October 2018

Guidebook for Developing a Community Air Monitoring Network

Steps, Lessons, and Recommendations from the Imperial County Community Air Monitoring Project

TRACKING CALIFORNIA
INFORMING ACTION FOR HEALTHIER COMMUNITIES

Comite Civico Del Valle, Inc.

SCHOOL OF PUBLIC HEALTH
UNIVERSITY of WASHINGTON

Guidebook for Developing a Community Air Monitoring Network

Steps, Lessons, and Recommendations from the Imperial County Community Air Monitoring Project

October 2018

TRACKING CALIFORNIA
INFORMING ACTION FOR HEALTHIER COMMUNITIES

Comite Civico Del Valle, Inc.

SCHOOL OF PUBLIC HEALTH
UNIVERSITY *of* WASHINGTON

Guidebook for Developing a Community Air Monitoring Network

Steps, Lessons, and Recommendations from the Imperial County Community Air Monitoring Project

October 2018

Lead Author:

Michelle Wong, MPH, *Tracking California*

Contributing Authors:

Graeme Carvlin, PhD, *University of Washington**

Paul English, PhD, MPH, *Tracking California*

Catalina Garzón-Galvis, MCP, *Tracking California*

Humberto Lugo, *Comite Civico del Valle*

Daniel Madrigal, MPH, *Tracking California*

Luis Olmedo, *Comite Civico del Valle*

Maxwell Richardson, MPH, MCP, *Tracking California*

Alexa Wilkie, MHS, MS, *Tracking California*

Reviewers:

David Chang, MA, *Tracking California*

David Holstius, PhD

Edmund Seto, PhD, *University of Washington*

Christian Torres, *Comite Civico del Valle*

** = former affiliation*

Contact:

Tracking California
850 Marina Bay Parkway, P-3
Richmond, CA 94804

www.trackingcalifornia.org
Phone: (510) 620-3038
Email: info@trackingcalifornia.org

Acknowledgments:

We would like to thank past and present team members of the Imperial County Community Air Monitoring Project, our academic and technical consultants, the Community Steering Committee, the Technical Advisory Group, community site selection participants, and air monitor hosts for their contributions to this project.

Suggested citation:

Tracking California, Comite Civico del Valle, and University of Washington. Guidebook for Developing a Community Air Monitoring Network: Steps, Lessons, and Recommendations from the Imperial County Community Air Monitoring Project. October 2018. Richmond, CA. www.trackingcalifornia.org/community-air-monitoring-guidebook

Research reported in this publication was supported by the National Institute of Environmental Health Sciences of the National Institutes of Health under Award Number R01ES022722. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Cover Photo: Comite Civico del Valle

Formerly the California Environmental Health Tracking Program, Tracking California is a program of the Public Health Institute in collaboration with the California Department of Public Health.

Foreword

Exposure to air pollution is increasingly being recognized as an urgent public health problem, with known effects moving beyond respiratory disease, lung cancer, heart disease, and premature mortality to include associations with diabetes and intellectual deficits. Air pollution is also being exacerbated by climate change, with incessant wildfires and heat waves increasing in length and intensity. But the stories of how air pollution affects the daily lives and long-term health of our families and neighbors are the tragic result of our inability to control these insidious pollutants.

One reason why some communities have been unable to make progress in addressing air pollution is the lack of access to information needed to take action. In Imperial County, California, with funding from the National Institute of Environmental Health Sciences, we formed a collaborative partnership between our community, academic researchers, a non-governmental public health organization, and government. Together, we took a community-led, citizen science approach to provide more timely, actionable data on particulate matter air pollution. The low-cost sensors used to collect these data are making it possible to democratize science, while providing greater data accessibility and public transparency. Scientific rigor and community priorities were successfully integrated to establish the Imperial County Community Air Monitoring Network. The Network has resulted in increased capacity within the community to address and solve air quality issues.

This guidebook documents the process and considerations for creating this Network. It is our hope that other communities, academic researchers, and government agencies will be able to use this guidebook to apply our model in other locations. Communities have a right to breathe clean air. We believe that by using our project's participatory and science-based approach, communities can take a lead role in conducting science and take charge to eliminate pollution so that their neighborhoods can grow and prosper.

Luis Olmedo

Executive Director

Comite Civico del Valle

Paul English

Principal Investigator

Tracking California

Table of Contents

Part 1: Before You Begin 1

Chapter 1: Introduction 3

Chapter 2: How to use this guidebook 7

Chapter 3: What is a community air monitoring network? 11

Chapter 4: The Imperial Air Project model 17

Part 2: Getting Started 23

Chapter 5: Establishing your team 25

Chapter 6: Engaging community members and other stakeholders 31

Chapter 7: Defining the purpose of the network 39

Part 3: Monitoring Hardware and Software 43

Chapter 8: Components of an air monitor 45

Chapter 9: Choosing a sensor 49

Chapter 10: Data storage and processing 55

Chapter 11: Quality assurance and control 61

Part 4: Network Design and Implementation 69

Chapter 12: Deciding where to put the monitors 71

Chapter 13: Obtaining permission to install monitors 79

Chapter 14: Monitor installation, operation, and maintenance 83

Part 5: Using and Sustaining a Community Air Monitoring Network 91

Chapter 15: Disseminating the air monitoring data..93

Chapter 16: Communicating air monitoring data on the web 99

Chapter 17: Analyzing air monitoring data 107

Chapter 18: Sustaining the network...113

Chapter 19: Conclusion..117

Resources cited 121

Appendix A: Project contributors 125

Appendix B: Example budget line items..129

Appendix C: Outreach and recruitment materials 133

Appendix D: Hardware components used in IVAN AIR monitor..................................139

Appendix E: Assessing the performance of your conversion algorithm.......................141

Appendix F: Monitor host recruitment materials 143

Appendix G: Description of data feed script to generate IVAN AIR data 149

Glossary of terms...151

This page left blank intentionally.

Part 1:
Before You Begin

Chapter 1: Introduction

Chapter 2: How to use this guidebook

Chapter 3: What is a community air monitoring network?

Chapter 4: The Imperial Air Project model

This page left blank intentionally.

CHAPTER 1

Introduction

Gathering data on air quality in your community can be the first step toward reducing air pollution

Air pollution is a major threat to human health worldwide, and communities across the country are now taking their own actions to address it at a local level. With the growing availability of low-cost air sensors, more communities are conducting their own air monitoring to better understand and address air quality issues.

