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Establishing an Aeroallergen Monitoring Network in the United States: A Framework for Action

Not cleared for distribution beyond CSTE membership

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Synopsis

This framing paper lays out a blueprint for achieving, maintaining, and enhancing a publicly accessible aeroallergen monitoring network. It is a complement to an assessment of pollen monitoring activities conducted earlier this year; the recently adopted Council of State and Territorial Epidemiologists (CSTE) position statement (http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/2016PS/16_EH_01.pdf); and its earlier white paper. It is intended to be a living document, subject to revision as we progress towards achieving this goal. Further, it is intended to fit within the framework of public health improvement strategies that address both the current and emerging threats of aeroallergen exposures.

Background

Approximately six years ago, both the CSTE and the Centers for Disease Control and Prevention (CDC) recognized the need for a national aeroallergen monitoring network to support tracking, forecasting, and research efforts focused on pollen and mold exposures. In light of both the recent trends of increasing pollen exposure and the increasing prevalence of asthma and other allergic diseases, along with the projections of increasing pollen exposure in the coming decades due to climate change, CSTE convened its first pollen summit in May 2015 (summary report available here: http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/PDFs/PDFs2/Pollen_Summit_Final_Report.pdf) .

The need to develop a nation-wide data pollen data repository was the major conclusion from the 2015 Summit. This repository will include data from traditional monitoring systems, but will also be flexible enough to accommodate data from more emerging technologies. Ultimately, though, the purpose of the repository will be to service a variety of critical needs for public health action. These needs include forecasting and health alerts, tracking climate and health trends, and supporting research. In essence, therefore, the primary objective of this repository is to facilitate the process of translating knowledge to effective health promotion activities. Figure 1 illustrates the conceptual framework of this repository below.

The initial focus of attention at the 2015 Pollen Summit was on the development of a pollen monitoring network rather than an aeroallergen network (pollen and mold). This was because much of the scientific literature on outdoor aeroallergen exposure focused on the impacts of pollen. Also, much of the health concern regarding mold exposure has been concentrated on the indoor environment. At the same time, the Summit participants recognized that outdoor mold exposure is a public health concern in its own right, and that climate factors such as extreme precipitation and humidity can increase both the levels and potency of mold spores. Further, very few monitoring stations measure pollen exclusively. Consequently, CSTE's focus evolved from a pollen monitoring network to an aeroallergen monitoring network.

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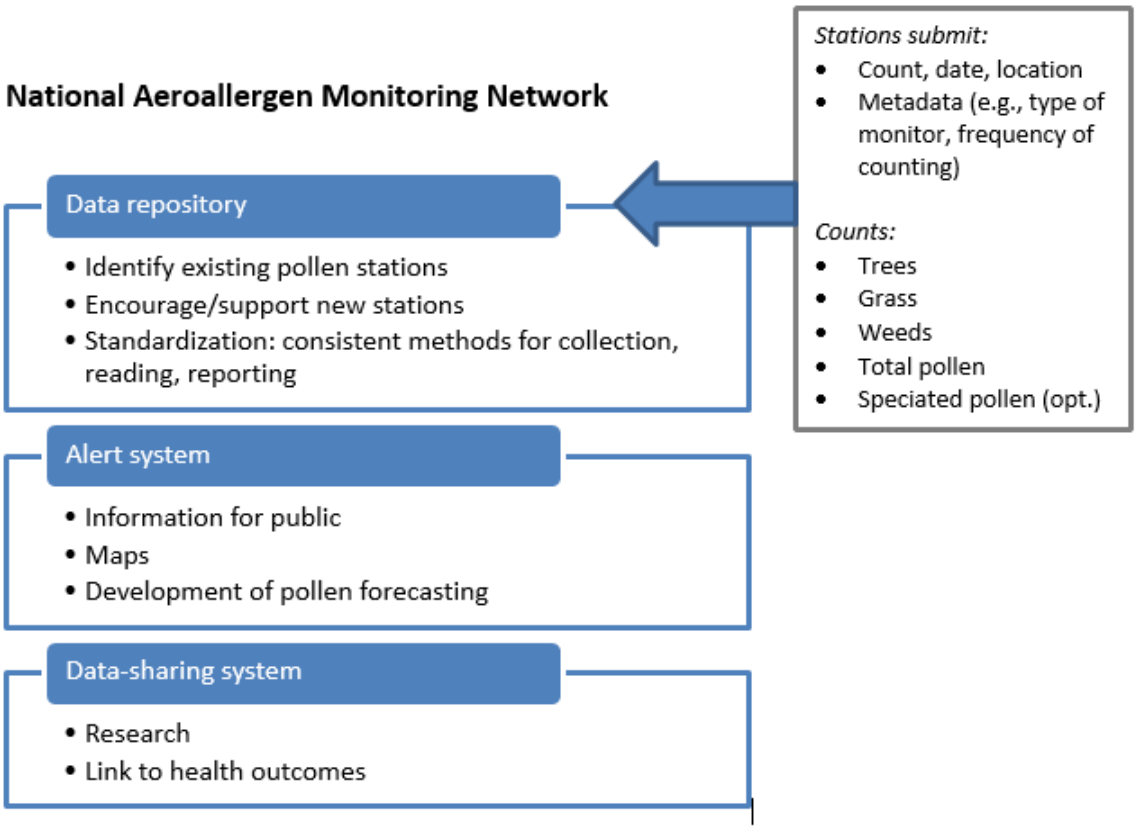
Figure 1. National Aeroallergen Monitoring Network Conceptual Framework



Why the Existing Aeroallergen Monitoring Network in the United States is Insufficient

One likely set of questions regarding the proposal to develop a national aeroallergen monitoring network concerns the assumption that such networks already exist. Two oft cited examples are the National Allergy Bureau and Pollen.com. Although Pollen.com is commonly referenced as a source of allergen information and forecasts, its website provides no detail concerning the underlying data that inform its products, and it considers the basis for its forecasts as proprietary information (https://www.pollen.com/help/about). Consequently, this company has not been considered in the development of this framing document.

