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Community-level exposomics: a population-centered approach to address public health concerns

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Abstract

Environmental factors affecting health and vulnerability far outweigh genetics in accounting for disparities in health status and longevity in US communities. The concept of the exposome, the totality of exposure from conception onwards, provides a paradigm for researchers to investigate

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the complex role of the environment on the health of individuals. We propose a complementary framework, community-level exposomics, for population-level exposome assessment. The goal is to bring the exposome paradigm to research and practice on the health of populations, defined by various axes including geographic, social, and occupational. This framework includes the integration of community-level measures of the built, natural and social environments, environmental pollution-derived from conventional and community science approaches, internal markers of exposure that can be measured at the population-level and early responses associated with health status that can be tracked using population-based monitoring. Primary challenges to the implementation of the proposed framework include needed advancements in population-level measurement, lack of existing models with the capability to produce interpretable and actionable evidence and the ethical considerations of labeling geographically-bound populations by exposomic profiles. To address these challenges, we propose a set of recommendations that begin with greater engagement with and empowerment of affected communities and targeted investment in community-based solutions. Applications to urban settings and disaster epidemiology are discussed as examples for implementation.

Keywords

community; environmental justice; public health exposome (PHE) framework; Big Data to Knowledge (BD2K) analytics; Justice 40 initiative (J40); transformative community engagement frameworks

Introduction

The exposome concept was originally proposed within a human context borne out of epidemiology,[1,2] but its value across all species has quickly become evident. It stands as the perfect foil to the genome and genomics, by providing a complementary and similarly comprehensive analysis of the non-genomic drivers of biology that affect the population as well as the individual. Exposomics is emerging as a thriving area of research that helps to explain the impact of environmental exposures and how they affect all species in our biosphere: humans, animals, and plants.[2-8] *Exposomics is the process of collecting comprehensive and systematic data on environmental exposures and evaluating how they impact biology across anorganism's lifespan*.[1,9,10] A number of EU-funded initiatives have spurred exposomics research, such as the European Human Exposome Network (EHEN).[11] In the US, the National Institute of Environmental Health Sciences (NIEHS) has led the push for greater implementation of the exposome, sponsoring multiple workshops, research and training initiatives.[12,13] During the most recent NIEHS-sponsored Exposomics summit in 2022, multiple environmental health researchers and practitioners met to discuss moving the field from theoretical discussion to practical implementation.[14] One key theme that emerged was the need for a broadening of our appreciation of the exposome, from the totality of exposure experienced by an individual to the multitude of exposures experienced by communities and the population-level health consequences.

The explosive growth in the synthesis and use of chemicals[15] combined with changes in climate manifested as extreme heat, drought, wildfires,[16] hurricanes, tornados, and flooding hazards,[17,18] increases in urban population,[19,20] and disruptive pandemics[21] are all creating new stress modalities that need urgent solutions—solutions that are community-based rather than solely being targeted at the individual.[22,23] Multi-factorial exposures associated with natural, built, social and digital environments are impacting the biosphere with effects ranging from adverse health outcomes to lower quality of life.[24] Effective application of *exposomics* at the community-level provides the ability to accurately measure and model exposures in real time to connect them to altered biological endpoints and rapidly develop mitigation methods. With this knowledge, it becomes possible to develop targeted public health interventions, including policies that improve the environment and stimulate behavioral changes through social outreach, implementation science and connected communities.

Community can be defined across a number of different axes, including by geographic, social and occupational factors. In 2014, Goodman et al provided a broad definition of community for the purposes of defining community health that incorporated "venues or areas that are physically-, geographically-, culturally-, and administratively- or geopolitically-defined" with standard definitions that included social ties and geography.[25] For the purposes of community-level exposomics, we take a similarly broad view of community and recognize the value that integrating a multi-domain view of exposure, as promoted by the exposome paradigm, can bring to diverse contexts. The specific definition of community will depend upon the public health context. In some instances, the community may be defined by characteristics such as geography or cultural heritage, as in the example of work in the Houston-Galveston-Brazoria Region[26] or in Atlanta.[27] In others, the community may be defined by a shared exposure history or profession, such as in the C8 Health Project[28] or in biomonitoring applications,[29,30] respectively. The unifying feature is the consideration of the population-level exposures and health effects, rather than focusing only at the individual-level.