In California, which has the worst air pollution in the country, residents have taken a lead in making positive environmental change in their communities. In Imperial County, residents face a variety of air pollution sources that contribute to levels of particulate matter (PM) that often exceed California regulatory standards, sometimes for long periods of time. These sources include windborne dust, unpaved roads, pollution blown in from the large industrial city of Mexicali in Mexico, vehicle crossings at the U.S.-Mexico border, agricultural field burning, and the drying Salton Sea. The county also has the highest rates of emergency room visits and hospitalizations for asthma among school-age children in California.

Imperial County has only 5 regulatory PM monitors to cover over 4,400 square miles (an area nearly the size of Connecticut), resulting in limited information about air quality. Individuals and communities in the county have long expressed a need for more information about local air quality in order to reduce air pollution and improve health.

An aerial image of Imperial County, California. The area's economy is based largely on agriculture and its shared border with Mexico. The Imperial Valley is surrounded by mountains to the east and west, and polluted air can often become trapped in between these mountains. *Photo courtesy of Treesarecool510, CC BY-SA 4.0 https://commons.wikimedia.org/w/index.php?curid=39438463.*

The **Imperial County Community Air Monitoring Project (Imperial Air Project)** was initiated in October 2013 to fill the need for more community-level air quality monitors. Funded by the National Institute of Environmental Health Sciences, the 5-year project was a collaborative effort among Tracking California (formerly the California Environmental Health Tracking Program), Comite Civico del Valle, and University of Washington. A Community Steering Committee of local community advocates and concerned residents played a key role in guiding project activities. Academic consultants and a Technical Advisory Group also provided scientific input. See Appendix A for a full list of project contributors.

Using community participation and air monitoring best practices, an innovative community air monitoring network of 40 PM monitors was established throughout the county. The goal of the community air monitoring network is to provide residents with accurate, real-time, local air quality data that can also be used in scientific analysis.

This document describes the steps, lessons learned, and recommendations from the Imperial Air Project. While each community has its own unique air monitoring interests, the experiences and lessons learned from this project may provide useful guidance to communities interested in developing their own community air monitoring networks.

Partner organizations for the Imperial Air Project

Comite Civico del Valle (CCV)- Founded in 1987 in Imperial County, California to improve the lives of disadvantaged communities, CCV believes informed people build healthy communities. Through partnerships, CCV improves access to health services, research, community service programs, and environmental justice to disadvantaged communities by way of education, capacity building, and civic participation. Learn more at www.ccvhealth.org.

Tracking California- Tracking California is informing action for healthier communities. By compiling, analyzing, and sharing data to identify and understand pollution and disease, Tracking California works to ensure that all Californians have the opportunity to live in healthy communities protected from environmental hazards. Formerly the California Environmental Health Tracking Program, Tracking California is a program of the Public Health Institute in collaboration with the California Department of Public Health. Learn more at www.trackingcalifornia.org.

University of Washington (UW)- The Seto Research Group at UW's Division of Environmental and Occupational Health Sciences conducts research that has the potential for societal health benefits, exploring new technologies such as the use of mobile devices and low-cost sensor systems to infer the relationship between individual and population behaviors and how they relate to exposures to environmental and workplace hazards. Learn more at www.edmundseto.com.

Academic consultants from the University of California, Los Angeles and George Washington University also contributed technical expertise to the project.

This page left blank intentionally.

CHAPTER 2

How to use this guidebook

If you are considering setting up a community air monitoring network, this guidebook can help you better plan and implement your project

What is the purpose of this guidebook?

This document aims to provide guidance for implementing a particulate matter community air monitoring network (CAMN) using the model developed by the Imperial Air Project. It outlines the major steps and considerations taken to develop the project's air monitoring network, called IVAN AIR.

This guidebook does not provide step-by-step instructions related to the construction, deployment, operation, or maintenance of monitors. It is not intended to be a substitute for the knowledge, training, and hands-on experience required to successfully implement a community air monitoring network.

Instead, the information provided here can guide communities in key aspects of developing a CAMN, including: engaging community and other stakeholders, selecting monitoring equipment, setting up data infrastructure, designing a quality assurance and control protocol, selecting sites and installing monitors, analyzing and disseminating data, and sustaining a successful network.

Other community air monitoring resources

Many community air monitoring resources have been developed and/or compiled by federal, state, and local government agencies and others. We recommend reviewing these resources. Examples include:

- Environmental Protection Agency
  Air Sensor Toolbox and Guidebook
  [https://www.epa.gov/air-sensor-toolbox]
  [https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook]
- California Air Resources Board
  Community Air Monitoring Toolbox
  [https://ww2.arb.ca.gov/capp-resource-center/community-air-monitoring]
- South Coast Air Quality Management District
  Air Quality Sensor Performance Evaluation Center (AQ-SPEC)
  [http://www.aqmd.gov/aq-spec]

While many of the activities described here can be adapted for different situations, the guidebook outlines the Imperial Air Project model, which emphasizes a community-led process to develop a CAMN that produces data that are scientifically valid and useful to the community.

It is also important to acknowledge that the Imperial Air Project is one of many community air monitoring efforts. This document does not review or describe other such efforts, nor does it attempt to be a definitive guide to community air monitoring. In addition, because technologies for air monitoring advance at a rapid pace, some of the specific technologies used by this project may become outdated quickly. This guidebook aims to focus on components and considerations of an overall approach to developing a CAMN that will still have relevance as technology advances.

This photo, from 1973, was taken as part of a large multiagency study to better understand air pollution in the Los Angeles area. Despite the aging of the original photo, the high pollution levels are evident in the photo, and over 40 years later, Southern California still has some of the highest levels of air pollution in the country. *Photo courtesy of Gene Daniels (NARA record: 8463941) - U.S. National Archives and Records Administration.*

Who is this guidebook for?

The guidebook was developed for community-based organizations[1] that are interested in establishing their own CAMNs. The guidebook may also be of interest to other audiences— such as regulatory agencies, non-governmental organizations, and university researchers— that are supporting or partnering in community-led air monitoring efforts.

This guidebook describes the development of a CAMN that measures particulate matter (PM2.5 and PM10) continuously and is intended to remain in operation over the long-term. However, some concepts and recommendations described here may be applicable to other air monitoring efforts.

1. A community-based organization is one whose core function is to serve the community in which it resides and whose staff live in the community. Community-based organizations are the primary audience for the guidebook because the Imperial Air Project model uses a community-led approach in which resources, capacities, decision-making, and responsibilities for operating the CAMN are centered in or shifted to the community.