CSTE and the National Allergy Bureau

The National Allergy Bureau (NAB) is the section of the American Academy of Allergy, Asthma & Immunology's (AAAAI's) Aeroallergen Network responsible for reporting current pollen and mold spore levels (https://www.aaaai.org/global/nab-pollen-counts/about-the-nab). The Aeroallergen Network is comprised of approximately 84 pollen and spore counting stations in the United States staffed primarily by trained AAAAI member volunteers who donate their time and expertise. The stations use standardized air sampling equipment to collect airborne pollen and spores which are then examined microscopically.

CSTE's commitment to establishing a national aeroallergen monitoring network is broader-based than the National Allergy Bureau (NAB) and could eventually serve as a long term repository for the station data. While CSTE does not see itself as the home for this repository, it does see itself as the catalyst for bringing such a system into being. As such, CSTE has a broad time horizon, on the order of decades, that addresses current as well as long term aeroallergen health impacts. By contrast, the NAB mostly serves the more immediate needs of allergists and their patients.

In the shorter term, there are two critical health tracking needs that are not currently met by the National Allergy Bureau. First, CSTE believes the NAB monitoring sites lack the sufficient temporal and spatial resolution to cover the entire country, particularly with respect to rural communities. Also, largely because the NAB is a partnership among independently operated monitoring sites, obtaining data for research projects can be very difficult.

These concerns notwithstanding, however, CSTE views NAB as a critical partner in the development of this aeroallergen network. The NAB sites represent a critical foundation of consistent and high quality data as a result of its training and certification processes. CSTE's intent, therefore, is to build on NAB's accomplishments. To that end, CSTE is working closely with NAB members Dr. Charles Barnes and Dr. Leonard Bielory from Rutgers University around a shared objective of using the NAB sites as the foundation for expanding the network. This expansion includes the addition of non-NAB sites and incorporating alternative approaches for assessing pollen exposure. These alternative approaches include working with the National Atmospheric Deposition Program, the National Phenology Network, as well as exploring remote sensing, automated collection stations, and low cost sensors.[1] In addition, we plan to coordinate with the Department of Agriculture's crop and forest information and with the state/federal ambient air quality monitoring networks.

The network development plan also includes objectives around optimizing the uses of the data for the public benefit (e.g., epidemiological and climatological research; National Oceanic and Atmospheric Administration (NOAA) style forecasting; modeling and forecasting; disease management) and ensuring long term sustainability as a result of successfully engaging medical and public health stakeholders.

CSTE's ultimate goal is the realization of a monitoring network that is sufficient to address this currently under-recognized and under-resourced problem. As significant as these challenges are, they are going to increase in severity with global warming. This places added importance on our establishing a robust monitoring system now.

Proposed Framework for a National Aeroallergen Monitoring Network

A diagrammatic representation of the aeroallergen monitoring network is presented (See Figure 2). While the data repository (database) is its foundational element, it is not the only element. Rather, the repository represents the platform upon which information from the data providers is translated into actionable knowledge for a variety of data users. The full network, therefore, includes: 1) the database and database management system; 2) the data providers; 3) health care

[1] See below for more detailed descriptions

providers; 4) people with asthma and allergies; 5) health, climate, and environmental science researchers; 6) meteorologists; 7) journalists and media outlets (for information dissemination and reporting); 8) governmental agencies; 9) supportive foundations and organizations; and 10) the general public.

The proposed national aeroallergen monitoring network unfolds from three central elements: 1) the data sources and providers; 2) the repository itself, in which data are collected, stored, analyzed, shared, and disseminated; and 3) how the network is sustained, including its location ("home"), organizational structure, governance, and funding.

Data sources and providers

An underlying motivation for the national aeroallergen monitoring network is the need to gather relevant temporal and spatial information from a large and growing number of data sources. In this regard, it is important to emphasize that the network intends to build on the successful mechanisms already in place to monitor and communicate aeroallergen information, not to create a system *de novo*. Indeed, the intent here is to use the certified fixed site counting stations as the foundation for more extensive sets of observations to be included in the network once they are found to be sufficiently reliable indicators of aeroallergen exposure. These additional observations can come not only from non-certified, fixed station sites, but also from emerging monitoring technologies (such as automated sites and low cost monitors) and recordings of phenological trends gathered through a variety of citizen-based efforts.

Citizen engagement through the promotion of non-traditional data gathering activities can both expand the knowledge base and promote the development of a motivated community of active participants in the network. Such motivation can be nurtured through opportunities provided by personal monitoring and engagement in citizen science projects (including school curricula development).