It is important to recognize that community-level exposomics is not equivalent to biomonitoring. Biomonitoring is an important tool for assessing the adverse impacts of toxic agents in communities; however, it is a targeted, resource-intensive, and time-consuming tool. Semi-targeted (translational sciences, such as key characteristics, mode of action, and adverse outcome pathways) and non-targeted approaches (exposomics, -omics platforms and machine readable "big data") coupled with what we know from targeted approaches is the future we need to realize in order to address the cumulative impacts of the complex, multi-chemical, built, and natural environments in which we live.[31] Community-level exposomics is, therefore, different from individual exposomics because of the scale and complexity. Individual exposomics can change over time for many reasons such as diet, aging and location. Community-level exposomics includes individual exposomics, but extends to account for the context of populations in their multi-chemical and non-chemical stressors in the built, and natural environment as framed by the global dimensions of time and space.[31,32] With community-level exposomics, it becomes possible to define communities by their shared exposure patterns and intensities, enabling complex analyses that exploit smaller within-community exposure variance than that encountered between communities. Previous examples from the environmental health literature, including the C8 Health

Project,[28] illustrate how communities consisting of diverse individuals can mobilize around a shared pattern of environmental exposures.

This commentary proposes a framework of community-level exposomics, defined as exposomal assessment of the shared environment at the community-level. We describe the need to prioritize community needs, incorporating best practices from existing approaches such as community-based participatory research and environmental justice. We will describe the measurement and modeling needs that are specific to community-level exposomics and highlight illustrative examples from urban settings and disaster epidemiology. Throughout, we propose recommendations that begin with greater engagement with and empowerment of affected communities and targeted investment in community-based solutions.

The need for applied exposomics at the community-level

Even though the concept of exposomics as a science is new and less studied, the application of exposure assessment and environmental epidemiology to understand community-level human health impacts has a long history.[7,33] Disparate disease prevalence caused by various pollutants such as arsenic, tobacco, nutritional imbalances, and air pollution are just a few examples where identified adverse causality led to mitigation. However, many of these successes have resulted from *reactive science* and were conducted after the effects had been observed in large populations. The science of exposomics provides us with a critical and evaluative avenue to study exposure and its effects on communities as a *proactive science*, centering discovery and untargeted approaches.

Personalized medicine is often cited as the long-term benefit of exposomics.[34] Similarly, we argue that precision public health[35] and personalized prevention[36,37] are the ultimate goals of the community-level exposomics framework. Greater knowledge of the exposures that influence population health can lead to novel interventions and prevention efforts. Similar to the observations of Rose that causes of cases are not the same as causes of incidence,[38] we highlight that factors leading to health disparities and unequal environmental burdens cannot be found by looking solely at exposomic signatures of individuals. Instead, approaches that seek to measure and quantify risk at the community-level can drive needed change. Both regulatory and public health efforts occur at the community-level and require evidence that characterizes community-level exposures and associated health outcomes. As argued by Senier et al., exposome research should not be merely an inventory of multiple exposures affecting an individual, but should incorporate the contextual drivers of exposure patterns in order to fuel population-level prevention and mitigation efforts.[39] In addition, our society faces a number of multifactor stressors such as climate change, and associated wildfires, floods, and pandemics that exert their influence at the community-level, not just on the individual.[40]

Community-level exposomics is a necessary complement to the more typical individual-level exposome investigations. A goal of exposomic research is the generation of knowledge that enables the primary prevention of disease and the propagation of health and well-being. This necessitates approaches that investigate multiple exposures. Similarly, there is a growing recognition in the field of regulatory toxicology that the traditional risk assessment paradigm has shortcomings in application to the multiple exposures people experience in everyday life. System biology approaches will be useful to address the challenges of moving forward toward next generation risk assessment, such as cumulative risk assessments.[31] However, the knowledge needed to prevent disease and advance health is not limited to only the biochemical and physiological responses to multiple environmental exposures but also the pattern and impact of multiple exposures across populations over time with varying vulnerabilities. The understanding of how exposures affect populations is built upon the etiologic knowledge generated by individual-level investigations, while the public health consequences of exposure are well characterized through community-level investigations. Together, these investigations generate the causal inference needed to implement solutions and reduce adverse health outcomes. To meet these goals, exposomic research must also incorporate an understanding of the context of exposure, both at the individual and population-level.

