Linking Environmental and Public Health Data:

Challenges and Solutions for Integrating Health Data into Environmental Policy Formulation

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Acronyms and Definitions

EJ	Environmental justice
EPA	Environmental Protection Agency
CDC	Centers for Disease Control and Prevention$_3$
EPHT/EPHTN	Environmental Public Health Tracking/Environmental Public Health Tracking Network
O_3	Ozone
$PM_{2.5}$	Fine particulate matter (< 2.5µm)
WHO	World Health Organization
CDPHE	Colorado Department of Public Health and Environment
USDA	US Department of Agriculture
DMNFR	Denver Metro/North Front Range
COPD	Chronic obstructive pulmonary disease
NAAQS	National Ambient Air Quality Standards
APCD	Air Pollution Control Division
NFRMPO	Northern Front Range Metropolitan Planning Organization
DRCOG	Denver Regional Council of Governments
MPO	Municipal Planning Organization

Introduction

Throughout history, public health has been influenced and shaped by the quality of the environment. In the 20th century, efforts to address infectious diseases and pollutants resulted in the formation of new environmental protection agencies and improved environmental quality. Now, as the 21st century progresses, the need for a comprehensive understanding of environmental hazards and exposures remains critical for protecting public health. The incorporation of environmental public health tracking into this framework has enabled the linkage of environmental hazards with adverse health outcomes, leading to an improved understanding of how environmental factors impact and influence public health. Moreover, as climate change strains communities and their environments, environmental policies must integrate health data in a comprehensive and meaningful way to ensure they adequately address emerging environmental public health challenges.

Environmental public health is an interdisciplinary field, owing to the need to integrate environmental hazard, exposure, and outcome data as well as link data across sectors, including health care, industry, economy, environmental quality, government, community development, and so forth. Thus, understanding the interdisciplinary nature of environmental health is critical to the efficacy of health tracking systems and their accessibility, as community members, advocates, policymakers, researchers, scientists, medical professionals, and public health organizations rely on timely, accessible, and actionable data relevant to their work.

This white paper will examine the development, uses, and shortcomings of environmental public health data and its usability across sectors, particularly as it relates to air quality data in terms of ozone (O_3) and fine particulate matter ($PM_{2.5}$). In doing so, this paper addresses an underlying question, which asks why health datasets are frequently not used in environmental policy.

Funding for this document was provided through the Alfred P. Sloan Foundation research grant and a subaward from Auburn University to Colorado State University. As part of the research grant, the research team developed a database on publicly available environmental and wellbeing-monitoring datasets. Health data was not included in this database, although it is important to note that the distinction between a health dataset and environmental dataset is often unclear. In developing the database, we struggled with understanding how the nation's diverse health datasets integrated with our gathered datasets, and conversely how they were different, which presented to us a general unawareness of how such datasets were used differently and/or integrated. Accordingly, this report discusses the linkages and disconnects between health and environmental datasets within the field of environmental policy.

Current Environmental Health Data Challenges

Despite progress made over the last two decades to close the environmental health gap, numerous limitations in data quality, collection, and integration, public health capacity, cross-agency partnerships and participation, and data actionability remain.

- Difficulties persist in maintaining a well-trained workforce that can analyze available data and deliver on public health needs.
- Chronic underfunding of public health agencies at the federal, state, and local level continues to present a problem in responding to current and emerging environmental and public health threats or incorporating environmental health data into policymaking. This includes the lack of funding for the CDC EPHTN that has prevented the program's expansion to all 50 states.
- Difficulty with the inclusion of the abundance and variety of relevant environmental health factors, most of which span multiple sectors, units, and disciplines.
- Timeliness of data is lagging behind the pace of new and emerging environmental health developments and needs despite nationwide improvements.
- Privacy limitations and confidentiality of health data continues to limit the extent of data access and inclusion in tracking databases and environmental policy.
- Health and environmental data for large geographic scales (e.g. national, state, and regional) continues to be widely available, however, more data is needed at finer spatial resolutions and smaller geographic scales (e.g. household-level, census tract, census block groups, and county).
- Current environmental health databases are being updated to improve usability, understandability, and public accessibility, but there is concern that these tools are generally unknown by the general public and underutilized as a resource at local levels.
- Though many current environmental public health tracking efforts are attempting to forge multi-sector partnerships, there is still a noticeable gap in linkages and intentional collaboration between researchers, public health professionals, policy-makers, community members, advocates, and other public health entities.
    - For example, the lack of participation and collective action of states in current nationwide efforts like the CDC's EPHTN.
- Efforts to incorporate environmental justice into environmental health data vary across states and localities. More work needs to be done to ensure data is understandable, actionable, and available in the relevant language.

Theoretical Application of Environmental Public Health Tracking for Policy and Practice

Environmental public health tracking expands on the practice of public health surveillance, which has traditionally focused on the systematic collection, analysis, and interpretation of health data for purposes of preventing and controlling disease (Qualters et al., 2015). In recognizing the importance of controlling health problems related to the environment, Thacker et al. proposed a conceptual model for environmental public health tracking centered around three types of surveillance: hazard, exposure, and outcome (1996). This model forms the basis for the U.S. Centers for Disease Control (CDC) National Environmental Public Health Tracking Network (EPHTN).

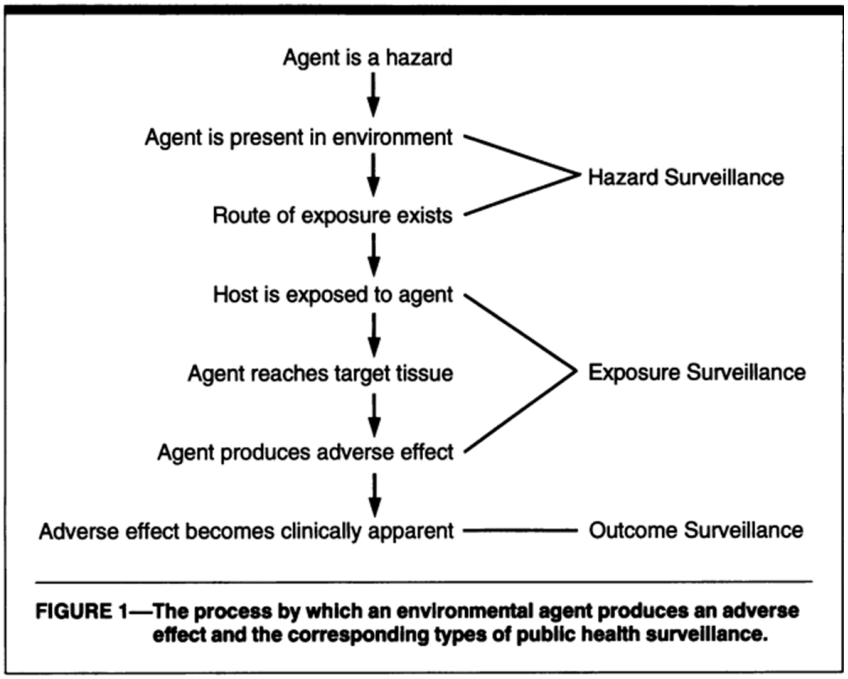

Figure 1. Conceptual EPHT Model (Thacker et al., 1996)

Environmental public health tracking (EPHT) is defined as "the ongoing collection, integration, analysis, and dissemination of data from environmental hazard monitoring, human exposure tracking, and health effect surveillance" (McGeehin et al., 2004, 1413). The aim of EPHT is "to provide information for public health decision-makers to reduce the environmental burden of disease" (Lauriola et al., 2020, 4). Whereas environmental monitoring has historically been used for the purpose of regulatory compliance and rulemaking, particularly after the 1970s with the establishment of the Environmental Protection Agency (EPA) as the primary authority on environmental protection (Kyle et al., 2006), EPHT in the 21st century has shifted towards protecting public health by guiding preventative action (Lauriola et al., 2020).