Finally, regardless of the data provider, adequate training on aeroallergen identification is a necessary precondition for inclusion in the network. While all aeroallergen monitoring locations likely have some form of training, training is a precondition for certification by the NAB. In Canada, Aerobiology Research Laboratories (ARL) has developed its own training program for technicians responsible for the analysis of all their aeroallergen data. With respect to citizen science based initiatives, the National Phenology Network could serve as a useful model as training is included in all of its programs.

Repository/Database.

The data repository in the form of a database constitutes the basic "engine" by which data inputs are translated into actionable knowledge outputs. The core functions of this repository are as follows: 1) collect; 2) store; 3) analyze; and 4) share. In this respect, it is understood that the major challenge to the success of the network rests with its ability to engage the participation of the data providers by emphasizing the public benefits associated with the results of the analyses. These benefits include the variety of analytical methods that can be employed, the ways that

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results are shared, and how this sharing can improve health from both an individual and collective perspective.

Collect

Aeroallergen samples in the United States are collected, counted, and stored locally through a decentralized network including health care facilities, academic institutions, and public institutions. In Canada, the process differs in that only the collection occurs locally, with the counting, storage and the analysis being conducted centrally through the ARL. In all cases, sample collection should be done in a manner that assures data quality and consistency. At the same time, it is recognized that depending on the end use, a rigorous level of detail need not always be required. For example, grouped pollen counts (e.g., total counts) may be suitable for certain purposes. In any case, metadata on the samples must include the information important for further analysis, including timing of the pollen season, frequency of sampling, and level of speciation.

Store

The repository's robustness depends on its ability to gather a diverse array of data inputs and to store them on a data management *platform***.** This platform can be structured in such a way that it can optimize opportunities for analysis by a wide array of credentialed data users, as would be accomplished by a relational database. A cardinal principle underlying the development of database management systems is that potential functionality be incorporated into the design at the outset, even if they are not implemented immediately, and not considered as incremental additions. The CSTE Asthma and Allergy Workgroup already has sufficient resources regarding both fixed site monitoring and more distributed forms of data collection that can assist with the visioning of these design aspects. Within the framework provided by the broad design vision, implementation of the repository can proceed incrementally through a focus on fixed sampling sites. It is important that the elements of the initial sample collection – data quality/consistency and metadata – are carried over as the data are incorporated into the repository. Also important is the assurance that the information technology infrastructure is sufficiently secure to prevent access of the raw data by unauthorized users.

Analyze

Beyond providing merely a means to collect and store data, the repository's platform can also serve as a means to analyze aeroallergen levels using a variety of data inputs through its relational database. It can also provide a means of analyzing aeroallergen data in relation to other meaningful physical and health variables. These variables include, but aren't limited to: weather, air quality, land use patterns, climate, and health outcomes associated with both aeroallergens and other environmental allergens**.** Climate data include important information from satellite observations (remote sensing), climate normals, changing plant hardiness (floristic) zones, and

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paleoclimate data. While it is unrealistic to consider that the aeroallergen repository will house all these supplementary data, it is reasonable to plan the structure of the database to accommodate such data uploads as appropriate.

The repository's database can enable the development of important reports that are not currently available because of limited data access and analytical resources. These include geographical reports focused on particular sites or regions. These reports can provide summaries of annual or seasonal aeroallergen levels, as well as trend analyses over the past several years or even decades. Reports can be supplemented with other types of information contained in the database, such as weather, climate, air quality, and land use.

Further, with the availability of validated sets of modeling inputs of sufficient spatial granularity, forecasting can be greatly improved on both a near-term and seasonal basis. Near-term forecasting can inform the issuance of health alerts (i.e., early warning systems), either to the general public or in a way that be incorporated into the personal health management plans of those with asthma and allergies. Local seasonal forecasting, informed by a rich database on pollen trends, can estimate the emergence, peaks, and closure of pollen seasons that are of critical importance to medical management.

A robust dataset of aeroallergen measurements over many locations as well as over several years can also provide the input for longer-term modelling, especially if there are analyzed in relation to other sets of data contained in the database. This modelling is crucial for estimating the future health burden of allergic diseases as we increasingly realize the importance of climate and other environmental factors in the development and exacerbations of these diseases. Further, model projections focused on aeroallergen can be viewed within the larger framework of ecologically mediated health impact projections associated with other environmental allergens, disease vectors, waterborne pathogens, and air pollution.

Share

There are a variety of means by which the data collected, stored, and analyzed in the repository can be shared with stakeholder partners. One category comprises specified users, either the data providers themselves or defined user groups (e.g., health care practices, epidemiologists, other scientific researchers). These sharing arrangements may likely require the development of specific data sharing agreements to ensure that the data and analyses are used properly once released from the repository. The sharing arrangements may also warrant the implementation of secure data transmittals or web portals.

Non restricted data sharing through the repository can also build on the various dissemination mechanisms already in use by the aeroallergen monitoring stations to convey important information to the public. These communication mechanisms include public web portals, email distribution lists, and connection with various media outlets (such as local television, radio, newspapers, and weather web sites). They can also incorporate more recent or emerging technologies such as social media and application program interfaces (APIs). Finally, there is the potential for communication tools to be developed that can service a variety of educational and outreach programs (e.g., through schools or allergists' offices).