How is this guidebook organized?

The guidebook is divided into five parts:

- Part 1: Before you begin
- Part 2: Getting started
- Part 3: Monitoring hardware and software
- Part 4: Network design and implementation
- Part 5: Using and sustaining a community air monitoring network

Each part contains brief chapters related to that topic, each describing key activities and decisions for implementing a CAMN. Where applicable, descriptions of specific Imperial Air Project activities are provided as examples. A resource list, appendices with example materials and technical details, and a glossary are provided at the end of the guidebook.

We recommend reading through the entire guidebook to get a sense of the scope of establishing a CAMN from start to finish, including considerations for sustainability and long-term maintenance. Recognizing that each community is unique, your organization's interest or ability to follow or adapt the project's model will be determined by your own goals, resources, capacities, partnerships, and timeline.

Why is no budget information provided?

Specific cost information is not included in this guidebook. The cost of developing and operating any community air monitoring network will vary extensively depending on many factors including:

- Location of your community, as incomes and other costs can vary greatly within and outside of California
- Size (number of monitors) and scope (number of pollutants being measured) of the network
- Monitoring technologies selected
- Skills and expertise available within your organization
- Extent to which existing processes, technologies, and infrastructure from your own or other organizations can be leveraged
- Funding available for establishing a CAMN

Instead, throughout the guidebook are "budget tips" to call your attention to potential cost considerations, and guiding principles around allocation of funds are described further in Chapter 4. Additionally, a list of possible budget line items is provided in Appendix B.

CHAPTER 3

What is a community air monitoring network?

Before starting a community air monitoring network, make sure it is the right choice for your organization and your community's needs

How is "community air monitoring network" defined?

For the purposes of this guidebook, a community air monitoring network (CAMN) is a collection of air monitors located throughout a community or region that:

- Is established and operated by a community-based organization
- Is intended to be long-term
- Aims to measure ambient air quality (versus measuring pollutants from a single specific source)
- Continuously measures air pollution
- Collects data that are made available in real-time to the public

What other kinds of community air monitoring are there?

Depending on a community's particular air quality concerns and the technology and resources available, other types of community air monitoring (besides CAMNs) may be more useful or feasible. For example, other successful community air monitoring efforts have included:

» **Fenceline monitoring:** Monitoring to measure air pollution coming from a specific source.

» **Grab samples/bucket brigade:** Monitoring to measure air pollution during specific times (possibly corresponding to an air pollution event) at specific locations. This monitoring is often used when technology for continuous monitoring is not available or affordable.

» **Personal monitoring:** Using a wearable monitor that collects information about air quality that an individual is exposed to as they go through their day.

» **Indoor air monitoring:** Installing an air monitor inside the home can help distinguish between inside and outside air quality or identify potential indoor sources of pollution.

» **Temporary stationary monitoring:** Monitors are installed in a location temporarily. This may be useful to assess air quality during a specific time period, such as the construction of a building.

» **Mobile monitoring:** Monitors are moved frequently in order to get a spatial picture of air quality. These monitors are generally installed on or inside a vehicle.

How does a CAMN work?

A CAMN consists of a network of air monitors that are installed at buildings or other sites within the selected community. The monitors continuously measure levels of specific air pollutants and send that information over the internet to a server, where the data are stored in a database. The data then undergo various quality control measures and calculations before being displayed on a website or downloaded in datasets.

What does design and implementation of a CAMN entail?

The basic process to deploy a CAMN is shown below in Figure 1.

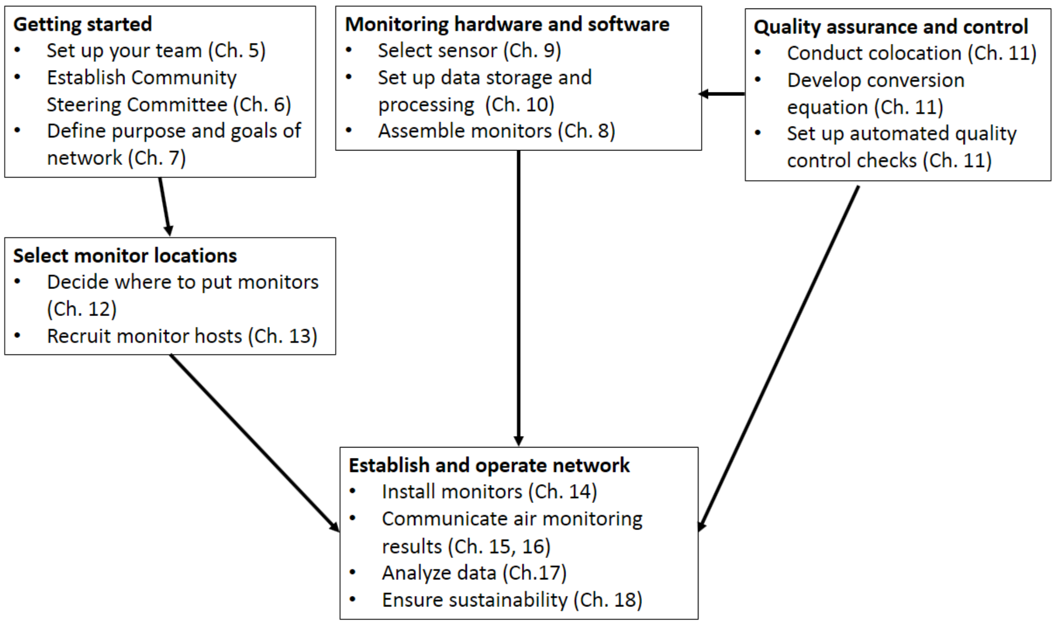


Figure 1. Process to deploy a CAMN.

What might a CAMN be useful for?

In general, data from a CAMN may be useful for:

- Providing information and notification when the air quality is poor, so individuals and institutions such as schools can take appropriate action
- Understanding geographic and time trends for air quality
- Providing data for research studies and other analyses
- Informing policies and programs
- Supporting community organizing and advocacy

It is important to note that CAMNs use low-cost sensors (the hardware inside the air monitor that measure air pollutants). These sensors are not approved by government regulatory agencies for use in regulatory actions, and their data cannot be used to prove violations (see Chapter 9). However, they can provide supplemental data that may be useful to communities, academic researchers, agencies, and others.

Is a CAMN right for you?