EPHT builds upon a tenet of public health surveillance that suggests no such system is complete without being linked to action, in which EPHT can contribute to interventions that reduce disease and improve public health (Kyle et al., 2006). Owing to U.S. federalism, the successful application of EPHT requires participation from a wide array of entities. Federal agencies such as the EPA and CDC have key roles in providing leadership and guidance at the national level, while states are primarily responsible for public health actions within their borders (Kyle et al. 2006). At the local level, public health agencies carry out actions and assessments related to environmental health while communities and other stakeholders influence policy through sharing their concerns and lived experiences (Kyle et al., 2006).

The multi-tiered approach adopted by the CDC EPHTN is a critical step towards collecting, integrating, and acting on environmental health data to improve the nation's health outcomes. By integrating data on environmental hazards, environmental exposures, and health effects, the EPHTN program seeks to improve public health by providing relevant agencies with information for planning, applying, and evaluating actions to prevent and control diseases linked to the environment (Science Applications International Corporation, 2004). In this way, the EPHTN is designed to help in the development, implementation, and review of regulatory and public health actions to prevent or control exposure to environmental hazards. For example, federal environmental statutes such as the Clean Air Act aim to prevent disease through the reduction or elimination of an environmental hazard. The Clean Air Act accomplishes this through National Ambient Air Quality Standards (NAAQS), which controls the maximum allowable concentration of each criteria air pollutant over a certain period of time. Air quality monitoring data demonstrates exposure to harmful levels of pollutants in a given area and thus enables interventions to control the level of pollutants that could cause adverse health impacts. However, the integration of hazard, exposure, and outcome data into the EPHTN has not translated to improved environmental policymaking. The Clean Air Act and other environmental policies largely focus on exposure assessments and risks to human health without considering public health outcomes, which is partly a consequence of the historical lack of knowledge about the relationship between health outcomes and exposure to environmental hazards. While the CDC EPHTN provides a crucial step towards improving public health through environmental policymaking, this paper highlights how the linkage between environmental public health tracking data and environmental policies that explicitly address public health outcomes remains weak, and advocates for the inclusion of public health outcomes in environmental policymaking.

Historical Background

Pre-2002 Data Issues

From the very first interactions between humans and nature, environmental hazards have posed a threat to human health. As human society has concentrated larger clusters of individuals within larger cities, consequential health problems have become more widespread and severe (Johnson & Lichtveld, 2018). One of the most significant driving forces behind this exponential growth was industrialization, as humans migrated to congested and unclean cities, worked hazardous jobs, and dramatically increased their exposure to chemical and biological hazards. Suddenly, definitions of 'health' and the 'environment' shifted. While public health had once meant addressing food safety, sanitation, infectious disease and vector-borne illness, the industrialized world and emergence of a robust built environment forced public health agencies to address chronic illnesses (Koehler et al., 2018). Simultaneously, environmental policies refocused environmental protection to air, water, and soil pollution and remediation, contributing to a divide between public health and the environment during the latter half of the 20th century (Koehler et al., 2018).

A 1988 report by the Institute of Medicine entitled "The Future of Public Health" described a nation that had "lost sight of its public health goals and [had] allowed the system of public health activities to fall into disarray" (Institute of Medicine, 1988, 19). In the context of environmental health, the report lambasted the removal of environmental health responsibilities from public

health agencies, leading to "fragmented responsibility, lack of coordination, and inadequate attention to the health dimensions of environmental problems" (Institute of Medicine, 1988, 12). This was the result of decades of national environmental policy development, in which environmental health responsibilities were delegated to the EPA and other environmental agencies while data collection was used primarily for regulatory purposes (McGeehin et al., 2004). While this shift was positive for environmental protection and regulation, public health agencies became detached from the federal scope of environmental protection and decision-making (Fox et al., 2017).

In 2000, the Pew Environmental Health Commission further exposed the fragmented and ineffectual state of environmental public health in the U.S. The report identified an environmental health gap in which information on the link between environmental hazards and chronic disease was severely lacking. Moreover, the report highlighted the patchwork of environmental public health tracking that existed at state and local levels, with variations in collection methods, analysis, dissemination, and regulatory standards of environmental health data (Environmental Health Tracking Project Team, 2000). The result of this fragmentation of environmental and public health data led to what the report noted as:

> [A] widely varied mix of programs across multiple federal, state and local agencies…there are no identifiable linkages between hazard, exposure and outcome tracking, and there is limited coordination in the collection, analysis, or dissemination of information. The combination of lack of leadership, planning, coordination and resources have left important questions about the relationship between health and the environment unanswered (Environmental Health Tracking Project Team, 2000, 13).

Simply put, health data and environmental data functioned in separate silos without broader integration. To counteract the **environmental health gap**, the Pew Commission called for the establishment of a nationwide Environmental Public Health Tracking Network (EPHTN) to provide the capacity and information necessary to better understand, respond and prevent chronic diseases and related environmental hazards (Environmental Health Tracking Project Team 2000). The CDC led this effort, outlining a program that would standardize environmental health data across federal, state, and local agencies in order to better respond to and prevent emerging environmental threats, improve public health policymaking, enhance public knowledge about environmental health, and track national progress.

Environmental Health Gap – The lack of basic information that could document possible links between environmental hazards and chronic disease.

Development of the CDC Environmental Public Health Tracking Network

In 2002, Congress provided funding to the CDC to formally establish and begin development of the EPHTN. By 2006, the Tracking Network was ready for implementation, starting with the funding of 16 states and 1 city (CDC, 2022). By 2009, the online Environmental Public Health Tracking Network was officially launched after seven years of capacity building, making it the first national health data standardization effort of its time (McGeehin et al., 2004).