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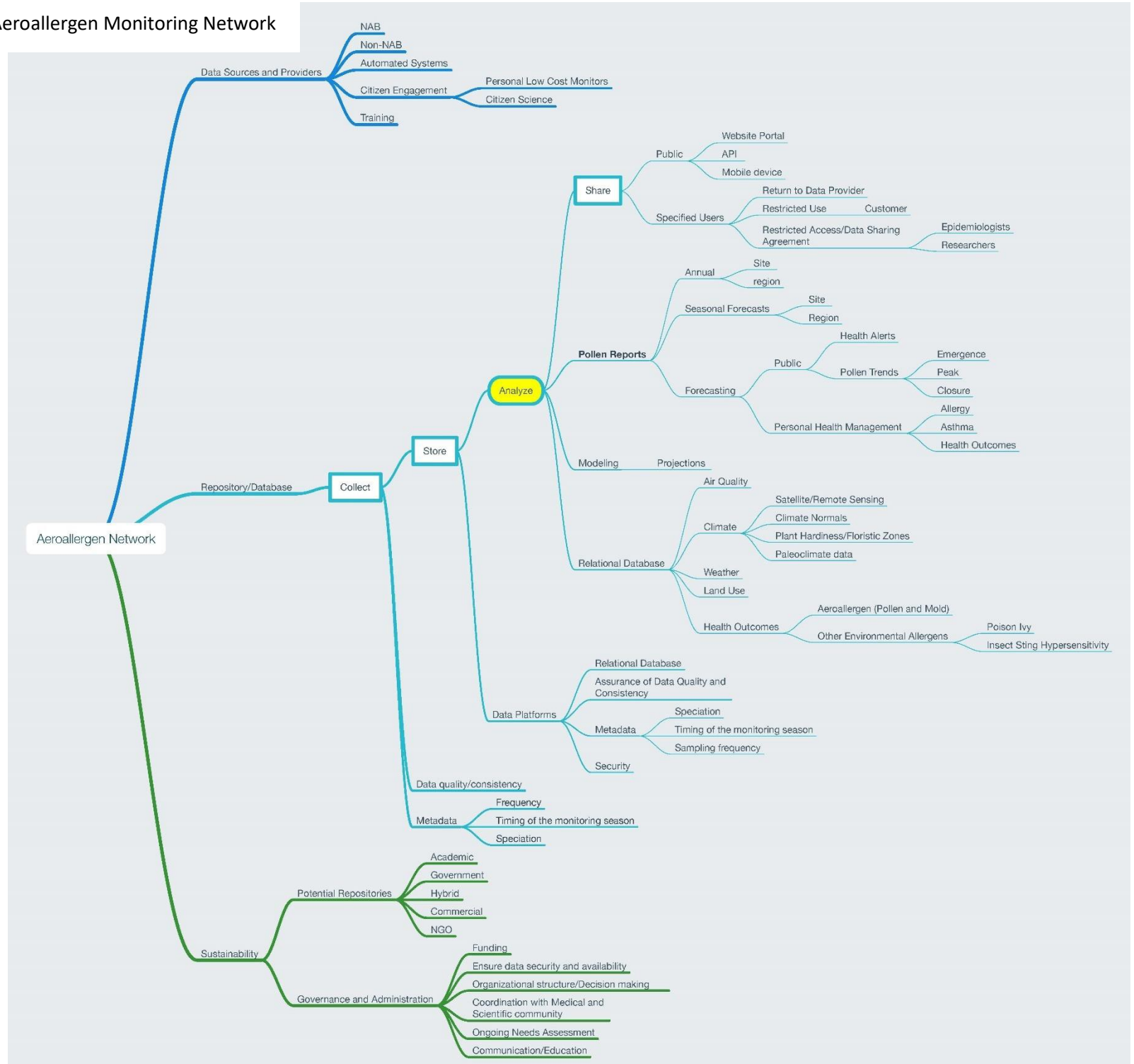
Sustainability

Current priorities regarding sustainability focus first on establishing a location ("home") for the repository as the foundation for the network as well as on putting into place the administrative and governance structures to ensure that the network is operated properly and effectively. Establishing a "home" for the data repository is not a trivial exercise. It essentially involves the alignment of the goals and functional needs of the monitoring network with the capacity and willingness of potential host institutions. Fortunately, our current network of stakeholders reflects a diverse array of interested sectors. These sectors include: 1) public agencies (state and federal); 2) academic institutions; 3) non-governmental organizations; 4) private sector enterprises; and 5) hybrid private/public partnerships. Collectively, such diverse representation provides a source of useful examples of potential network attributes to guide future conversations on establishing the repository.

Irrespective of where the repository is housed, much thought will have to go into how the network will be managed and governed. Above all, the network's organizational structure and decision making processes need to be consistent with the underlying reasons behind the creation of the monitoring network in the first place, as detailed in the Position Statement. The **Statement of Guiding Principles**, which appears at the end of this document, provides an initial articulation of guiding values, which can potentially form the basis of an organizational charter. Also, as mentioned above, administrative systems will to be put in place to ensure data security and availability. Further, to keep current and relevant, the network needs to incorporate into its operating plan an ongoing needs assessment as well as continual engagement with appropriate medical and scientific communities. Moreover, the network needs to design and implement a communication and education strategy focused on conveying its public benefit in order to enhance stakeholder engagement and ensure funding. Assurance of long-term support and funding is critically important, especially in light of the priority to track aeroallergen exposures and health impacts relative to our changing climate.