First, it is important to identify some basic needs around air monitoring to determine which type of air monitoring would best address your community's air monitoring needs. Questions to consider include:

- Do you want to measure the general air quality within your community?
- What pollutants are you interested in monitoring?
- Are you concerned about a specific source of pollution?
- Is there a specific decision or policy you are trying to influence?
- Do you want to collect data continuously or during specific times of the day (for example, when there are odors)?
- How long do you want to monitor for?
- What do you want to do with the data?

Project partners and stakeholders can help you to further identify your monitoring needs and define the purpose of the network (Chapter 7).

It is important to note that implementing a CAMN can be very time and resource intensive, depending on the sensor you select and your desired level of data quality and control. However, there are also multiple potential benefits from establishing a CAMN. Reading through this guidebook can give you a better sense of the skills, expertise, and resources needed to embark on this process and how to plan your approach.

IVAN AIR

For the Imperial Air Project, the CAMN is operated by Comite Civico del Valle. Real-time data from the CAMN are made available on IVAN (Identifying Violations Affecting Neighborhoods), a community-based environmental reporting website (https://www.ivan-imperial.org/). Collectively, the network and website are referred to as **IVAN AIR.**

Children playing soccer at Heber Elementary School adjacent to an agricultural facility in 2017. An indoor gymnasium has now been built in this location. The need for local air quality data to protect children's health was a key reason for developing IVAN AIR. *Photo courtesy of Comite Civico del Valle.*

This page left blank intentionally.

CHAPTER 4

The Imperial Air Project Model

The Imperial Air Project model emphasizes community engagement and scientific integrity

What are the guiding principles used in this model?

The guiding principles of the Imperial Air Project model fall into two broad categories.

First, the CAMN should ultimately be community-owned and operated.

- A community-based organization should have a lead role in initiating, planning, and implementing the CAMN. This can be in partnership with other organizations or agencies.
- The broader community should be engaged in designing and implementing the CAMN.
- The process should build capacity within the community-based organization to operate the air monitors and conduct or direct other activities related to ongoing maintenance of the CAMN.
- The community-based organization should have full access to and decision-making rights for the CAMN data.

Secondly, data from the CAMN should be relevant and reliable.

- » Data from the CAMN should be made available to communities in accessible, understandable, accurate, and useful formats.
- » Data from the CAMN should undergo quality assurance and control measures.
- » Monitors should be actively maintained and repaired or replaced when needed.

How are community members engaged in this model?

A community-based organization cannot entirely represent the varied experiences, knowledge, or perspectives of the community members it serves. Therefore, the Imperial Air Project utilized a tiered community participation structure (Figure 2) that provides a variety of opportunities and methods for community members to participate in the development and implementation of the CAMN.

In addition to a community organization as a lead partner in the project, a Community Steering Committee of community leaders, advocates, and concerned residents (Chapter 6) provides important guidance in the implementation of project activities. Other residents can participate in selecting monitor locations, hosting monitors, and other project activities.

Community-based organization **(project lead/co-lead)**	• Initiate, design, implement, and make decisions about project activities • Operate the CAMN • Conduct outreach and dissemination activities
Community Steering Committee (CSC)	• Help formulate project goals • Guide and participate in project activities • Identify actions that should be taken based on the data
Other community participants	• Help identify, collect data about, and select air monitor locations • Host air monitors • Use and share CAMN data

Figure 2. Tiered community participation structure for Imperial Air Project, with the top level representing the deepest level of engagement.

Budget tip

Apply the guiding principles of the Imperial Air Project when planning a budget

- **Distribute funds equitably:** It is essential that the budget distribution among community, academic and other partners is transparent and equitable. In particular, community-based organization staff should be fully compensated as professional public health professionals and not assumed to be providing volunteer or in-kind time simply because the project benefits their community or their position is underfunded by necessity. In the Imperial Air Project, over 30% of the total annual budget went to the community partners, reflecting the significant amount of work conducted.
- **Prioritize opportunities to build community:** Whenever possible and practical, funds should be spent on developing local technical capacity for air monitoring, rather than funding partners or consultants to conduct the same work. In the Imperial Air Project, for example, the original plan was for the technical partners at University of Washington (UW) to install and operate the monitors. However, based on community interest, the project shifted to a capacity-building approach, where Comite Civico del Valle hired community members to be trained by UW to install, operate, and eventually assemble the monitors based on UW's original design. UW staff provided technical assistance and support throughout this process.
- **Compensation for community volunteers:** Participation as a volunteer on a Community Steering Committee or in other project community engagement processes (such as site selection) can be time-intensive and should be compensated whenever possible. Compensation can take the form of stipends for meeting attendance, store gift cards, meeting meals and refreshments, and direct reimbursement of travel or childcare costs.

How is scientific integrity maintained in this model?

The Imperial Air Project model was designed to produce research-quality CAMN data that can be used by communities and others to understand and take action on air quality levels. To do this, the model emphasizes several principles:

- » **Data quality:** The implementation of quality assurance and control procedures helps to ensure good quality data.
- » **Transparency:** Clear communication about the project methods and data limitations supports the appropriate use of data and reproducibility of this work.
- » **Utility:** Decisions about the CAMN design and the communication of air monitoring data are made to ensure that data are relevant and accessible to community members and can be used to improve individual and community health.

Is there more information about the Imperial Air Project?

An overview of the project has been published[2], and other resources related to the Imperial Air Project are listed in the Resources section of this guidebook. You can also learn more at [www.trackingcalifornia.org/imperial-air-monitoring].

The project used a variety of methods to obtain input and guidance from the CSC and other community participants, including by vote. *Photo courtesy of Comite Civico del Valle.*

---

2. English PB, Olmedo L, Bejarano E, et al. 2017. The Imperial County Community Air Monitoring Network: A Model for Community-Based Environmental Monitoring for Public Health Action. Environ Health Perspect. 125:074501. Available online at: [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5744720/].

Funding details for the Imperial Air Project

The Imperial Air Project was developed through a 5-year, $2 million grant from the National Institutes of Environmental Health Sciences (NIEHS) that was secured by Tracking California (formerly the California Environmental Health Tracking Program) in collaboration with partners at Comite Civico del Valle, University of Washington, and others.

Most efforts to develop a CAMN will not require as extensive a budget or timeline. In developing the Imperial Air Project, a lot of upfront effort was spent in the exploration of methods and planning, which was extensive because there was not an existing model for this type of effort.