The goal of the CDC Tracking Network is to integrate health and environmental data that facilitates actions to improve community health. Using a core set of standardized health, exposure, and hazards data, the Tracking Network enables states to track their own environmental indicators and specific priorities in addition to aggregating and tracking national data (McGeehin et al., 2004). In doing so, the Tracking Network consolidates information that is otherwise difficult to find, provides data at the national, state, and county level, and improves the understanding and accessibility of otherwise complex data, demonstrating to wide audiences how

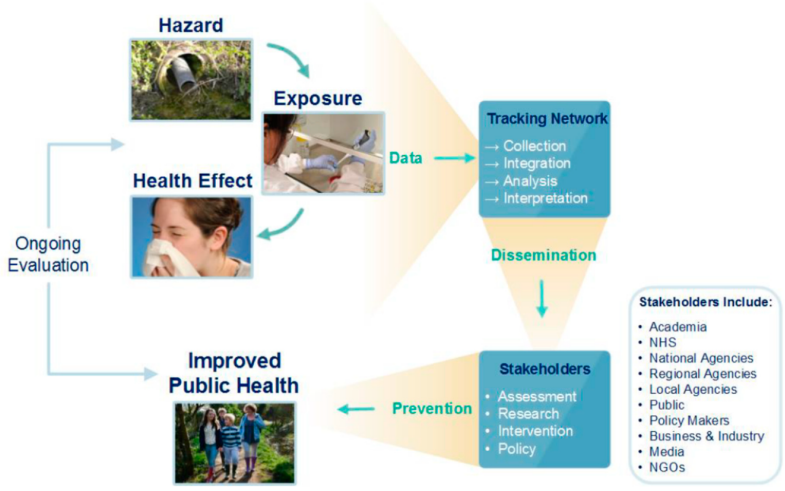

Figure 2. Environmental Public Health Tracking Components (Lauriola et al., 2020)

human health and the environment are related (National Center for Environmental Health, 2015). Moreover, the Tracking Network is a valuable tool for decision-makers and public health leaders by providing easy-to-understand maps, charts, and tables to identify the relationship between, and locations of, health and environmental problems (National Center for Environmental Health, 2015).

Current State of the Field

The current state of the environmental public health field has seen tremendous progress in terms of data aggregation, usability and dissemination. However, there is still a long way to go in regards to the nation's capacity at both the federal and state level. To fully examine the extent of the progress made and measure the response needed for the future, it is imperative to discuss the state of the field at both the national and state levels as both contribute differently to the overall comprehensiveness and ultimate applicability of data in decision-making settings:

> At the local level, data are used to monitor population health and to target interventions; at the national level, data are used for resource allocation, prioritization, and planning…In addition to their primary use by public health agencies, routinely collected public health data have become valuable for secondary use such as academic research and technology development (van Panhuis et al., 2014).

National

Due to the expansive scope of issues addressed by the public health field, it is necessary that a comprehensive national response exists to support efforts at the state and local level. However, formulating a network that sufficiently meets the needs of professionals in various public sectors, communities, advocates, and scientists while also including the social, political, economic, environmental, and public health aspects of environmental public health is a significant task. The state of national environmental public health tracking has made significant strides in the past two decades, as more coordination between federal agencies is on the horizon. Fox et al. noted in 2017 that the EPA was looking to link EPA mapping sources like EJScreen and EnviroAtlas, which will be discussed further in the following sections (Fox et al., 2017).

However, there is still much progress to be made nationally. Moving into 2023, the Council for State and Territorial Epidemiologists notes that less than half of all states have adequate environmental epidemiology capacity (CDC, 2022a). Despite the success and expansion of the CDC Environmental Public Health Tracking Program, the CDC claims that it would need approximately $75 million per year to expand the program to all 50 states (Trust for America's Health, 2019). While the emergence of new and precise tools suggest continued growth in the field, there is also a concern that a lack of funding may inhibit more substantial progress in terms of data linkages and multi-level coordination.

Today, three tools from both the CDC and EPA represent the most comprehensive efforts at the national level to improve environmental public health tracking. The aforementioned CDC Environmental Public Health Tracking Network and the EPA's EJScreen and EnviroAtlas have expanded access to health data to include social determinants of health and increase data usability across sectors.

CDC EPHTN

Today, the CDC's Tracking Program has improved the nation's environmental public health capacity. Specifically, the Program has been successful in:

> [E]nhancing technical expertise, creating access to data, facilitating the development of a multidisciplinary 'people' network of grantees and federal partners across the nation, as well as partnerships and data sharing across agencies and community organizations within states (Fox et al., 2017, 15).

Currently, the CDC funds 33 recipients, comprising 32 states and one county, to create, maintain, and add to their own local tracking networks as well as contribute to the national Tracking Network (CDC, 2022b). In terms of specific issues, the

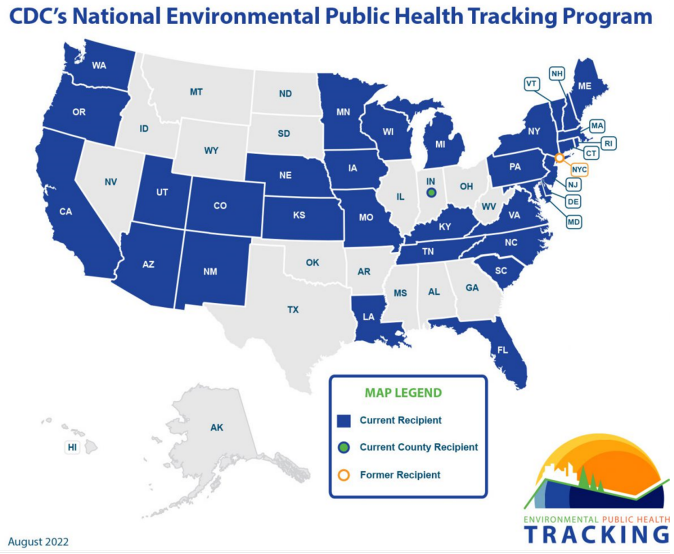

Figure 3. CDC EPHT Recipients and Participants (CDC, 2022b)

Tracking Program addresses 27 topic areas categorized into Environmental, Exposures, Health Effects, and Population Characteristics, 151 indicators, and 600 publicly available environmental health measures (CDC, 2023). The data collected under the Tracking Network covers over 180 million people in the U.S. and has enabled state and local public health officials to implement more than 740 public health actions since 2005 related to preventing adverse health effects from environmental exposures (CDC, 2022a).

The Tracking Program has established the first national health database of its kind, and plans to improve the efficacy of the Tracking Program in the future. Moving forward, the CDC envisions the Tracking Network as a tool that is adaptable and beneficial across sectors, ultimately informing and shaping policies and decisions that positively impact the health of communities. Specifically, per the CDC's 2022-2026 Strategic Plan for the Program, this looks like:

- Creating updated systems and processes that yield more timely, local, accurate, and accessible environmental public health data
- High-functioning, mutually beneficial partnerships with internal and external groups
- Informed public health actions based on those quality data, tools, and resources
- A knowledgeable and skilled public health workforce (CDC, n.d.)