Environment is a critical determinant of longevity, health status and access to health-supporting resources. Research in several disciplines undeniably demonstrates the social stratification of environmental harms, which in turn contribute to health disparities.[41,42]"Environmental racism" describes how communities of color and/or low-income people are most likely to be situated near sources of contamination and away from clean water, air, and soil.[43] The literature clearly documents the effects of the social and economic policies that led to differences in exposure across communities. For example, redlining is a practice through which federal and local governments and financing entities systematically denied public and private financial services to Black individuals and other people of color.[44] Understanding how environmental conditions are informed by legacy land use practices helps us better focus and refine our current and future health and environmental policy development and implementation. Rigorous exposomic science can generate the knowledge needed to more effectively take action to address inequitable historical, and often discriminatory, land use and environmental health policy decisions. Senier et al contend that a focus on individual-level exposures often supports prevention focused on personal responsibility, rather than acknowledging the inequitable population-level practices that contribute to harmful effects of environmental exposures.[39] Taking a community-level approach to exposomics makes the explicit connection between population-level policies, patterns of exposure and health effects. Examples from the environmental justice literature such as work around confined animal operations in the American South[45,46] and existing environmental regulations and programs[47] provide a blueprint for community-level exposomics to create scientific knowledge that translates to policy.

Prioritizing community in community-level exposomics

Even though a complete measurement of the exposomic profile of a community may be unattainable, the collection and analysis of complex environmental data via exposomics will likely yield great insights. Whereas the genomics and other omics concentrate on individuals, cells, and tissues, we believe that exposomics should integrate the wide exposure horizon with what is happening at an individual level. It is not necessary to capture the totality of exposures across the lifespan, but rather to focus on the reality of exposures—

measure, integrate and study exposures on a wide spatial and temporal scale, rather than solely focusing on an individual level.

In moving forward to address public health concerns with a human-equity centered focus, trans-disciplinary scientists working on intersections of cumulative risk assessment and cumulative impacts need to bridge relationships with communities and policy makers using data.[48] Community and participatory science, which involves engaging communities in performing scientific work, should be included from the beginning.[49] To rebuild trust with marginalized communities, government and academic parties need to be intentionally inclusive of communities in co-designing, co-producing, and co-benefiting from the results. Community-level education and connections to citizen science are beneficial for propagating skills and data that can remain in a community, yet inform policy decisions and demonstrate the need for investments.[50] Acknowledgements of the potential for conflicts and differing priorities with communities and strategies for resolution are a key component of successful scientific partnerships.

Recommendations:

We recommend that community-engaged and participatory science be part of a community-level exposomics approach from its onset. Decades of extractive research practices generated mistrust in research and science among many affected communities.[51] As such, any efforts to implement exposomics at the community-level must center the community itself, and enable interactive co-planning through intentional, thoughtful community engagement. A large literature on the implementation of community-centered and participatory research in the environmental health sciences illustrates the ability to maintain scientific rigor while integrating community voices throughout the scientific research pipeline.[50,52,53] Existing models of community engagement frameworks, such as the E^6 (Enhancing Environmental Endeavors via e-Equity, Education and Empowerment),[54] provide a starting point for exposomic efforts to prioritize communities at the beginning. These efforts include rebuilding trust with historically marginalized communities, enhancing transparency around increased measurement and monitoring activities, establishing clear guidelines on data ownership and stewardship, and integrating with community-level education and citizen science initiatives. The use of scientifically-rigorous methods for data collection, analysis and interpretation are maintained through technical knowledge from scientific partners and advanced through community education.[50] Researchers interested in implementing the community-level exposome framework are encouraged to collaborate closely with established community leaders and those experienced in community-engaged work.

Centering community within the community-level exposomics framework includes consideration of the ethical consequences of labeling communities using potentially negative aspects of their environments. Writing with reference to climate change research, Haalboom and Natcher provide a thorough discussion of how labeling of communities, using terms such as “underdeveloped” or “vulnerable” can impact both how they view themselves and are viewed by others.[55] Labeling can have unintended consequences, some harmful, particularly with respect to the solutions that are implemented to improve conditions. Dedicated efforts to bring together stakeholders, including members of diverse communities themselves, to discuss and develop guidelines on the ethical practice of community-level exposome research are required. These efforts could parallel those focused on ethical considerations to big data and machine learning, recently hosted by NIH.[56,57]