Additionally, the NIEHS grant was for a research project that required the application of results for public health actions. Therefore, in addition to costs associated directly with developing the CAMN, the project budget included costs for conducting specific data analysis projects, community action planning and implementation, participating in national research meetings, grants management activities, and developing scientific publications.

Much of the Imperial Air Project experience can now be used by other communities to substantially reduce their costs, such as by adapting our monitor siting criteria or using our data storage, processing, and display infrastructure by joining the IVAN Network (learn more at http://www.ivanonline.org/). Other community air monitoring projects may also have lessons and infrastructure that you can leverage.

This page left blank intentionally.

Part 2:
Getting Started

Chapter 5: Establishing your team

Chapter 6: Engaging community members and other stakeholders

Chapter 7: Defining the purpose of the network

This page left blank intentionally.

CHAPTER 5

Establishing your team

Before setting up a community air monitoring network, identify the skills and expertise needed on your team and determine who will provide them

What skills and expertise are needed?

A variety of skillsets and expertise are essential in the implementation of a CAMN. While specific tasks are described throughout the guidebook, the general capacities needed may include:

- Equipment assembly, installation, and maintenance
- Software and web application development
- Web design and user experience design
- Data management
- Data analysis
- Air quality science and technology
- Meeting planning and facilitation
- Outreach and stakeholder engagement
- Communications and materials development
- Project management

After reading through this guidebook, you should have a better idea of the specific activities and skillsets needed to implement your CAMN. Before beginning your project, you should determine how these activities will be accomplished, and by whom.

It is unlikely that all of these skills will be available within a single organization's staff. Therefore, you may have to reach out to other organizations or individuals for certain expertise. Everyone's respective roles and responsibilities should be understood and delineated upfront, and a plan should be established for communication and collaboration between all parties.

Even if a specific capacity does not currently exist within your community organization, consider ways in which current staff or other community members may gain this expertise during the development of the CAMN, so that you build more local capacity to sustain and manage the network (see Chapter 18).

What is the role of outside entities in a community-led effort?

As noted in Chapter 2, this guidebook is intended for a CAMN project which is led or co-led by a community-based organization. However, the implementation of a CAMN is a complex endeavor. There may be other community, government, academic, non-governmental, or industry entities that are or should be involved in this effort. They may be involved as partners, paid consultants, advisors, or stakeholders.

Your community-based organization should have a meaningful and genuine leadership role in the development and implementation of the CAMN. With an effective process, this can occur under a range of circumstances, such as: your community-based organization could have its own funding to develop a CAMN, you may be asked by an outside group to join an existing effort, or you may initiate the effort in collaboration with other partners.

Budget tip

Budget for management and communications

Often, project budgets don't adequately account for the amount of time and effort needed to maintain effective administration and communication among project leaders and staff, particularly when they may reside in different institutions. Do not underestimate the time needed to effectively conduct project management and team communications.

Effective partnerships among technical and community partners require frequent communication and will benefit from the building of trust– so consider allocating additional time for regular project team phone calls and in-person meetings at fixed intervals.

How can effective and equitable partnerships be established to develop a CAMN?

As described above, establishing a CAMN will likely require building and sustaining a trusting and equitable partnership between your community-based organization and your partners, including academic, nongovernmental, and government entities. Strategies for accomplishing this include:

- **Clearly defining the roles and responsibilities** of each partner to ensure that critical project functions are covered.
- **Ensuring adequate funding and resources** for each partner to carry out their defined work.
- **Establishing a clear and agreed upon structure** for effective coordination and communication among partners. This can include regularly scheduled meetings with the entire project team (with a designated facilitator and a note-taker), as well as less frequent project and strategic planning sessions.
- **Defining capacity-building and learning objectives** for each partner, so that efforts to support each partner's needs can be integrated into the project plan. For example, community partners may prioritize eventually taking on roles that strengthen community ownership and sustainability of the CAMN, such as monitor installation and maintenance. Academic and research partners may identify professional capacities to enhance, such as communicating research methods and results more effectively to the public.
- **Creating a jointly-written collaborative agreement,** such as a Memorandum of Understanding (MOU), to document these partnership agreements may be a useful activity, particularly if your collaboration involves new partners. Agreements can include shared goals, guidelines for joint decision-making and communication, roles and responsibilities across partners, and other relevant agreements (such as how CAMN data and projects will be shared or used).

It can be more challenging to implement these strategies if not all partners are actively involved in the planning of the project. Ideally:

- **All project partners should collaborate to secure funding for the CAMN.** This can provide an opportunity to better ensure that the division of labor among partners is clear, all critical project functions are addressed, and resources are adequate and equitably distributed.
- **The community-based organization should be a lead or co-lead on any grant proposals.** For scientific grant proposals, having someone from the community included as a co-investigator can affirm the value of the community's contributions while expanding opportunities to co-author publications and secure additional funding.

» **Include processes to support and enhance the partnership in the project plan.** This can include training opportunities, evaluation activities, or other methods to improve partner communication and provide additional support.

Roles and responsibilities within the Imperial Air Project

Roles and responsibilities within each project will be different based on project goals and each partners' capacities. These may change over time as new capacities are developed. While each partner was engaged with all aspects of the Imperial Air Project, the roles and responsibilities were generally distributed as:

Tracking California provided epidemiological, community engagement, health education, and project management expertise. Responsibilities included:

- Developing and coordinating the community engagement, site selection, and data dissemination strategies
- Planning and facilitating CSC meetings, community site selection and action planning meetings
- Managing grants, facilitating project team calls, and reporting to funders
- Providing scientific oversight and fulfilling requests for CAMN data

Comite Civico del Valle provided community outreach, education, and organizing expertise, as well as local knowledge and relationships within the community. Responsibilities included:

- Recruiting and engaging with CSC members, site selection participants, air monitor hosts, and other stakeholders
- Planning and hosting IVAN AIR launch celebrations and other community events
- Providing and updating IVAN web platform to display air monitoring data

- Conducting outreach, education, and advocacy related to IVAN AIR data
- Assembly, installing, operating, and maintaining monitors

University of Washington provided expertise on exposure assessment, air monitoring technologies, and spatial analysis. Responsibilities included:

- Designing and assembling monitors; and training Comite Civico del Valle staff to assemble, install, and maintain monitors
- Conducting quality assurance (colocation, validation) and establishing quality control protocol
- Designing and implementing data storage and processing infrastructure
- Research analysis using IVAN AIR data

Additional research consultants at the University of California, Los Angeles and at George Washington University provided expertise on the health effects of air pollution and on the monitoring of ambient particles, respectively. Software development and web design consultants also contributed to the project.