While there are many existing programs that can inform the dialogue on network sustainability, specific programs identified in the development of this paper include the following Environmental Public Health Tracking Program, US National Phenology Network, National Atmospheric Deposition Program, National Centers for Environmental Information, Aerobiology Research Laboratories, and the National Allergy Bureau. These programs are described briefly in the next section. CSTE also anticipates more in depth conversations with those entities responding to the recently adopted position statement (http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/2016PS/16_EH_01.pdf). Collectively, these stakeholders could comprise a potential list of participants for the 2017 Pollen Summit, where CSTE would move beyond the conceptual framework to matters of implementing the proposed framework

Figure 2. Aeroallergen Monitoring Network



Summary of Selected Programs

CSTE recognizes that there are many opportunities for collaboration with other entities in the development of the aeroallergen monitoring network. In addition to the National Allergy Bureau (cited above), the following represent an initial list of agencies and organizations with whom a dialogue around the vision articulated in this framing paper can be initiated or enhanced. As CSTE proceeds with this dialogue, it will seek to expand both the number and the diversity of potential partners.

Environmental Public Health Tracking Program (http://ephtracking.cdc.gov/showHome.action)

The Center for Disease Control and Prevention's (CDC) Environmental Public Health Tracking Program (EPHT) was established approximately 15 years ago following a Pew Commission report that outlined our nation's inability to assess the environmental determinants of major chronic diseases, including asthma (http://www.jhsph.edu/research/centers-and-institutes/center-for-excellence-in-environmental-health-tracking/pew_technical_report.pdf). In fact, the present focus on aeroallergen monitoring had its beginnings in the EPHT as a special project of one its workgroups. In addition, the EPHT program contains many elements relevant to the development of aeroallergen monitoring network, including: 1) partnerships between CDC and other federal agencies, state/local health departments, and academic institutions; 2) processes for determining consistent data and measures; 3) data analysis projects; 4) expertise in analysis, visualization, and reporting (AVR) tools, including display on secure and public web portals; 5) standard protocols for data sharing agreements and metadata.

USA National Phenology Network (https://www.usanpn.org/)

The USA National Phenology Network (USA-NPN) had its origins back in the 1950s, with over 2,500 citizen volunteers began tracking lilac phenology under the direction of Dr. Joseph Caprio at the Montana State University. In the early 2000s, the Network developed a more expanded focus, in close collaboration with the National Ecological Observatory Network (NEON). In 2007, it was established as a formal entity at the University of Arizona, with major funding from the US Geological Survey. The USA-NPN's National Coordinating Office and Advisory Committee, consisting of individuals from agencies and academia, regularly provide guidance on the structure, function and planning of the organization. The Network is a consortium of individuals and organizations that collect, share, and use phenology data, models, and related information. The USA-NPN manages *Nature's Notebook*, a project focused on collecting standardized ground observations of phenology by researchers, students and volunteers. The organization also fosters phenology communities of practice, and the development of tools and techniques to support a wide range of decisions made routinely by citizens, managers, scientists, and others, including decisions related to allergies, wildfires, water, and conservation. Its new project focused on juniper phenology is designed to assist researchers in the integration of data from citizen scientist observers of juniper phenology, satellite images of tree green-up, and data from health centers to better understand the dynamics of seasonal allergies.

National Atmospheric Deposition Program (http://nadp.isws.illinois.edu)

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The National Atmospheric Deposition Program (NADP) is a cooperative effort between many different groups, including federal, state, tribal and local governmental agencies, educational institutions, private companies, and non-governmental agencies. Established initially in 1977 by the US State Agricultural Experimental Stations, its mission is to measure atmospheric deposition and study its effects on the environment. NADP station locations (currently 350+) are distributed across North America and now in Asia and South America as well. The NADP is located at the Illinois State Water Survey within the Prairie Research Institute at the University of Illinois-Urbana-Champaign. The NADP is a public, nonprofit, unincorporated, interstate association of parties. It is structured as a cooperative program which represents coordinated efforts of 100+ funding partners and individuals from federal, state, academic, and private organizations who operate monitoring sites, report data, and oversee research activities related to atmospheric deposition. The NADP consists of the following five networks: 1) The National Trends Network (NTN, established in 1978, currently 270 sites) measures weekly concentrations and wet deposition fluxes of acidic species, base cations, and nutrients in precipitation. 2) The Atmospheric Integrated Research Monitoring Network (AIRMoN, 1992, 6 sites) measures the same species as NTN, but collects samples on a daily bases and preserves them by refrigeration to better preserve nutrient species. 3) The Mercury Deposition Network (MDN, 1995, 112 sites) measures weekly concentrations and wet deposition fluxes of elemental mercury, plus methylmercury at selected stations. 4) The Atmospheric Mercury Network (AMNet, 2009, 24 sites) measures gaseous ambient concentrations of mercury fractions including elemental, oxidized and particulate-bound mercury. 5) The Ammonia Monitoring Network (AMoN, 2010, 103 sites) measures gaseous ambient concentrations of ammonia. During this past year, NADP has collaborated with the Climate Change Institute at the University of Maine to develop a means of extracting and analyzing pollen grains from its monitoring filters. Initial results are promising. If successful, this approach could immediately provide a tool for assessing pollen emergence, peaks, and closure at regional, national, and even international levels.