EPA EJScreen

On the national level, multiple tools exist outside of the CDC's Tracking Program to assess and track environmental health indicators. In 2015, the EPA formulated a new tool that utilizes GIS mapping to display the interactions between environmental, socioeconomic and demographic information in particular geographic areas (EPA, 2022c). The goal of EJScreen is to provide a tool to visualize and gauge environmental justice (EJ), and does so by including 12

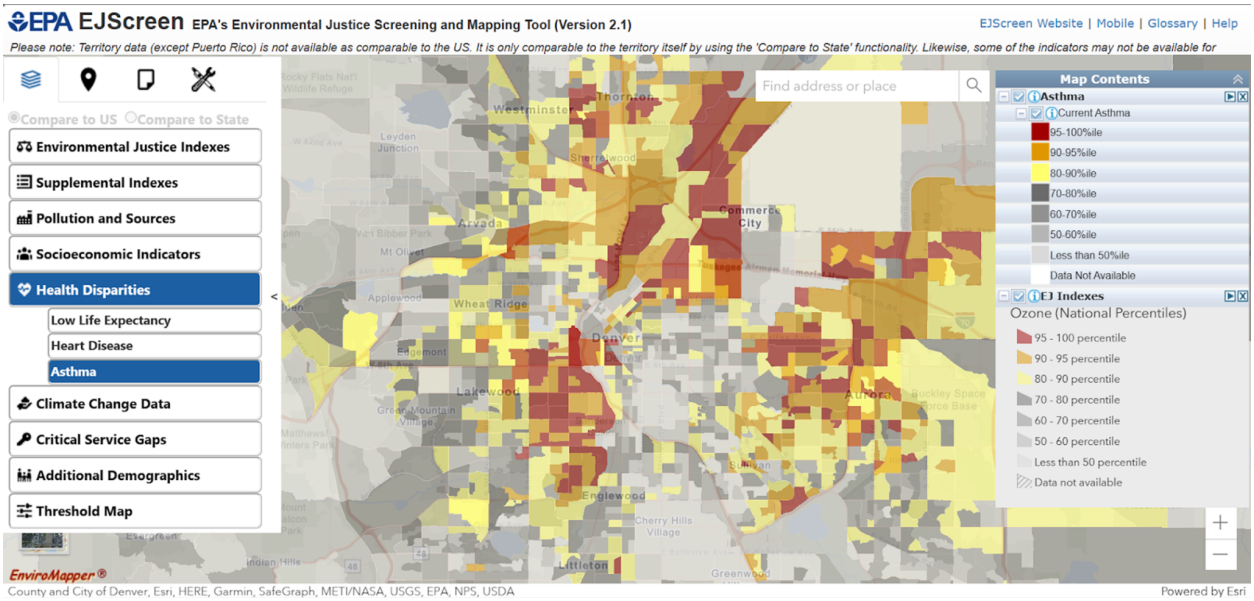

Figure 4. EPA EJScreen Online Mapping Tool

environmental indicators, seven socioeconomic indicators, 12 EJ indexes, and 12 supplemental indexes, all of which utilize publicly available data (EPA, 2022c). EJScreen is therefore highly usable, accessible, and contains high levels of data completeness, which makes the tool useful for policymakers looking to make informed decisions on environmental justice matters and for community members and other stakeholders who seek more information related to environmental exposures and health outcomes (Fusi, Zhang, and Liang, 2022; EPA, 2022c).

Though the EJScreen tool does not specifically measure or track health outcomes, exposures, or include health data, the environmental and socioeconomic indicators align exactly with traditional social and environmental determinants of health. According to both the World Health Organization (WHO) and the CDC, social determinants of health include but are not limited to education level, unemployment and job insecurity, income and social protection, housing, and social inclusion and non-discrimination (WHO, n.d.). EJScreen examines these indicators and integrates them with environmental indicators to provide geographic and demographic information to create a useful tool for predicting and addressing environmental health outcomes (EPA, 2022c).

Figure 5. EPA EnviroAtlas Regions (EPA, 2022a)

EPA EnviroAtlas

Publicly launched in May 2014, the EPA's EnviroAtlas tool aims to communicate the benefits of ecosystem services as they relate to human health via high-resolution mapping, including over 530 data layers that range from ambient concentrations of air pollutants to avoided asthma exacerbation from ecosystem services measured in cases per year (EPA, 2023). EnviroAtlas was developed out of a collaborative partnership between the EPA, the U.S. Geological Survey, the U.S. Department of Agriculture (USDA), LandScope America, and other federal, state, and local stakeholders and organizations (EPA, 2022). Today, the EnviroAtlas Project Partners have expanded to also include the USDA U.S. Forest Service, the USDA Natural Resources Conservation Service, Forest Trends, and the USDA Office of Environmental Markets (EPA, 2022).

This tool integrates quantitative scientific data with a community component, measuring the impact on specific geographic regions using census data to include information about demographics and specific populations (EPA, 2020). According to the EnviroAtlas Fact Sheet, the tool is designed to "...screen and understand the potential implications of planning and policy decisions…" and aims to assist "...staff from all levels of government, environmental and public health professionals, researchers, educators, non-governmental organizations, and anyone else

with an interest in ecosystem services and their role in sustainable and healthy communities" (EPA, 2020, 2).

The figure above shows the areas of focus that EnviroAtlas has built high-resolution data for, which includes "...more than 1400 cities and towns centers on 30 U.S. urbanized community areas" (EPA, 2022a). While it may appear narrow in scope, the EPA notes that these regions were selected based on geography, ongoing local research, availability of data, and opportunities to leverage other EPA projects in the future (EPA, 2022a). Frequent updates are made according to the emergence of new data and analytic methods and tools, suggesting that this relatively new apparatus will continue to expand as research progresses (EPA, 2020).

State-Level

States have the primary authority in carrying out public health functions, thus their involvement in environmental public health tracking is crucial. Data collection and dissemination at the state and local levels are critical components in framing any environmental health issue and/or policy. This is because state and local governments are more equipped to provide region-specific data that accounts for local demographic factors and environmental concerns "[d]ue to their physical and administrative proximity to their constituents" (Fusi, Zhang, and Liang 2022, 7).

The future of a more coordinated public health tracking network relies on the increased inclusion and participation of states to "better facilitate data completeness and linkages" (Fox et al., 2017, 17). Fully realizing the potential of a nationwide tracking network will involve all states building out their own environmental health systems in collaboration with national tracking efforts.

Case Study

This case study explores air pollution and respiratory outcomes in the Denver Metro/North Front Range (DMNFR) region of Colorado. Air quality data for ozone (O_3) and fine particulate matter ($PM_{2.5}$), cross-agency collaboration, public health outcomes, and policy interventions are discussed using a multi-level framework that incorporates federal, state, regional, county, and municipal levels.

Colorado operates the Colorado Environmental Public Health Tracking (Colorado Tracking) program, a web-based surveillance system that is nestled within the national Tracking Program. Prior to 2009, Colorado did not have the capacity to track environmental health indicators. As a result, crucial information on exposures, hazards, and health was missing from community health assessments and planning efforts at the state and local levels (CDC, 2014). However, with support from the CDC, the Colorado Department of Public Health and Environment (CDPHE) launched its own tracking program in 2011, allowing the state to develop nationally consistent environmental health indicators as well as prioritize state-specific indicators (CDC, 2014). As of 2023, the Colorado Tracking program provides 15 health indicators, 11 environmental indicators, and 5 broad community indicators, with a substantial amount of data contained within each (CDPHE, n.d.).

