engineers, community-based organizations, and citizen scientists should convene forums on exposure science to discuss ways in which citizen science data can be integrated and contribute to this field.

Before discussing barriers and recommendations, the group discussed the definition of environmental health risk communication. The group decided on the definition “The exchange of ideas and information that enables ‘stakeholders’ (all of us) to make decisions that affect our health, and to engage in collaborative problem-solving.” This definition represents the iterative nature of this work, with a mutual exchange of information and skills from researchers and community groups/citizen scientists. Additionally, this definition takes into account the end goal of the work: knowledge for action – the action of changing behavior to prevent exposure to toxicants, or action to remediate the exposure if prevention is not possible.

Barriers and Recommendations

Policy, Politics, and Competing Interests

Policies, politics, and competing interests all create barriers to researchers engaging communities in exposure science. Policies can be defined as any principal or structure adopted by an institution. An example of a policy that restricts community-engaged exposure science is limitations (of funding, as well as culturally) on activities by federal and state employees that may seem advocacy-oriented. Politics are defined as activities associated with governance of an area, as well as dynamics among members of a community (geographical, cultural, institutional, etc.). Politics and power relationships can influence interests, priorities, and funding in institutions, as well as dynamics of organization and trust in communities. Competing interests can hinder citizen science and community-engaged exposure science when researchers’ and communities’ priorities are misaligned. A common example is when a researcher may only be interested in examining and revealing an exposure, while a community may expect the researchers to play a larger role in solving the problem causing the exposure.

Recommendations

- Researchers should strive to engage all relevant community members in the process of scoping a research project, collecting and analyzing data, and deciding what to do with the finished data product. The following activities have shown to be effective ways to engage varied stakeholders.
 - Make it easy for community members to connect with participating researchers by creating a fact sheet or web site that identifies who they can contact for assistance to understand and address a potential exposure to environmental toxicants in their community.
 - Researchers and their community partners should develop MOAs that clearly outline roles and responsibilities to avoid conflicting priorities. In particular, researchers and community partners/citizen scientists should discuss goals for the data and outline the process for sharing and publishing.
 - When not currently included, environmental health questions should be incorporated into county Community Health Assessments led by local divisions of public health. Environmental exposure questions can be included to understand large-scale community exposures, understand community priorities around environmental exposures, assess the community’s available resources to address these issues, and make environmental exposure issues a priority to local government agencies.
- Community-based researchers should consider the value of Community IRBs, which include guidelines for community researchers around privacy, disclosure, and informed consent of research participants, in order to protect the privacy of participants and ensure they are fully aware of the intentions of the research.

- University researchers, agency staff, or experienced community groups could create community IRB trainings and templates for newer community partners.

guidelines should be institutionalized in IRB and CITI training.

Trust

Trust is vital to community-engaged research, especially when addressing environmental justice issues or working with vulnerable groups. Both researchers and members of the communities they work with can experience lack of trust as a barrier to their work. Common issues of trust identified by the working group include accessibility of information by community and researchers; inappropriate data collection strategies; issues of informed consent and privacy; ownership of the data and intentions for use; return of results; a history of negative relationships between the community and researchers or a research institution; current or historical political/social context of the community and research institution.

Recommendations

- Information about the research goals and objectives, data collection strategies, and intent for data should be decided by researchers in partnership with their community collaborators and study participants.
 - Individuals in positions to communicate environmental health risk to communities should receive training and resources to ensure adequate, clear, and respectful dialogue when explaining the results of exposure research.
 - The research community should create a more ethical framework, with standards and guidelines, for researchers' interactions with community research partners and stakeholders.
 - However, this should not take the form of a one-size-fits-all model: researchers must develop this framework and standards while remaining flexible to the context of communities and the specifics of different research projects. These standards/

- Academic and government researchers who are experienced in community-based participatory research, citizen science or other models of engaged research (such as community-owned and -managed research, COMR) should promote their experiences within the research community and build greater understanding of and support for such approaches. Such efforts would bring environmental justice issues into greater focus in exposure science.