An effective element of the Imperial Air Project partnership was knowledge sharing and local capacity-building. Comite Civico del Valle's Humberto Lugo joined co-investigator Edmund Seto from University of Washington to learn how to install the first community air monitor and soon after took on all monitor installation activities. *Photo courtesy of Comite Civico del Valle.*

CHAPTER 6

Engaging community members and other stakeholders

Engaging community members and other stakeholders can facilitate and strengthen project activities, increase awareness and support of the CAMN, and build community capacity

Why engage other community members?

Since a single community-based organization may not adequately represent the diverse perspectives within a community, it is important to identify and include other community members who may be interested in a CAMN. Creating opportunities for diverse community members to participate throughout the development of a CAMN can also contribute to its success by:

» Leveraging their capacities, knowledge, and social networks

» Building capacity and awareness in the community about air quality and its potential health impacts

» Strengthening local credibility of the CAMN and the data that it produces

» Increasing the likelihood that CAMN data will be used to support actions that reduce exposure and pollution sources

Community members who may be interested in getting involved in a CAMN project can include individuals who are:

- Living or working in close proximity to sources or air pollution
- Personally affected by or caring for others with health conditions related to air quality such as respiratory illness
- Interested in gaining technical skills and knowledge that are transferrable to career pathways in science and technology fields

Finally, interested community members could include parents, students, teachers, childcare providers, school administrators, physicians, nurses, respiratory therapists, and workers in occupations such as agriculture, manufacturing, and trucking.

To identify community members to engage in the project, begin by leveraging your organization's existing relationships with community stakeholders. These relationships can include ties to:

- Other community-based organizations
- Parent and student groups
- Churches and other places of worship
- Local advisory boards and committee
- Multi-stakeholder coalitions
- Professional associations
- Social clubs and networks
- Community leaders

Budget tip

Community meetings may have many small costs

The costs of CSC meetings, or any event where community members are involved (such as meetings to select monitoring sites or share project results), can include meeting room rental, meals and snacks, participation stipends and travel reimbursements, supplies and photocopies, translation and simultaneous interpretation costs, and any travel or other costs for any partners or consultants who may be invited to the meeting.

Why establish a Community Steering Committee?

One way to engage interested community members is through a Community Steering Committee (CSC). The CSC should be established early in the project to:

- **Provide guidance and decision-making on CAMN activities,** such as refining goals for community monitoring, defining the monitoring area or priority communities, and determining data display and dissemination needs.
- **Participate in activities to implement the CAMN**, such as identifying possible monitoring locations, recruiting monitoring hosts, conducting outreach and education about the project, and strategizing and implementing community actions.
- **Provide feedback on project implementation,** such as evaluating the project and making recommendations for improvement.

Your organization may already have or belong to an existing advisory group which can fulfill the functions of a CSC.

Who should join the Community Steering Committee?

The CSC should include community leaders, advocates, youth, representatives from other community-based organizations, and other concerned citizens whose participation would help the CSC to fulfill its role.

For the Imperial Air Project, representatives from government agencies, academic institutions, or industry were not included in the CSC (see Appendix A for a list of past and present members). This decision was based on a desire to keep the CSC's decision-making power within the community and to create a safe space for community members to discuss ideas and provide input. However, you may wish to include other types of stakeholders in your CSC. For the Imperial Air Project, a Technical Advisory Group (described later) functioned as a way to get input from non-community stakeholders.

When determining CSC membership, consider having diverse representation by geographic area, area of expertise/interest, familiarity with your organization, and demographic factors such as age, race/ethnicity, and gender.

Furthermore, recruit members who have a strong interest in the project, would likely work well in a diverse group setting, and have availability to participate in the CSC throughout the term of the project (i.e., until the CAMN is complete).

Appropriate recruitment methods will vary based on the individuals you have identified and may include phone calls, emails, personal invitations through trusted intermediaries, and so forth. You may also wish to develop communication materials, such as formal invitation letters and factsheets, about the CSC and about the project (see Appendix C).

Imperial Air Project CSC Meetings

The CSC was asked to provide input and make decisions related to a number of project activities. Presentations and trainings were provided to ensure that all CSC members had the project information and background knowledge necessary to provide well-informed, well-considered, and relevant input. CSC input and decision-making was needed on:

- **Overall project implementation**
  - Informing project goals, objectives, and activities
  - Confirming the role and responsibilities of the CSC
  - Identifying project evaluation priorities
  - Reviewing evaluation results and suggesting course-corrections
- **CAMN design**
  - Selecting the sensor
  - Identifying communities and locations for siting monitors
  - Providing input on and assistance with monitor host recruitment
- **Data analysis and results**
  - Reviewing research analysis questions
  - Informing methods
  - Examining and interpreting results
- **Display of real-time monitoring data**
  - Identifying display methods
  - Selecting air quality metrics and other display features
  - Reviewing draft and final website
- **Project outreach and data dissemination**
  - Determining outreach and dissemination goals and audiences

    - Identifying communication methods and strategies
    - Participating in outreach and dissemination activities
- **Using data for action**
    - Prioritizing goals for public health action
    - Developing action strategies
    - Implementing strategies
- **Sustainability and expansion of the CAMN**
    - Identifying sustainability goals and requirements
    - Developing a transition plan and sustainability strategy

The recommended size for the CSC is about 10-15 permanent members. As with any group, there may be turnover in membership or, as the project progresses, you may identify individuals who would contribute a new perspective or expertise. Early on, determine the process you will use to replace or add members to the CSC and be sure to communicate this with the CSC.

How is the Community Steering Committee convened?

The frequency and length of CSC meetings will depend on your project timeline and the activities for which you would like the CSC to provide input or make decisions on. Minimally, the CSC should convene in person at least 2-3 times a year to provide guidance on project activities and get updates. Depending on the scale of your project and available resources, full-day meetings are recommended for this purpose, but are not essential, particularly if the CSC is able to convene more frequently.

Planning for CSC meetings may involve:

- Developing a detailed agenda and identifying roles (e.g., facilitators, presenters, note-takers, time-keepers)
- Developing (and translating, if needed) presentations, handouts, and meeting evaluation forms
- Arranging for meeting space and meals/refreshments
- Arranging for simultaneous interpretation, if needed
- Preparing participation stipends

» Providing other support as needed to facilitate participation, such as arranging for transportation and childcare

» Providing reminders to CSC members via phone, text, or email

Meeting times, dates, and locations should be selected to maximize participation and reduce burden to CSC members. While not preferred, webinars and phone meetings can also be used if in-person meetings are not possible. In between meetings, emails and newsletters can be used to keep the CSC members updated.