The Colorado Tracking program has sought to close the information gap in terms of how the environment affects chronic disease, for example by providing data on asthma and cancer and

how they are connected with environmental exposures (CDPHE, n.d.a). CDPHE maintains a Colorado Health Information Dataset that provides state and local-level data on health and related issues in Colorado. In addition, the CDPHE offers online tools such as Colorado EnviroScreen, an environmental justice mapping tool that identifies disproportionately impacted communities in order to help direct resources and make data accessible, understandable, and actionable (CDPHE 2022).

The CDPHE, in partnership with 54 local public health agencies, comprises Colorado's governmental public health system (CDPHE, 2022). While Colorado has enacted legislation aimed at providing every person in Colorado with a consistent standard of core public health services, the state's public health system faces numerous systemic challenges, including "chronic underfunding, limited and inflexible categorical funding, and challenges with maintaining a well trained workforce" (CDPHE, 2022, 76). These challenges within the state's public health care system are reflected in the state's environmental health programs. Environmental health concerns are continuously evolving in Colorado even as funding for agencies remains limited (Murphy et al., 2021). Consequently, agencies have stretched their resources thin across programs to ensure they continue to function (Murphy et al., 2021). Moreover, while the Colorado Tracking program has contributed to a substantial amount of data becoming available for Colorado, the data is not consistently available across indicators, timeliness of the data is lacking, and data is not always available at finer spatial resolutions (Murphy et al., 2021). In response to these challenges, the Colorado Tracking program has embarked on an effort to improve its EPHT database by including sub-county lead exposure risk information, working to expand its datasets, and strengthening partnerships with local public health agencies (Murphy et al., 2021).

Focusing in on One Environmental Issue: Air Pollution

Air pollution is a salient issue for public health and represents both the challenges and advancements confronting environmental policy and public health today. Air pollution remains the leading environmental health risk in the U.S., with fine particulate matter ($PM_{2.5}$) responsible for 88,000 deaths per year and ozone (O_3) exposure causing 9,000 deaths per year (Koehler et al., 2018). Multiple studies have demonstrated a causal relationship between exposure to $PM_{2.5}$ and ambient ozone with respiratory effects (Strosnider et al., 2018).

For example, Strosnider et al. conducted a national study that found positive associations between air pollution and emergency room visits for asthma, chronic obstructive pulmonary disease (COPD), and respiratory infections and diseases (2018). Stowell et al. found significant associations between wildfire smoke and acute respiratory outcomes in Colorado, pointing to the heightened public health threat posed by $PM_{2.5}$ from wildfire smoke compared to non-smoke $PM_{2.5}$ exposure (2019). These studies filled in critical gaps present in air pollution epidemiology and improved the evidence used to inform national ambient air pollution policies and regulations (Strosnider et al., 2018). The CDC Tracking Network was instrumental in providing applicable data for the study conducted by Strosnider et al., allowing the authors to analyze data on the association between ozone and $PM_{2.5}$ and respiratory emergency room visits for people of all ages across hundreds of counties. Previously, multicity studies only had data on air pollution effects among older adults (Strosnider et al., 2018). Similarly, few prior studies focused on the effect of wildfire smoke on respiratory outcomes, and those that did so lacked information on wildfire-specific air quality and non-urban air pollution measurements for fire-related exposures (Stowell et al., 2019). These studies demonstrate how the establishment of the CDC Tracking

Program, combined with greater understanding of the relation between environmental exposures and health outcomes, has improved national air pollution standards and policies.

Multi-Level Model of Colorado Air Pollution Governance			
Federal Level			
Actor	Centers for Disease Control and Prevention	Environmental Protection Agency	
Program	National Environmental Health Tracking Network	Clean Air Act; NAAQS	
State Level			
Actor	Colorado Department of Health and Environment	Regional Air Quality Council	
Sub-Agency	Air Pollution Control Division		
Program	Colorado Environmental Public Health Tracking Program		
	Colorado EnviroScreen		
	Colorado Health Information Dataset		
Regional Level			
Actor	Northern Front Range Metropolitan Planning Organization		Denver Regional Council of Governments
County Level			
Actor	Larimer County	Weld County	Adams County
Sub-Agency	Larimer County Dept. of Health and Environment	Weld County Dept. of Health and Environment	Adams County Health Department
Municipal Level			
Actor	Fort Collins	Greeley	Aurora
Sub-Agency	Fort Collins Environmental Services Department	City of Greeley Planning Commission	Aurora Planning & Development Services

Table 1. Multi-Level Model of Colorado Air Pollution Governance

Colorado represents an intriguing case study for exploring air pollution and respiratory health outcomes in relation to environmental health data and policy. The state boasts rapid population growth, a growing energy industry, and a robust agricultural sector, but these factors plus emerging ones such as greater wildfire size, frequency, and intensity due to the changing climate also contribute to air pollution (Colorado Air Quality Control Commission, 2022; Murphy et al., 2021). Subsequently, the DMNFR nonattainment zone, which includes major urban cities such as Fort Collins, Greeley, and Denver, has consistently been out of compliance with the EPA's National Ambient Air Quality Standards (NAAQS) for ozone. In 2022, the region was downgraded to Severe Nonattainment under the 2008 Ozone NAAQS and Moderate Nonattainment under the 2015 Ozone NAAQS (Colorado Air Quality Control Commission, 2022). One of the state's top priorities is to improve air quality by reducing emissions, improving

the public's health, and addressing environmental justice (Colorado Air Quality Control Commission, 2022).

CDPHE is the primary agency tasked with addressing air quality in the state. Within CDPHE, the statewide air quality monitoring network is maintained by the Colorado Air Pollution Control Division (APCD). Data collected from this network provides yearly measures of ozone levels and is represented in two metrics for ozone and four metrics for $PM_{2.5}$. In addition to the statewide network, local governments also maintain their own monitoring programs. The Weld County Department of Public Health and Environment operates an Air Quality Program via a contract with CDPHE and gathers data at the local level using monitors in Greeley and other areas across the urbanized portions of the county. Larimer County Department of Health & Environment performs ambient air monitoring for ozone and $PM_{2.5}$ in partnership with the APCD, while the City of Fort Collins has worked to develop localized air quality monitoring data that it tracks and reports to the state. Adams County implemented the Adams County Health Department on January 1, 2023 in response to the three-county Tri County Health Department dissolving. As a result, information on current air quality programs for Adams County and the City of Aurora is not publicly accessible at this time. For the purposes of this case study, Adams County will be assessed using the old Tri-County Health information on air quality monitoring.