U.S. Department of Agriculture **(**www.usda.gov**)**

The United States Department of Agriculture (USDA) is an important source of data to interpret the spatial and temporal pattern of aeroallergen concentrations and for forecasting their potential change over time due to climatic factors. For example, the USDA's Economic Research service provides land use and land cover estimates, including grassland pasture and ranges, cropland, and forest-use land. The National Agriculture Statistics Service (www.nass.usda.gov) provides county-level data of crop types on a year-to-year basis. Information about land use and crop types will assist in interpretation of aeroallergen concentrations from cropland, tree, and vegetation source regions. In addition, USDA Climate Hubs (http://www.climatehubs.oce.usda.gov/) provide data for forecasting the potential impact of climate change on crops and drought conditions.

National Centers for Environmental Information. (http://www.ncdc.noaa.gov/)

The National Centers for Environmental Information (NCEI), formerly the National Climatic Data Center, is part of the National Oceanographic and Atmospheric Administration (NOAA). For over 60 years, NCEI has been responsible for preserving, monitoring, assessing, and providing public access to the nation's climate and historical weather data and information. It

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hosts and provides access to one of the most significant archives on Earth, with comprehensive oceanic, atmospheric, and geophysical data. NCEI's top priority during the near future is to build on the full spectrum of atmospheric, oceanographic, coastal, and geophysical products and services that the Data Centers delivered. NCEI's climate data intersect with a number of areas relevant to the aeroallergen monitoring network, including agriculture, air quality, education, forestry, health, insurance, and landscape design.

Aerobiology Research Laboratories (www.aerobiology.ca)

Aerobiology Research Laboratories (ARL), located in Ottawa, Ontario, is Canada's only source for outdoor allergen levels. ARL's monitoring network includes 30 collecting sites throughout the country that send their samples on a daily basis to a central laboratory for analysis. Analyses are conducted by trained and certified technicians. The standardization of sampling methodology and analysis ensures data comparability, along with the fact that ARL owns and maintains all the aeroallergen counting equipment. ARL also has data sharing agreements regarding the dissemination of its analyses back to the pollen counters as well as to other customers. Agreements are also made with governmental agencies, research institutions, and other businesses on the use of the data to ensure data integrity and maintenance of intellectual property. Having been in operation for over 20 years, ARL uses its accumulated knowledge to conduct pollen forecasts on a both a seasonal and daily basis.

National Allergy Bureau (www.aaaai.org/global/nab-pollen-counts/about-the-nab)

The National Allergen Bureau (NAB) is a section of the American Academy of Allergy, Asthma and Immunology's (AAAAI) Aeroallergen Network and is responsible for reporting current pollen and mold spore levels. The Network consists of approximately 84 counting stations in the United States (as well as one in Canada and six in Argentina) staffed primarily by AAAAI volunteers who undergo a AAAAI training and certification process. Historical data are not available through the NAB, though arrangements can be made on a case by case basis with the individual counting stations. Also, pollen counts from the NAB are based on actual counts, which reflect the real day to day weather events. The NAB recognizes, however, that predicted counts may appear on many websites and may be based on pollen data from previous years and weather forecasts.

Key Attributes of the Proposed Framework

Emphasizing the Systems Approach: Data Input and Information Output

Of special note is the central position of the **Analyze** step, featured in yellow in Figure 2. . The analysis component represents the key active element of the network: the process of synthesizing aeroallergen data in ways that meet the needs of the various data users. From a systems perspective, this step represents the conversion of *data input* into *information output*, a process ultimately determined by the needs of the end users.

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Conceptually, addressing both the data inputs and the information outputs require versatility. The data input activities recognize that there are both traditional and emerging approaches to monitoring pollen exposure. These approaches include direct monitoring at fixed sites (as is currently being done); distributed low cost sensors; and indirect assessment through modeling and phenological observations. They also include manual and automated counting applications. This diversity of inputs is necessary if the repository is to address the information needs of the users, specifically around the need to provide temporal and spatial resolution in ways that can prevent exacerbations of asthma and allergies.

From an output perspective, the end users differ in their needs regarding the type and quality of information. There are certain users, such as academic researchers, who may require quantitatively precise data sets across monitoring stations, with consistent sampling methodologies and quality assurance procedures. For other uses, such a general local pollen forecasts on either a daily or seasonal basis, quantitative precision may be less important than the ability to characterize local patterns of aeroallergen emergence, relative intensity, peak releases, and the end of the seasonal exposure.

The opportunities of the network include the ability to engage an inclusive and robust network development process that meets multiple user needs. Also, with this robust engagement, we have the opportunity to solicit funding support from various private and governmental sources.

Conversely, the fact that we have potentially a large constellation of project partners can complicate the ultimate decision regarding where the repository will be housed. We will also run the risk that it could be spread too thin in an attempt to be as inclusive as possible in responding to user needs and quickly overwhelm analytical resources and capabilities. Finally, the development process will require consideration that the optimal solution balances the contribution of all partners, with no single partner or group of partners can unduly influence the integrity of the project or detract from its main goal of serving the public good. These challenges and opportunities will be addressed in the next phase of the CSTE aeroallergen network development process.

Providing a Context for Specific Aeroallergen Related Initiatives

As important as the objective of establishing a national aeroallergen monitoring program is, it is also important that the network development promotes state and local activities that can serve as pilots for more intensive public health research and action. Despite lack of successful funding proposals, collaborative ideas have been developed in states such as Minnesota and Maine (See Appendix). The network could also provide a foundation upon which targeted research proposals are developed, vetted, and launched, addressing one or multiple areas of its inclusive needs and aspirations.