Why establish a Technical Advisory Group?

A technical advisory group (TAG) of government, academic, and/or private sector representatives may also be established early in the project to obtain guidance on technical aspects of the project, such as selecting an air sensor, colocation and calibration activities, and scientific interpretation of the data and research results. The TAG is also an opportunity to build relationships with these stakeholders, keep them updated on the project, address their questions and concerns, and identify opportunities for assistance or collaboration (e.g., colocation with regulatory monitors). Unlike the CSC, the TAG should not have decision-making power, since control of the CAMN's implementation and maintenance should be held within the community.

Staff from Tracking California facilitate a meeting with CSC members and other community members in Imperial County. In-person meetings often lasted a full day to maximize face time between project partners and community participants. Meetings would consist of a mix of prepared presentations, open discussions, and hands-on demonstrations. *Photo courtesy of Comite Civico del Valle.*

Members of the TAG can include representatives from regulatory agencies (local air district, state air agency, U.S. Environmental Protection Agency) and other agencies with an interest in air monitoring, air quality, and health. For the Imperial Air Project, membership was not restricted and invitations were offered to individuals who had expressed interest in the technical operations of the CAMN during initial project outreach (see Appendix A for list of TAG members).

The frequency and length of TAG meetings will depend on your project timeline and activities. For the Imperial project, the TAG met semi-annually or as needed by phone for 90 minutes. Agendas and presentations were distributed beforehand.

You may also wish to consider whether you have the capacity and interest in facilitating any relationship or communication between the TAG and CSC. For example, would it be useful for one group to receive updates directly from the other? Or is it better for your project to maintain a separation between these distinct groups?

Who else should know about the project?

When initiating a CAMN project, it is recommended to reach out to other stakeholders to notify them about the project, such as the local, state, and federal air quality regulatory agencies; the local health department; city and county officials; and the media. This outreach is particularly important if you plan to colocate with a regulatory monitor (Chapter 11) or if there might be controversies around the establishment of community air monitoring network.

It may be helpful to develop a list of stakeholders to contact based on who might be interested in the project, who may have resources or support to offer, and/or whose support or permission may be needed to implement specific activities. Methods of contact include emails, phone calls, in-person appointments, or formal presentations. It is helpful to have factsheets describing the project aims and activities (see Appendix C for examples). When communicating with government agencies, it can also help to have a methods document that describes your scientific approach.

Are there other ways to engage community?

You can identify additional opportunities for community engagement in the development of the CAMN and build this into your design. For the Imperial Air Project model, additional residents were recruited to participate in a weekend-long process to identify possible air monitoring sites (see Chapter 12). Community members were also engaged in the project by serving as air monitor hosts, granting permission for a community monitor to be installed on their property (see Chapter 13). The broader community also can be engaged during the data dissemination process (see Chapter 15).

This page left blank intentionally.

CHAPTER 7

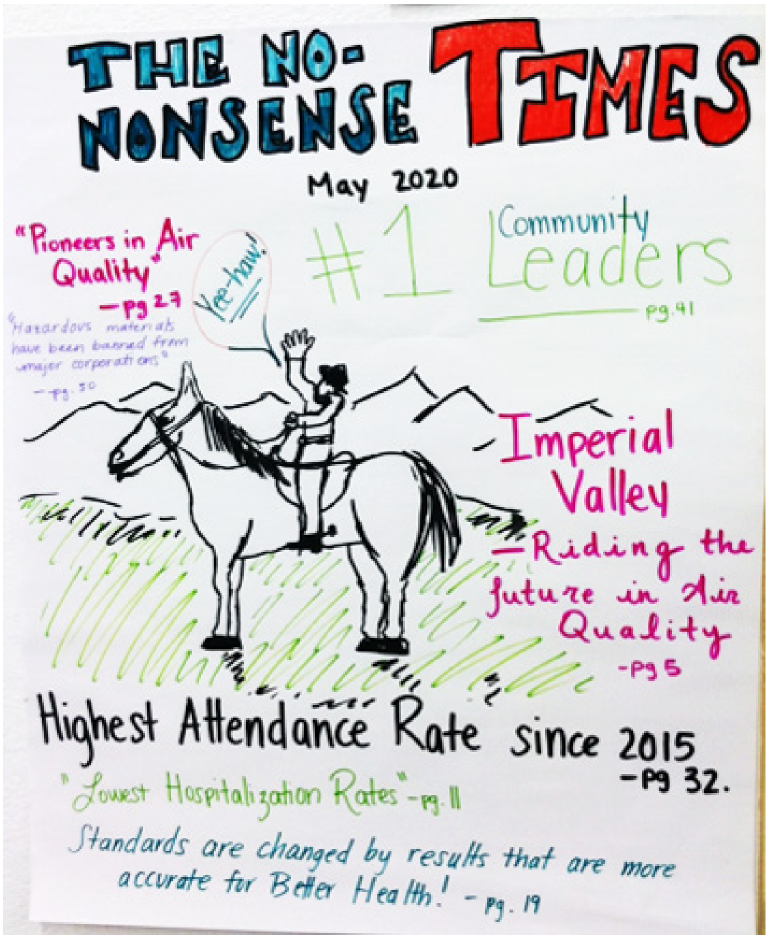
Defining the purpose of the network

Having clearly-defined goals for the community air monitoring network will help guide decisions related to network design, data analysis, and dissemination

Why is it important to define air monitoring goals?

The goals of the CAMN should be a key factor when making your network design decisions (such as which air sensor to use, how monitoring locations are determined, how data are processed, and how data are disseminated to the community). An important guiding question is **"What do we want to do with the data?"** While you may already have goals in mind for the CAMN, it is helpful to engage the broader community to hear about their perspectives. The CSC can help to augment and refine the vision for the network.

In addition to informing activities and decisions, taking the time upfront to have discussions with the CSC and other project partners will help to collectively determine goals, identify potential areas of disagreement, and assist future decision-making processes.



In 2015, the CSC participated in a visioning activity to identify impacts they would like to see in 5 years as a result of the air monitoring project. The activity involved drawing the cover of a magazine focused on Imperial County. *Photo courtesy of Comite Civico del Valle.*

How can CSC input be obtained?