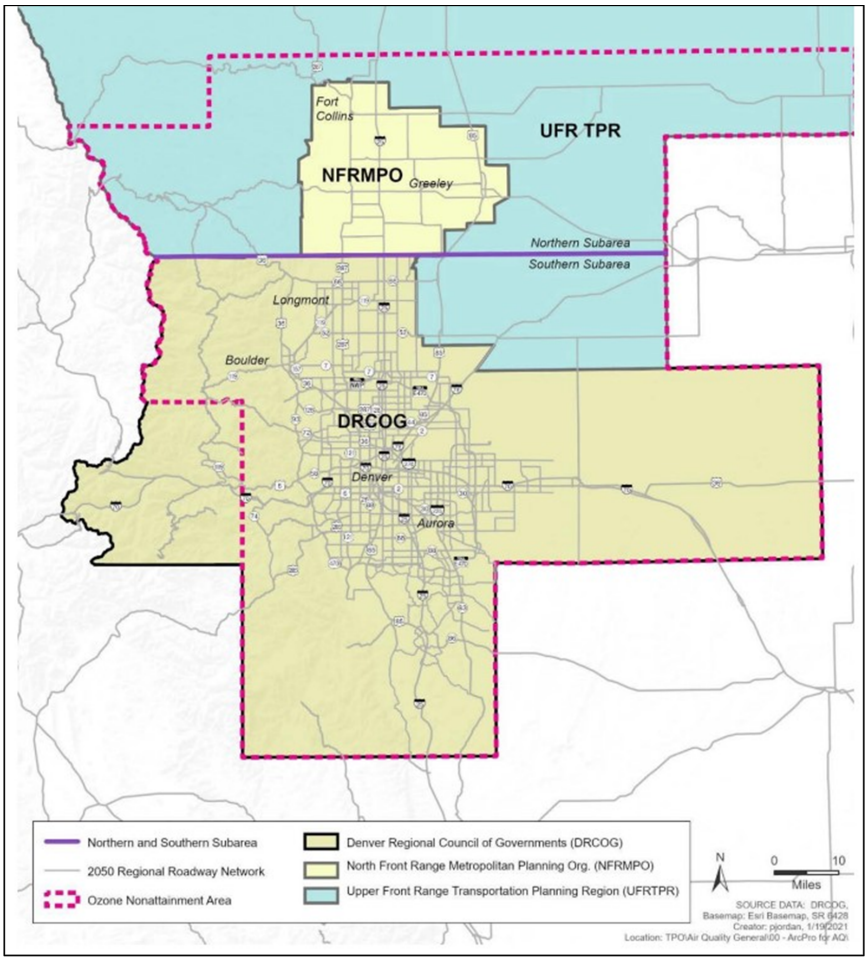

Figure 6. DMNFR Nonattainment Zone and MPO Boundaries (DRCOG, 2019)

Two regional Municipal Planning Organizations (MPOs) serve as lead organizations for transportation and air quality planning in their respective regions. The NFRMPO includes Larimer and Weld Counties and the cities of Greeley and Fort Collins. The NFRMPO and the local governments it encompasses work with the APCD and EPA to plan for and address air quality issues and influence policies. DRCOG includes Adams County and the City of Aurora and is responsible for ensuring its transportation plans and programs support air quality goals and meet air quality standards. Both MPOs collect data from federal, state, local, and private sources and engage local governments in collaborative data initiatives.

All three counties regularly monitor air quality and conduct community health surveys that gauge residents' beliefs and attitudes about air pollution. Both Adams County and Weld County state that they collect primary and secondary data that is qualitative and quantitative at local, state, and federal levels and from non-government sources. Through this data collection, Adams County observed that worsening air quality was posing health risks for its residents. The county noted dangerous ozone levels were present in the summer of 2021, fueled by wildfire smoke, the built environment, and mobile emission sources (Tri County Health Department, 2022). Moreover, residents identified air quality as a key environmental health concern, which is reflected in the county's 2022 Community Health Assessment. Similarly, Weld County found that 61% of its residents considered outdoor air pollution to be a problem (Weld County, 2017). As Weld County states, "[t]here is a variety of health data available at the county level that are used to inform health strategic planning and policies" (Weld County, 2017, 1). In this way, counties are leveraging air quality and community data to inform their planning efforts and policies.

However, the three counties also acknowledge the limitations to the data they collect. While health improvement interventions are frequently carried out at the local level, decisions may be made using county or state level averages that don't reflect local demographics and community needs (Weld County, 2017). Large, national environmental health surveillance systems primarily collect data at the state level, meaning data at the county, city or neighborhood level is limited or unavailable and thus harder for local governments to target resources and interventions where they are most needed (Tri County Health Department, 2022; Weld County, 2017). Furthermore, Adams and Weld Counties discuss a lag in data timeliness. For example, data used in Weld County's October 2021 Community Health Assessment Report mostly reflected residents' health prior to COVID-19 (Weld County, 2017).

Larimer County and others have acknowledged these limitations and recommended that future actions include working with state and local partners to monitor health outcome data and community environmental data (Larimer County, 2020). The City of Fort Collins has gone even further, outlining multiple air quality-related strategies in its "Our Climate Future Two-Year Tactical Plan (2021-2022)" that aims to improve communication strategies to inform and empower local communities, localize air quality monitoring data, and ensure information is representative, easily accessible, and broadly communicated (City of Fort Collins, 2022). Furthermore, the city has proposed expanding community-scale monitoring to report more spatially representative data and better identify localized impacts, improving ozone monitoring to better understand regional transport of pollutants, and installing monitors or leveraging national monitoring networks that measure $PM_{2.5}$ composition in order to define strategies that can reduce particle pollution (City of Fort Collins, 2019).

Air quality data at the state level contains similar limitations. CDPHE suggests that the data they collect does not measure actual exposure to ozone or $PM_{2.5}$ for individuals or communities, as that data is based on monitors at fixed locations. Therefore, they fail to reflect the variation of air quality within an entire county, that different factors may contribute to the health of different individuals despite elevated air pollution in a particular area, that air monitors tend to be located in urban areas and thus many counties may not have air quality information, and that counties with more than one air monitor utilize the highest reading on any given day, which generalizes the air quality present (CDPHE, n.d.b).

Improving policy interventions in the DMNFR will therefore require actions originating from both the state level down as well as the community level up. Improving monitoring and surveillance of ozone and $PM_{2.5}$ statewide can increase data on air quality exposures and corresponding health impacts. Simultaneously, increasing air quality monitoring at a neighborhood or individual level combined with greater community participation can lead to better health outcomes that reflect local needs and conditions.