Assessing Public Health Actions

As stated above, the ultimate goal of the aeroallergen monitoring network is to motivate, inform, and evaluate public health actions. In this respect, it is important to promote ways of disseminating the pollen information in a timely way, ensuring that the information produced through the repository can help guide health protective public policies.

Multiple dissemination methods were identified through the CSTE Pollen Assessment. These have included relatively passive methods (such as posting on a web site or responding to requests) to a variety of active distribution mechanisms (television/radio/newspapers, email/phone, social media, etc.)

Further, some environmental decisions can have the effect of either increasing or decreasing aeroallergen exposure. For example, while promoting green space development through tree planting serves a critical public need, there may be unintended local consequences if increased pollen exposure from certain allergenic tree species results. Conversely, we know from the air pollution literature that approximately 80% of our exposure to particulate matter occurs while we are indoors. Consequently, use of air filtration and air conditioning systems might provide health benefits to those with asthma and allergies by reducing intrusion of pollen and other similarly sized particles in indoor environments.[2]

These examples illustrate the network's importance to the evaluation of the effectiveness of public health actions. The network is critical to our evolving understanding of the relationships between aeroallergen exposure and health impacts, particularly in light of environmental threats and our steadily worsening climate conditions. Evaluation research is thus instrumental to continuous improvement strategies that help us better manage respiratory health risks.

Statement of Guiding Principles for a US Aeroallergen Monitoring Network

In this concluding section of the framing document, the emphasis is not on the technical details regarding the establishment of the aeroallergen monitoring network. Rather, it is on the core values and public health principles which should serve as the foundation for the path forward. Above all, these values and principles embody the central importance of trust among the data providers, the database managers, analysts, and end users in establishing a network in which the public benefit is of paramount importance. It also recognizes the fact that for the network to be successful, it must be a collaborative effort across governmental, non-governmental, academic, and private sectors.

1) Serve as the premier repository of publicly available aeroallergen data in the United States, both from established and emerging technologies, with appropriate metadata by:

- Ensuring open access to sampling methods
- Seeking research-based consensus of best practices
- Ensuring data quality and integrity via a documented quality system with consistent sample analysis, data processing, and data distribution.

[2] See for example, ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers, *ASHRAE Position Statement on Filtration and Air Cleaning*, January, 2015.

2) Oversee the development of effective training programs on aeroallergen counting and analysis.

3) Provide scientific peer review for forecasting models on daily, weekly, and seasonal bases.

4) Provide a means to analyze raw data from a diversity of end user group purposes. These user groups include: clinicians; researchers; individuals; governmental agencies; and media.

5) Create and sustain a stable funding mechanism to ensure both adequate spatiotemporal resolution of aeroallergen data and a means to assess the ever emerging impacts of climate change.

6) Ensure the appropriate use of ambient aeroallergen data in addressing acute and chronic human health concerns by limiting real-time data distribution to qualified subscribers.

7) Make historical data available for bona fide research purposes by publishing them in open data repositories.

8) Develop data sharing agreements between primary data providers and appropriate end users to ensure that the data are used and disseminated appropriately to further our public benefit.

9) Maintain and enhance dialogue with relevant health and scientific organizations, data providers, and other stakeholders to ensure continued best practice and an ongoing assessment of needs and opportunities.

10) Promote and support cross disciplinary research opportunities in areas related to air pollution, climate, phenology, land use, and overall allergic disease burden.

11) In collaboration with network partners, develop and implement communications strategies designed to convey network attributes and benefits to a variety of audiences.

12) Serve as an international collaborative consortium to develop consensus methods and best practices for ambient sampling methods, laboratory procedures, quality assurance, data processing, and information distribution.

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Appendix: State Based Initiatives to Better Understand Aeroallergen Exposures through a Collaborative Implementation Approach

The following proposal ideas from Minnesota and Maine are examples of pollen monitoring initiatives that could be supported by this network. They are presented here for illustrative purposes, as other examples may exist.

Minnesota Pollen Monitoring Proposal (August 18, 2015)

Date: August 18, 2015

Subject: Feasibility study of a statewide pollen monitoring network for Minnesota

Author: Brenda Hoppe, PhD, MN Climate and Health Program

Background:

Factors related to climate change have led to increases in the amount of pollen released by allergenic plants, as well as the overall length and severity of the pollen season. These changes have serious health consequences not only for allergy and asthma sufferers and people with respiratory diseases, but for everyone exposed, especially children, given that large amounts of ambient pollen increase the risk of allergic sensitization (and potentially the onset of asthma) in otherwise healthy individuals. In addition, land use and community planning decisions can amplify climate change impacts on pollen, further exacerbating the problem.

Recent evidence demonstrates that the ragweed season has already lengthened across areas of the Midwest, including Minnesota, where the season has grown by 21 days since 1995 (Ziska et al., 2014). For many allergy sufferers, ragweed pollen is the primary trigger of hay fever. Rates of ragweed sensitization are especially high in Minnesota compared to other states (Quest Diagnostics, 2011), although the cause of this is unclear.