In addition, the goal of community-level exposomics should be to inform community-level actions that improve public health. Increasingly frequent and consequential shocks such as the COVID-19 pandemic and the climate emergency exacerbate a changing and uncertain environment requiring greater flexibility, nimbleness and engagement for adaptation and protection of human health. Community-level exposomics can play a role in developing this greater level of adaptability, but only if it works toward solutions that center the needs of the community and includes a focus on population-level mitigation efforts and risk assessments that incorporate the cumulative impacts of multiple exposures and unique vulnerabilities of communities in the built, social and natural environments. This includes using exposomic tools to inform community-based interventions, expanding cumulative risk assessment exercises and expanding connections between community exposomics monitoring and health. Community-level exposomics can play a role in existing efforts to build sustainable communities that are socially inclusive, economically viable and environmentally friendly by advancing our ability to measure changes in community-level environments and document relationships with health outcomes. However, community-level exposomics must go beyond documenting disparities, and begin taking the steps to ensure health equity.[58] Rockstrom et al defined five attributes that are necessary for building resilience to systemic risks such as the COVID-19 pandemic.[59] These attributes, diversity, redundancy, connectivity, inclusivity/equity and adaptive learning are also relevant to planning community actions related to the exposome and underscore the need for community-level evidence to support the implementation of activities designed to build these attributes. In order to inform community-level action, we highlight the changes in measurement and modeling needed to fully implement the community-level exposomics framework.

Measurement in community-level exposomics: where we are and what needs to change

There are existing data resources that measure environmental parameters at various geographically defined community-levels. These include, but are not limited to, environmental monitoring data on air pollution, ambient air temperature and other ambient exposures, population-based census information, and commercially available built environment databases. One notable example is the public health exposome, a U.S.-based population-level resource that uses a socio-ecological framework to integrate existing multi-domain exposure and health data at a consistent spatial scale.[24] This resource has already been used extensively in combination with advanced computational tools to investigate a number of health outcomes, including pregnancy-related mortality, preterm birth, cardiovascular disease and lung cancer mortality.[60-64] Despite these advances, gaps in measurement remain and progress depends upon combining these traditional indicators with better-informed and more time-sensitive data collection.

Many of the existing measures we rely on for environmental monitoring at the community-level are lagging indicators, preventing earlier identification of signals that could influence health. While lagging indicators provide valuable retrospective information, the lack of near real-time data collection hinders our ability to intervene to protect public health in a timely manner. Similarly, use of real-time data is limited, as an understanding of the magnitude or variability of typical exposomic measures for a given community is not established. Just as health departments use background rates of influenza to identify the presence of an epidemic, community-level exposomics requires understanding of a community's baseline exposomic measures to identify periods of change that require targeted intervention.

While ambient exposure data from routine monitoring systems are often available for research purposes, existing monitoring networks may not meet the specific needs of a community. The location of monitors may not align with locations of pollution sources, and may not be equitably distributed across communities. In addition, biomonitoring data are often not available at a community scale. This data void includes not just understanding geographic distribution of internal measures, but having estimates that accurately represent socially defined communities, such as specific racial, age or occupational groups. This gap limits the ability to use these exposure data for targeted and localized assessments of health effects. The data gap also hinders the ability to understand how population-level exposures connect with internal biomarkers of exposure and response for diverse communities.

Recommendations: To address these gaps, we propose advances in exposure measurement. First, we support supplementing existing monitoring networks with lower-cost sensor networks that can address gaps in space, time and equity. Technology has evolved to create multi-purpose sensors that can obtain data on multiple exposures simultaneously in order to help create a more complete picture of the multiple exposures within a community and how they vary over time.[65] These sensors can also offer more real-time monitoring, again, providing an avenue for faster intervention. As described above, the first step is to center community and assess the technical needs and barriers to deployment. Considering the specific context of the community will facilitate creation of an infrastructure with the greatest potential for both community-level acceptance and ability to successfully augment existing approaches. These sensor networks could be accompanied by citizen science initiatives and integrated into community exposomics platforms.

Second, we encourage greater implementation of population-based biomonitoring approaches, such as using wastewater surveillance. Many municipalities have used wastewater monitoring for COVID19 and CDC launched the National Wastewater Surveillance System in 2020.[66,67] Expanding these efforts to include monitoring for environmental hazards would provide both spatially- and temporally-varying sources of population-level exposures. Wastewater monitoring has been extended for detection of opioids and other drugs in certain areas of the US and Mexico[68], suggesting that there is acceptance of this type of tool for public health monitoring. In addition to targeted surveillance, untargeted approaches applied to wastewater samples, will provide a path for discovery in community-level exposomics.