This case study demonstrates the differences in air quality data collection, analysis, and dissemination at the state, regional, county, and municipal level. Air quality monitoring and data collection is primarily conducted by CDPHE, with Weld, Larimer, and Adams Counties also implementing smaller-scale monitoring of ozone and $PM_{2.5}$. The two regional MPOs and the cities of Greeley and Aurora appear more disengaged with monitoring local air quality, although they are involved in informing air quality policies through representation on the Regional Air Quality Council. Additionally, this examination of state, county, and municipal efforts demonstrates the trade off that occurs with data granularity and capacity. At the state level, CDPHE's capacity is far greater while their data lacks spatial and temporal specificity, leading to data that is incomplete, inaccurate, and often outdated. On the other hand, smaller entities like those of counties have the ability to monitor health using knowledge of local geography and region-specific methods, but their capacity for data dissemination is far more limited. Overall, this case study demonstrates the need for increased vertical collaboration between health tracking entities to close this gap and bring the best of what each level has to offer in terms of capacity and data specificity. By doing so, states and localities can improve the link between air pollution and respiratory health and target policy interventions that better address environmental health impacts.

Discussion: Current Issues

Following the previous analysis of the current state of the field, it is clear that much progress has been made in terms of environmental public health tracking capacity at national and state levels. However, it also remains clear that the field has areas in which it can improve moving forward to ensure more efficacy of current and future efforts. Among the most pressing large-scale issues include the state of the public health workforce, cohesion and participation between federal and state levels, and difficulties with the integration of complex and robust datasets.

First, it is incredibly clear that public health officials are asked to cover a wide range of issues and work in a generally underfunded field. There is no doubt, though, that a lack of continuity in training has led to a workforce that is lacking standardized training across the nation. Though the initial Pew Commission report calling for a national tracking system was published over two decades ago, current evaluations of the efficacy of the CDC's Tracking Program note that an important component of completing its initial mission includes "building on the network of people (individual and organizational expertise) and the network of information (the national and local Tracking networks and data)" (Eatman & Strosnider, 2017). While some progress has been made, more widespread participation in the Tracking Program will likely produce more continuity in training. Additionally, calls for cross-agency workforce training have been introduced to "lead the creation of technical assistance teams that can boost the capacity of practitioners, conduct HIAs, and integrate data on health with data on the environment" (Koehler

et al., 2018, 40). With a lack of consistency in workforce training, it is reasonable to conclude that national tools like the EPHTN, EJScreen, and EnviroAtlas are underutilized as training tools, suggesting that "[w]hile the data might be useful, if policy makers and key stakeholders are unaware of the potential of the data, [these] resource[s] will not be used to inform decision making" (Fox et al., 2017, 15).

The second substantial issue facing the completion of a robust multi-level tracking effort is the lack of participation from all 50 states in national tracking efforts. As the analyses of the EPHTN and the EJScreen tools illustrated, there are an abundance of regions across the United States where national, state and local collaboration does exist. While achieving full participation may be a tremendous undertaking, it is also critical to ensuring data that is inclusive and demonstrative of "environmental health processes and impacts, local variation in outcomes" and that would allow for the "dissemination of finer spatial resolution data," all of which work to provide a clearer picture of local health problems and contribute to more targeted and effective intervention strategies (CDC, 2022). It is important to note that the original goal of the CDC at the inception of their Tracking Program was to "strengthen the state's ability to access and track environmental public health data for surveillance purposes," and made the specific goals of state and local entities their top priority (Ali et al., 2007, 359). Additionally, the 2000 Pew Commission report noted that there was an urgent need for a coordinated local, state, and national environmental health tracking system, suggesting that until there is full participation of local and state governments, the envisioned network will be lacking in standardization and completeness (Environmental Health Tracking Project Team, 2000).

Finally, the third category of issues with the current state of environmental public health tracking data involves the sheer volume and heterogeneity of data. As has been demonstrated by the examinations of the current tracking tools, there is a need for analysis across scientific, demographic, and geographic timescales, presenting challenges in how data is aggregated and analyzed in a standard way:

> Being able to link health, exposure, and hazard data on an ongoing basis will enable environmental public health practitioners to evaluate the spatial and temporal relations between environmental factors and health. However, detecting even these ecologic relations through the network will require careful analysis and interpretation. The pitfalls of drawing etiologic conclusions based on these ecologic relations are well documented and include issues such as confounding, measurement error, variation in event classification, and migration patterns (McGeehin et al., 2004, 1412).

To make this data analysis more challenging, issues with timeliness and spatial resolution of data have been noted by individuals when attempting to utilize national tools for decision-making and policy formation. Of course, tools that do have high resolution mapping like the EPA's EnviroAtlas are extremely useful but highly limited to the regions that have been identified by the EPA as areas of significance and collaboration. For this level of specificity to be implemented in a more robust fashion and at higher levels, significant progress will need to be made in terms of participation and data mapping technology.

For example, tools like EJScreen face several limitations despite their seemingly exhaustive dataset. As a national screening tool, EJScreen is unable to provide comprehensive data on every environmental and demographic factor relevant to any particular location because some datasets on environmental factors are not available in nationwide databases (EPA, 2022d). For certain

environmental factors, such as drinking water quality and indoor air quality, the EPA states that data does not possess the adequate quality, coverage, and resolution required to be included in EJScreen (EPA, 2022d). The EPA also cautions that demographic and environmental data contains substantial degrees of uncertainty, particularly at small geographic levels such as census tracts, and environmental indicators are only screening-level proxies for actual health impacts (2022d). As a result, the EPA states that EJScreen should not be the single basis used for making a key decision (EPA, 2022d).

This discussion serves as both a commendation of current tools and a recognition of the large challenges still facing the field today. The subsequent recommendations will reflect these acknowledgements and draw upon current suggestions to address the aforementioned ongoing issues.

Recommendations

Expanding Partnerships and Vertical Data Integration

1. Provide adequate funding to the CDC to expand the Environmental Public Health Tracking Network to all 50 states so that a truly nationwide tracking program exists.
    a. *It has been suggested that the CDC may require up to $75 million in funding to adequately expand the capacity of the EPHTN* (Trust for America's Health, 2019). *While this is a significant increase in funds, it suggests that the federal government may be one of the only entities that can encompass the necessary funding, resources, access to data, and reach for a successful and comprehensive tracking database.*
2. Develop further funding to sub-state entities to create more localized tracking programs, integrated data networks, and enhanced public health capacity and expertise in environmental health surveillance.

Environmental Justice and Civic Engagement in Data

3. Utilize citizen science to make data collection more accessible, increase community knowledge of environmental health issues, and combat the limitations of census tract data for individuals who cannot/do not complete their census information.
4. Integrate health data from national and local databases into Community Health Impact Assessments (HIAs) to be utilized for local health and community planning efforts.
5. Increase community outreach from national, state, and local agencies and partners to include community input and knowledge of environmental health tracking efforts and databases for greater accessibility and reach.
6. Increase public knowledge about, and usage of, EJ mapping tools such as EJScreen so that communities, including disproportionately impacted communities, are better informed about environmental health hazards impacting them and empowered to act.