Data on pollen types, quantities, and distribution patterns are needed in order to implement effective public health responses and inform environmental control strategies, such as eradicating allergenic plants or landscaping with less allergenic species. Many state agencies, such as the Minnesota Department of Transportation and the Department of Natural Resources, promote the planting of native plants and trees but are in need of more information on those species that are a potential allergenic source. Based on current knowledge there is only one pollen monitor active in the state of Minnesota which is certified by the National Allergy Bureau, ensuring collection of consistent and reliable pollen data. This monitor is located in south Minneapolis. To what

extent this single monitor represents pollen risk across the metro area is currently unknown. Pollen risk has been shown to vary substantially across time and space (Katz & Carey, 2014), necessitating a more comprehensive monitoring network. To the extent that the density of pollen monitors can be increased in both urban and rural communities across Minnesota, characterization of exposure and potential risk can be enhanced and mitigation strategies implemented locally that may lead to a reduced public health burden and more sustainable, pro-pollinator/pro-people community landscaping.

Purpose: To produce a detailed accounting of the components necessary to develop, maintain, and utilize a pollen monitoring network in order to mitigate health impacts and inform sustainable planting practices, as well as pilot a select methodology that will also enable evaluation of existing data.

Plan:

- Identify those agencies, organizations, or individuals with a key role to play in developing, implementing and maintaining a statewide pollen monitoring network in Minnesota, including potential data users, such as health care providers, people with allergies, researchers, and public health professionals.
- Convene these individuals through a series of workshops to conduct a feasibility study that would detail the necessary components of a monitoring system, technology options, existing resources (including roles and responsibilities of system administrators and partners), major challenges, costs, funding opportunities, issues of data quality, and potential uses of collected data (with emphasis on public health research and interventions).
- Investigate existing technologies for pollen monitoring, select and implement a monitor, and pilot a method for collecting and maintaining data from this monitor for at least one pollen season. There is potential for "piggy-backing" pollen monitors on to existing statewide systems that collect and maintain data on ambient air quality or weather conditions.

Deliverables:

- A compendium of workshop proceedings that will serve as a blueprint for development and implementation of a pollen monitoring network in Minnesota. This final report will also be a useful resource for numerous other states that are currently grappling with how to implement or expand pollen monitoring within their own jurisdictions. As a case study of state-level resources and challenges related to pollen monitoring, it will also provide important feedback to interested federal agencies, such as the CDC, EPA, USDA, USFS, and others.

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Pilot data from a new pollen monitor that will be used in a to-be-determined proximity to Minnesota's only existing certified pollen monitor (in Minneapolis) in order to: 1) compare and contrast trends in spatial and temporal variability of pollen distribution to expand our understanding of the catchment area for a single monitor, and 2) test methods for capturing, uploading, accessing, and maintaining data from a pollen monitor, likely by utilizing an existing data collection system. Creating a Prototype Statewide Pollen Monitoring Network

Maine Pollen Monitoring Proposal (December 12, 2012)

Maine Ad Hoc Pollen Monitoring Group

Purpose: To develop a one-year pilot project designed to provide seasonal pollen counting data on a systematic basis.

Spatial Resolution

- Currently we have two pollen/aeroallergen monitoring sites. Bangor and Presque Isle, representing two of three Maine's climate zones (northern and southern interior).
- At a minimum, we should expand this network to include a coastal zone site (possibly in the Portland area).
- Other options include monitoring sites representing Maine's 7 geophysical zones or 8 air quality regions.
- Farmington's monitoring effort was discontinued earlier this year and there are no plans to resume it.

Monitoring stations versus counting stations

- We agreed that it would make the most sense not to increase the counting stations, but rather have a number of monitoring stations feeding a common counting site (e.g., Bangor).
- Affiliated Labs could serve at the counting site for all monitoring sites except for Presque Isle (which is currently being operated by the MicMacs under an EPA grant).
    - Affiliated Labs does both pollen and mold counting
    - It has developed a database (or spreadsheet?) so that it can now enter the aeroallergen counts electronically.
    - It also has a new microscope camera to take pictures of emerging or unusual pollen/mold spores.
    - With this camera, it can construct a reference atlas of pollen and mold species that we are likely to encounter throughout the pollen season. This atlas could also be region specific.
    - It should be feasible to identify multiple monitoring locations. For example, Farmington (Franklin Memorial) might resume pollen monitoring as long as the counting and identification of predominant species is done elsewhere.

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- It might be possible to address transportation issues by sending the samples through the hospitals' courier system.

Coordination with Other Activities

This specific pollen monitoring project could be integrated into a set of broader phenology activities coordinated by the University of Maine http://umaine.edu/signs-of-the-seasons/ This expanded scope could serve to place the project within the context of comparing ecological and human health indicators, similar to what the Maine CDC's Climate and Health project is now doing now with vector borne diseases, ticks, and temperature/precipitation trends.

Evaluation

- This one year pilot will be evaluated for the purpose of determining both the value and the design/operation of an ongoing monitoring system.

Cost issues:

- Aside from the Presque Isle, pollen counting to date has been done on a largely volunteer basis. This situation will have to change if we want to develop a sustained network with multiple monitoring locations.
- One possibility is to contact Affiliated Labs regarding a direct contract either directly with them or their individual technicians (who could have access to the microscope/camera after hours).

Funding sources:

- None identified to date.
- It might be possible to get funding through a Supplemental Enforcement Project (e.g., through EPA), though these projects generally focus on one time equipment expenditures.

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