Finally, we support the construction of large scale, exposomic maps that integrate across environmental measurements and available exposome data resources that have been and will be generated for research and practice. Similar to the existing public health exposome resource that compiles publicly available resources, exposomic maps would compile diverse community-level data across the domains of the exposome. Even though there are maps available for some of the environmental toxicants[69-71], we believe that an integrated map that coalesces all types of exposures (environmental, ecological, diseases, chemical, climatic, built-environment, etc.), across air, water and soil would be a necessary tool that will help to provide a *baseline exposure map* that can be used for multiple purposes. Integrating anonymized metabolomics, adductomics and disease incidence with exposomic maps, will make it a powerful tool that can provide novel ways of researching the effects of exposures on the population's health in communities. With the growing recognition for a systems biology approach to address the complexities of cumulative impacts, integration of data sets from the chemical and non-chemical (built environment and social structures) exposure perspectives will be more useful when integrated for policy decisions. For these maps, we support inclusion of measures most relevant for community-based action. For example, metrics of food availability should focus on the accessibility of foods that mitigate adverse biological responses to exposures, rather than just proximity to grocery stores. Using actionable measures of the exposome to construct these maps would facilitate their broad use across research, communication and public health planning.

There are some potential barriers to creating these maps. It must be acknowledged that exposome research has been primarily focused on physical and chemical exposures.[72] Many have argued for greater inclusion of social and psychosocial exposures.[39,73] We also recommend that exposomic maps include measures from across the multiple domains of the exposome, including neighborhood-level measures from social domains such as crime metrics, proportion of intergenerational households and proximity to community resources. Similar to other applications of spatial epidemiology, exposomic data may not be available on the same spatial scales. These change of support problems[74] will require methods to align data in order to generate appropriate inferences. Existing screening tools, such as EJSCREEN[75] and CalEnviroScreen,[76] might be initially useful in addressing neighborhood-level indicators and community characteristics. In addition, methods and regulatory permissions for linking spatial data on a large number of metrics must be adapted to avoid individual identification, while allowing small-area investigation for precision public health.

Modeling in community-level exposomics: essentials to connect the exposome to population-level health

Advances in measurement and data access will enable the use of more complex modeling approaches within community-level exposomics for the purposes of both understanding health effects of the exposome and planning solutions to improve health. The difficulty of achieving social, environmental and economic sustainability and resilience in complex systems is a widely recognized basic and applied scientific challenge. Classic linear engagement modes dominated by one-way dialogues are limited in their ability to explore problems and solutions within complex systems. Currently, innovative modeling approaches combine advances in artificial intelligence and machine learning technologies with human expertise and local knowledge to enable interactive co-planning with residents from vulnerable communities. Examples include the use of Bayesian networks to model complex relationships between environmental and sociodemographic features on women's health outcomes.[64] Such approaches will allow for the discovery of how to leverage human-machine teaming to generate better communication and dialogue between the professional policy planners and the communities that they serve.

Geographically defined communities require modeling approaches that can integrate multiple data sources with Geographic Information Systems (GIS) to predict personal and small-area exposures and their health effects for community studies. Additional evidence for the importance of spatial considerations comes from an August 2022 release from the White House Office of Science and Technology Policy of the National Emerging Contaminants Research Initiative.[77] This document was developed in coordination with numerous federal agencies and organizations to create a national research initiative to improve the identification, analysis, monitoring, and treatment methods for contaminants of emerging concern. The initiative is primarily designed to identify contaminants in the drinking water across the country, but the report specifically highlights exposomics and an important conceptual framework for the systematic identification and analysis of contaminants of emerging concern that vary spatially. The community-level exposomics framework is precisely the type of system that is needed to coordinate and harmonize the type of data that will come from these large-scale efforts and connect them to population-health indicators in a subsequent modeling framework. The statistical and computational models for environmental mixtures provide a strong foundation for the analytics needed to support these types of initiatives, but these approaches have limitations. Much has been written about the computational challenges for exposomic analysis within individuals,[8] including highly correlated variables and compounding measurement error across multiple exposures. Modeling within the framework of community-level exposomics requires stronger considerations of geographic variability in exposure, integration of social and structural determinants of both exposure and health and greater development of exposomic models for the purposes of population-level intervention.