- Academic and government researchers should support the use of and training for community-engaged research approaches.
- Non-governmental organizations addressing environmental justice and other environmental health issues are in a position to share lessons learned with other community stakeholders and researchers. Participants recommended creating a national network of such organizations who could prepare others to effectively engage with researchers.

- Researchers should share tools with communities and help to build community capacity to conduct citizen science that will be accepted by regulatory and legal agencies.
 - Areas of capacity-building identified by the group included informed consent, privacy and protections of study participants, data collection and analysis methods. These areas can help ensure that citizen science is perceived as valid, credible, and more likely to be accepted by regulatory agencies, legal agencies, the research community, and publications. However, these capacity-building efforts must not inhibit community innovation and approaches. Instead, they should complement the goals of the community. Additionally, researchers and policy makers should work with community members who have led

successful citizen science projects and legal campaigns to remediate pollution to create a guide to best practices for citizen science that can be shared with community stakeholders as well as policymakers, regulators, and other researchers.

Data Quality and Translation

Environmental health data can be complex, and researchers often struggle to translate their data (including issues of scientific certainty and probability) into meaningful, clear information for lay audiences. Uncertainty in exposure science presents an additional challenge for community partners hoping to apply findings to specific real-world decisions or situations. Confusing or unfamiliar terminology, inaccessible data, and uncertainty can all contribute to distrust in researchers.

Furthermore, there needs to be a greater understanding of what “adequate data” means for different groups. For example, government agencies require data of a certain level to create new regulations for previously un-monitored pollutants, or to take action against polluters who are not complying with existing regulations. State regulating agencies and legal agencies require rigorous data for regulations. Addressing issues of data quality and limitations of monitoring tools can help to build trust between communities and researchers, and enable communities to generate and translate data that can be used for public health improvement.

Recommendations

- Researchers should adopt or be trained to use a range of approaches to manage data quality and present their data (and concepts of probability, risk, uncertainty of exposures) to community stakeholders in a culturally-appropriate way.
 - They should work with community partners and citizen scientists to understand existing environmental health knowledge and perceptions, translate the data into common vernacular, and test messaging for understanding before presenting data to multiple stakeholders.

- Websites that provide exposure information should be publicly accessible, location-specific, and user-friendly.
- Researchers should consider creating public reports on environmental exposure research, distilling their findings into a common-language abstract, videos, infographics, and other communication tools that can reach non-scientific audiences, advocacy groups, elected officials and regulators.

Environmental Health Literacy

As described at the NIEHS Partnerships for Environmental Public Health (PEPH) meeting in September 2014, environmental health literacy (EHL) is the understanding of the link between environmental exposures and health. There are many levels of EHL attainment that may inform and stimulate action. Understanding the environmental health literacy level of all partners plays an important role in risk communication.

Recommendations

- Efforts should be made to assess and address EHL of all partners – especially among non-traditional partners – allowing for targeted training and educational materials can be developed for varied audiences.
 - Improved understanding of environmental health literacy levels among decision makers would help researchers and community stakeholders to communicate more effectively about exposure science.
 - Environmental health professionals should make the effort to train local government officials (especially newly-elected) about environmental exposures and health, and on their responsibilities to protect communities from environmental health risks and exposures.
 - Healthcare professionals (clinicians, nurses, pediatricians) could benefit from training to build their EHL. Including environmental health information in a regular patient visit could help them to deliver tailored information on patient

exposure and risk.

- Exposure scientists should include city and regional planners and other public health partners involved in infrastructure building, maintenance, and compliance in their work. These groups are often involved with environmental remediation and exposure, and can provide valuable insight into data collection methods, as well as how to use data to address environmental exposure.