Improving Data Quality

7. Increase the standardization of data collection methods, database features and navigability, and indicators of environmental public health across the board for

participating states to ensure state and local levels reflect and expand upon national database information.

   a. *Some global and private sector work is already being done on bridging the gaps between ontologies and data formatting between sectors. We recommend that agencies on the federal level collaborate with these current methodologies and initiatives to create a larger, more uniform network of health data collection, analysis, and aggregation. Some of the current initiatives include the "Findable, Accessible, Interoperable, and Reusable" (FAIR) Guiding Principles for scientific data management and stewardship led by more than 50 researchers globally. The FAIR principles are contributing to the creation of the NIH's Data Commons platform for data management and cataloging. Further, these principles have aided in the creation of tools like the EPA's CompTox Chemicals Dashboard and are working to standardize reporting formats for clinical and non-clinical data. In the private sector, work is being done to standardize semantic descriptions and ontologies to disease phenotypes, ultimately allowing for comparisons across genotypes, disease pathways, and experimental models. Finally, work is being done with the Environmental Defense Fund (EDF) in collaboration with Google Earth Outreach by attaching mobile sensors to Google Street View cars in an effort to increase data timeliness and resolution. Eventually, the data will be aggregated in a Dataset Search that makes the data accessible and usable for those working in "the environmental and social sciences, government data, and news organizations"* (Comess et al., 2020)

8. Expand the tracking capacity of state and local public health agencies to increase data timeliness and develop more geographically localized, granular datasets that can be utilized in federal, state, and local decision-making.

Developing Public Health Capacity and Leadership

9. Increase and standardize public health curriculum to incorporate knowledge of national and state tracking networks, environmental policy, and health data methods that align with current national and state databases.
10. Build and fund a well-trained and skilled workforce that can collect, analyze, and interpret environmental public health data, translate this data into actionable health and policy interventions, and effectively respond to emerging environmental health threats.
    a. *Specifically, this may look like integrating computing competencies into the training of the public health workforce. Currently, the American Association for Public Health does not require computer skills in the core competencies for Master's of Public Health (MPH) programs in the United States* (Comess et al., 2020)*. By including computer skills as an expected competency of new public health officials entering the field, researchers with the ability to utilize high-level integration technology will make the advancement of more powerful and comprehensive environmental health tools possible.*
11. Encourage horizontal partnerships and collaboration across sectors to establish a consistent understanding of regional environmental health issues, data, and policy.

Limitations and Future Research

Limitations

The lack of total participation of all 50 states in national tracking efforts like the EPHTN, EJScreen, and EnviroAtlas pose limiting factors to the success of the above recommendations. This collective action problem arises from the individuality of states and state politics, lack of funding, limited community knowledge of national efforts, and demands on politicians outside the realm of environmental public health. Also, due to the complex nature of this issue, there exists very little predictability in terms of a timescale for when all 50 states will get on board.

Along the lines of timescales, it is critical to note that a national health database that is constantly up-to-date may be nearly impossible, especially while national capacity building is still taking place. While many of the data timeliness issues can be resolved by incorporating more localized datasets and increasing local collaboration, maintaining the timeliness of an entire national dataset will take a significant amount of time and funding in the future. Additionally, the standardization and growth of the training of public health professionals will necessitate coordination across public health agencies and institutions of higher education, both of which will require first an agreement about standards and then a coordinated and accredited training effort nationwide, likely amounting to at least two decades of reconfiguration and capacity building.

Finally, the confidential nature of health data makes complete public access to all types and indicators of health information an incredibly complicated task. While current databases and vertical partnerships certainly have room for improvement, there will remain limits to the extent and types of data that can be included and displayed for public access.

Future Research

As more work is put into developing a nationwide, standardized environmental public health tracking network, it is imperative to understand how large-scale environmental health datasets are influencing decision-making at the local level. Conversely, it is also important to study how more data can be collected, analyzed, and disseminated at the local level to better inform both local and national policymaking. Future research should explore how environmental public health data is bound to local political factors, capacity, civic engagement, and environmental conditions. Furthermore, future research should look into how to better integrate data at different scales (federal, state, local) to best fit the needs of the appropriate agency or public health concern.

Local-level research should survey residents about perceptions of environmental health hazards in their community and the degree of data availability, accessibility, and usability present for voicing concerns and engaging with decision-makers. In practice, this could take place as a community-wide survey to determine a standardized set of questions to gauge awareness of national tracking databases and local environmental health issues, level of engagement with policy-makers, existing community efforts and the level of community interest in environmental health. This white paper advocates for a community-based approach to address the aforementioned local concerns, as a bottom-up effort would better inform decisions regarding the specific needs of the communities and individuals future environmental policies will impact.

Additionally, this white paper acknowledges the current efforts being put into computing models and data standardization. Specifically, we acknowledge the research being done in Recommendation 7a. and would advocate for future research in these global, national, and private efforts and how these could translate to a federal initiative in the future. We believe there is strong evidence to suggest that data integration, standardization, and communication is not only possible across sectors, but also inevitable. A future study that examines how the best elements of the aforementioned current initiatives could be utilized in a federal program could lay the foundation for a federal program that addresses the inadequacies of current models discussed in this white paper.

Finally, this white paper has examined historical, current, and future initiatives in the public health and environmental policy sectors on a large scale. However, we argue that future research on the historical dissonance between the protection of environmental quality and that of human health may reveal the similar yet uncoordinated timeline of scientific health discovery and the formulation of environmental policies like the Clean Air and Clean Water Acts of the 1970s. A deep dive into historical failings of coordinating health research and policy would likely shed light on patterns that may carry into these fields today, inform future collaborative efforts, and promote a common understanding and shared history for both public health officials and policymakers in terms of the immense progress made and the necessary next steps to improve the fields of environmental health and health policy.

Conclusion

Environmental public health is a rapidly growing and incredibly interdisciplinary field that is increasingly relevant in the face of existing and emerging environmental and health threats. It is clear after this examination that there is an inextricable link between health data and the environment, as the environment contributes greatly to health outcomes, exposures, and hazards. The CDC EPHTN and other national efforts demonstrating the linkages between environmental exposures, demographic indicators, and health outcomes have greatly contributed to increasing the capacity of and accessibility to environmental health data.

However, issues remain in environmental public health tracking, including the lack of environmental surveillance and public health capacity among all 50 states, the lack of up-to-date data available for smaller geographic scales and environmental public health indicators, and funding, workforce, and political limitations at state and local levels that prevent data from being available and actionable. To address these issues, a coordinated response amongst relevant sectors and geographic levels must be informed by local data and needs but implemented and funded on a large, national scale. Over the course of the 21st century, the nation has made impressive strides towards closing the environmental health gap and has laid the groundwork for a more comprehensive and coordinated response to threats to environmental health. While there is certainly room to grow, this paper examines current systems and intends to guide future efforts that address the evolving needs of the environmental public health field.

Finally, it should be stressed that health tracking *must* be inclusive of environmental factors to convey an accurate and effective picture of health trends for various regions and social groups. Not only does the divide between health and environmental data contribute to an incomplete

picture of the state of environmental health, but it also undermines the very cohesion and collaboration across sectors that so many professionals and scholars in the field are calling for. After this analysis and literature review, we advocate that all current and future health data research be inclusive of environmental and social determinants of health to accomplish these goals.

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