Recommendations: Greater collaboration between the fields of environmental health sciences, spatial epidemiology, social epidemiology and statistics is needed to expand our modeling capabilities. Flexible and statistically optimal models and tools from the field of geo-statistics, including applications of multivariate linear spatial regression modeling can provide direction, but development and validation of new approaches will be essential moving forward. Models to investigate the associations between exposomics at the population-level and health indicators need to integrate the contextual information that influences both the distribution of exposures and the barriers to potential solutions. Approaches such as hierarchical or multi-level modeling, routinely used in social epidemiology, will need to play a role in community-level exposomics analyses. In addition, approaches from both machine learning and statistics, such as clustering that enable visualization of exposure patterns within high-dimensional data could provide greater understanding of how multiple environmental contaminants co-occur with social and structural factors known to influence vulnerability and ultimately contribute to health outcomes.

Example applications of community-level exposomics

We briefly highlight two examples to show the potential for community-level exposomics to advance public health research and practice.

Addressing the complexity of the urban ecosystem—The overall health of the urban ecosystem is stressed by numerous challenges including pollution, greenhouse gas production, acidification, UV radiation due to ozone layer depletion, climate change and rapid population growth. Characterizing the exposome within urban settings provides a holistic approach to measuring the impact of such challenges on these complex ecosystems (e.g., see work by Andrianou and Makris, 2018).[78] The urban exposome was defined as the continuous spatiotemporal surveillance/monitoring of quantitative and qualitative indicators associated with the urban external and internal domains that shape the quality of life and health of urban populations, using small city areas, i.e. neighborhoods, quarters, or smaller administrative districts, as the point of reference. Research should focus on the urban exposome's measurable units at different levels, i.e. the individuals, small, within-city areas and the populations.[79] Federal and other regulatory air quality monitoring networks cannot capture the spatial and temporal variability in air pollutants needed to understand how various sources affect the urban exposome. These networks are also ill equipped to address community concerns of environmental exposures and injustice. Regulatory monitoring stations are expensive to operate, resulting in sparse networks that are not representative for many people who live and work far from monitors. Recent advances in chemical sensors, distributed sensing, and wireless networking have led to the feasibility of high density, low-cost sensor networks. These technologies have created unprecedented opportunities for community participation in research and citizen science.[80] Leveraging input from high-granularity stationary monitoring networks for a wide range of pollutants to capture small spatial scale and high temporal variability in communities would provide more data that can be included in exposomic maps.

Enabling proactive responses within disaster epidemiology—Various disasters (anthropogenic (climate change, heat waves), biological (influenza, COVID-19), natural (forest fires, flooding)) are affecting humans, costing the economy trillions, motivating a need to assesses the complex interplay between the built, social, physio-chemical, and environmental factors.[81,82] Greater baseline measurement of chemicals in the environment and how they penetrate and accumulate in humans, animals, and plants coupled with disease incidence measurements can be important tools in mitigating exposure effects during disasters. Mobile monitoring capabilities, a key component of community-based exposomics, provides a mechanism for rapid response to unexpected events such as fires or chemical releases, which are typically of short duration. Untargeted analyses, including analyses of wastewater, will allow identification of previously unrecognized contaminants and will enable the simultaneous quantification of emerging contaminants. Right now, most research is done in a reactive fashion and long after the disaster has happened.[83,84] Having access to existing data on the built, social, physio-chemical, and environmental factors that influence disaster resiliency can enable extensive simulations and development of targeted preparedness plans before disasters occur.

Conclusions

Advancing community-level exposomics will require resources targeted at improving community-level infrastructure for exposure measurement, including the use of new methods to supplement traditional exposure indicators and modeling techniques more closely aligned with generating evidence for action. We encourage investment and greater availability of resources for increased implementation of targeted community-level sensing, initiating wastewater epidemiology in municipalities and enhanced biomonitoring at a community scale. Researchers interested in pursuing work in community-level exposomics should center the communities where they work and meaningfully collaborate with investigators with experience and expertise in community-engaged research and practice. Collaboration across stakeholder groups, including community leaders and ethicists, are needed to ensure benefits from community-level exposomics work are equitable and negative consequences from labeling communities are avoided. The community-level exposomics framework serves as a true complement to the investments being made in exposomics targeted at individual-level health, and together can help transform the field of environmental health sciences to improve health, and support sustainable, equitable and resilient communities.

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Data availability

No new data were generated or analyzed in support of this manuscript.

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