Social and Scientific Complexity

The social complexity of communities is often a barrier for researchers. Community-engaged research approaches take time and require honest dialogue, ultimately enabling researchers to identify, understand, and respect the sensitive issues that make up the context of the community (e.g. institutionalized racism, segregation, political disorganization, or a history of community organization that the researcher is unaware of). Community-engaged research approaches validate the skills and knowledge of the local residents.

The working group recommends researchers seek to understand the historic and current context and dynamics of communities, identify and acknowledge their skills and knowledge, while also increasing their partner communities' environmental health literacy. Additionally, the group recommends researchers involve community members and other health communication/behavior experts in the design of their studies and also in communicating risk data to the stakeholders.

Recommendations

- In communicating complex risk information, scientists should consider fit-for-purpose by allowing key stakeholders from the community to drive the communication strategy. Scientists should tailor their messages and formats to the community.
 - Some ideas for this include seeking to understand stakeholders' existing knowledge of relevant environmental

health concepts; testing outreach formats and messages with key informants from the community; allowing key informants to devise the outreach and communication strategy.

- Communities and community-based organizations have been creating and receiving exposure data and addressing environmental justice issues in their communities for over 20 years. Academic institutions and government agencies can support these efforts by supporting opportunities for communities and community-based organizations (e.g., NC Environmental Justice Network,) to exchange ideas, best practices, and past actions around risk communication, use of data, and environmental remediation.
- Risk communicators should identify existing models of health education/communication that can be adapted to exposure science. Environmental scientists should collaborate with health behaviorists, health educators, community health advisors, and community leaders to better understand effective environmental health messaging, as well as theories and frameworks of behavior change that can strengthen risk communication.
 - Exposure scientists should take lessons from crisis management, medical triage, and other "crisis disciplines" to understand ways to communicate scientific findings without perfect information. Often, scientists will have enough information to make a judgment about potential safety, but they will wait to inform people, hoping for perfect information, which is unattainable. It is important for stakeholders to be able to understand and respond to risks to which they are exposed, and such decisions must be made even when the information is incomplete.
 - As part of federal grant support, exposure scientists should be required to receive training on risk/health communication and health education.

Plenary and Panel Presentations: Day 1

William Ross (Co-Chair of The Collaborative at Duke University's Nicholas School of the Environment) and **Jennifer Orme-Zavaleta** (US EPA, Office of Research and Development) offered opening remarks and began the summit.

Before separating into context-specific working groups, participants convened for

plenary and panel presentations from experts in the field of exposure science. The content of these presentations provided perspectives of government, academia, and community organizations, raising salient themes that would continue to emerge in discussions throughout the conference.

Exposure Science in the 21st Century

Exposure science seeks to measure every exposure we experience and understand how these exposures affect our health and environment. In order to accomplish this goal, new technologies and data management tools must be created. Of equal importance is the cultivation of public trust of this work in order to engage communities not

as "subjects," but as collaborators in research. Additionally, agencies should not only reach out to communities about research, but to educate the research community about the importance of involving communities as collaborators in the research process.

North Carolina Perspective on Citizen Science Panel

Moderated by **Aubrey Miller**, of the National Institute of Environmental Health Sciences, this panel discussion expanded on the ways community members can contribute to exposure science research in the state. When scientific researchers respond to communities' concerns, though well-meaning and eager, they are often unable determine level of risk, leaving the community with more questions than answers. Researchers can improve how they communicate their data to community groups by translating highly-technical work into plain-

text when possible. Local governments are often responsible for a wide range of decisions related to the environment and human health in their communities. It's important that researchers communicate their findings and recommendations to local government officials in plain-text, and in ways that can enhance decision-making on policy. Researchers should be willing to share risk data with local communities and local governments in order to secure their trust in the research process and be able to take action on pressing health issues.

Citizen Science in Action Panel

Liam O'Fallon, of NIEHS, moderated this panel, which discussed the possibilities for community-engaged and -led research in the field of exposure science. The panel emphasized the importance of using research tools that are appropriate for including community members to participate as citizen scientists. The panel talked specifically about biomonitoring devices

to understand what happens to people who are exposed to harmful chemicals. This can be done by creating passive sampling tools (such as the air pollution monitoring wristbands created by Oregon State University), or hiring trained community members as research staff involved in data collection. The panel also emphasized the need for researchers to quickly report their find-

ings back to the participants and their community partners, rather than waiting for the study to be published. An effective way for this to be done is through educational workshops, where communities are not only informed of their risk,

but also educated about research methods and how to understand complex data. In this process, community members become the experts on environmental health in their communities and can advocate for changes.

Setting the Stage Panel

This panel, moderated by **Hal Zenick**, of the US Environmental Protection Agency, discussed the challenges of measuring exposure and risk. Major advancements in data collection and management technology have contributed to an unprecedented era for seamless sharing of exposure data across federal and state agencies. Despite advancements in technology, the large quantity of data proves to be a challenge for management and analysis. Additionally, increased volumes of accessible data have shifted the paradigm of science by giving citizens a greater role in data collection. The panel acknowledged that citizen science presents a valuable opportunity to track exposure data over longer terms. However, researchers can't ignore communities' need for quick, understandable information about

their exposure. The urge to publish findings in scientific literature is a crucial component of research, but can't be the ultimate goal of exposure science. A translational component of this work is invaluable, and researchers must bring their exposure information to the intended audience. Changes in media infrastructure (e.g. social media) grant scientists with new opportunities for communicating research with people. However, quick communication through media cannot substitute for building relationships with vulnerable communities. First, this builds trust in the information scientists hope to share. Second, this allows researchers to develop risk communication strategies and messages that are tailored to their target audience.

Plenary and Panel Presentations: Day 2

NIEHS: Where Exposure Science and Citizen Science Meet

Rick Woychik, Deputy Director of NIEHS, discussed NIEHS' strategic plan for interdisciplinary exposure science research. He introduced the concept of predictive toxicology, calling for more testing of chemicals before they enter the market. He explained the Tox-21 initiative to promote better understanding of toxicology by measuring the deleterious effects of chemicals on the market. Along with Tox-21, NIEHS is working to share environmental health risk information to the public before people enter toxic situations to help people limit their exposure. Within NIEHS research, communities

are often equitable partners, submitting grants and sub-contracting with investigators.

Of central interest to NIEHS's exposure science work is studying the exposome: the accumulation of everything humans are exposed to – not just chemical agents, but drugs, diet, and other lifestyle choices. One way NIEHS is examining this field is by working with gene sequences to understand how people respond differently to the environment. Another way NIEHS furthers knowledge of the exposome is through their work in data integration and knowledge management.

Steven Patierno, Deputy Director of the Duke Cancer Institute at Duke University, began his plenary by reflecting on the reality of environmental-health disparities in incidence and mortality among racially- and ethnically-diverse minorities and the medically-vulnerable and underserved populations. He explained that different levels of exposure influence somatic and inherited genomes, which is influenced by the individual's biological macro-environment, the individual's lifestyle choices, and the individual's macro-environment. Individual choices (e.g. diet, exercise, smoking) and the individual's macro-environment are affected by social relationships, networks, physical context, institutions, and social conditions. Within this framework, Patierno explained, researchers can identify at what points of exposure intervene: risk assessment, detection,

diagnosis, and/or treatment phases.

However, Patierno explained, environmental health faces an important issue: the exposure biology gap where exposure is connected to risk for disease. Exposure does not always result in disease, and researchers must continue to explore this relationship. Lifetime monitoring of the exposome coupled with personalized genomics monitoring could help answer whether an exposure actually causes a change in a cell that predetermines that cell to cause a disease, and how lifestyle and social factors affect this change. With this sophisticated understanding, exposure science research can contribute to understanding and solving health disparities, some of which may be attributable to the interplay of biology, genetics, environment, and lifestyle choices.

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