There are a number of direct and indirect questions that you can ask CSC members in order to better understand community needs and interests around a CAMN.

These include:

- » Why are you concerned about air quality? What are other air quality concerns in your community?
- » How and where do you currently get air quality data and information? What data are missing?
- » How do you currently use air quality data and information?
- » What additional air quality data and information do you need?
- » Where do we need to monitor the air?
- » What would you do with the CAMN data?
- » What do you want others to do with the CAMN data?

You can ask these questions as part of a group discussion during your first CSC meeting. If there is concern that you may not be able to hear everyone's input, consider integrating small group discussions and/or written feedback forms into your agenda.

Finally, if you don't know your CSC members well, consider asking the above questions as part of individual phone interviews prior to the first meeting. One-on-one conversations are a helpful way to get to know each individual, hear about their engagement in community efforts, and learn about their air quality concerns.

How often should goals be assessed?

Continue to be mindful of how well your air monitoring goals match your network design, instruments, protocols, analyses, and dissemination methods used. As changes occur— for example in the form of new political or policy developments, improved technology, shifting community priorities, evolving partnerships, and changes in available resources and capacities— it is important to continue to assess your goals for air monitoring to more quickly identify and adapt to new needs. Consider scheduling time every year to review and discuss air monitoring goals with your partners and the CSC.

Air monitoring goals for the Imperial Air Project

- Measure ambient PM2.5 and PM10 levels
- Get air quality data for parts of the county that are far from existing regulatory monitors
- Identify air pollution hot spots
- Map air quality throughout the county
- Provide data that is useful and accessible to communities, including real-time data
- Assess how well our experimental monitors perform compared to the existing regulatory monitors

This page left blank intentionally.

Part 3:

Monitoring software and hardware

Chapter 8: Components of an air monitor

Chapter 9: Choosing a sensor

Chapter 10: Data storage and processing

Chapter 11: Quality assurance and control

This page left blank intentionally.

CHAPTER 8

Components of an air monitor

The choice to purchase a complete monitor versus doing a custom assembly will depend on factors such as which sensor you choose and the level of control that you want over the data

Sensor vs. monitor: What's the difference?

The terms "sensor" and "monitor" are often used interchangeably. However, the definitions used for this guidebook are distinct.

An air **sensor** measures a physical property of the air and reports its measurement. Sensors are not useful by themselves, since they don't output data that can be read by humans. Instead, data are usually in the form of voltages or currents. Some sensors are sold alone, while others may only be sold as part of a monitor (see Chapter 9).

An air **monitor**[3] integrates one or more air sensors with a microcontroller (a small computer) and other components to process the data and make it available in a human-readable format. For example, data may be displayed on a monitor's screen, recorded to a memory card, or uploaded to a server via the internet.

3. This may also be referred to as a "sensor packet."

A community air monitor assembled in Imperial County. The Dylos sensor and fan are located on the left side of the opened enclosure and connect to the power source on the right side. The enclosure protects the monitor in the harsh desert environment. *Photo courtesy of Zoe Meyers/The Desert Sun.*

Is it necessary to custom-build your own monitor?

There are a lot more air monitors on the market now compared to when the Imperial Air Project started. Today, some low-cost monitors come close to being a "plug-and-play" solution and cost less than $300. These monitors come with their own weatherproof enclosures, built-in Wi-Fi or cellular connections, and are set up to send their data to a web database. Some even have multiple types of air sensors in one unit. These monitors might be a good choice, depending on your air monitoring goals, data quality requirements, budget, and experience in monitor assembly.

There are also a number of reasons to assemble your own custom monitor. For example, you may want to:

- Use a certain monitor that is not available with a plug-and-play monitor
- Have more control over what data are uploaded and when
- Have a clear understanding of how monitoring data are being processed, which may not be transparent with some commercial monitors
- Upload data to your own database

In general, if transparency, control, and ownership of the monitoring data are important to you, you may wish to custom-build your own monitor. You may also want to add accessories such as:

- An antenna to boost signal
- A heater or cooler for extreme temperatures
- An inlet heater to reduce the effect of relative humidity on measurements

In addition to the physical assembly of a custom monitor, software for the microcontroller is also required. It's possible that software may already have been developed by other community, government, or academic groups using the same sensor for their own monitoring efforts. If they are willing to share the software, you may be able to modify it for your network.

What are components of an air monitor?

Below are some monitor components that you might consider if custom assembling a monitor.

- **Air quality sensor:** The instrument that measures air quality. See Chapter 9 for more details on features and considerations.
- **Custom circuit board and microcontroller:** Effectively a mini-computer, these components are used to record, send, and/or display sensor data. The microcontroller, using a custom program, takes in the data from the sensor and outputs a value in a human-readable format. Consider computing power, cost, and the programming language and any existing code libraries you wish to use when selecting these components.
- **Internal data storage:** Even if your monitor sends data to a server, it is a good idea to have another copy of the data stored on the monitor itself. The data can be stored on a memory card (such as a SD card) or on internal memory.
- **Temperature and humidity sensor:** Temperature and humidity can impact a sensor's readings. Therefore, it may be important to measure and record temperature and humidity at each monitoring site, particularly if these variables are integrated into your conversion equation (Chapter 11). A conversion equation is used to convert the sensor's measurements (called particle counts) into a more commonly used measurement (called particle mass concentration).
- **Cellular modem (mobile hotspot):** This is purchased from a cell phone company or other retailer. It allows the monitor to upload data to a server using a cellular connection if internet at the site is unreliable or not available. If a location has poor cell connection, no Wi-Fi, and no Ethernet, an alternative would be a satellite or radio connection.
- **Enclosure:** The casing that protects the internal monitor components.

- **Cooling fan or heater:** There may be a need to install a cooling fan or a heater if your monitor is sited in a location with extreme temperatures. It is best to follow the sensor and microcontroller manufacturers' guidelines, if available. In general, at lower temperatures, battery and capacitor performance drops off, which causes power instability. At higher temperatures, things can overheat or melt, causing the microcontroller to reset or turn off. In general, a system with heating and cooling components should maintain a temperature of 60°F -80°F.
- **Lock:** Depending how secure the site is, a padlock for the monitor enclosure may be desired for extra security.

For specific components used for IVAN AIR, see Appendix D.

CHAPTER 9

Choosing a sensor

Assessing your air monitoring goals, capacities, and budget is critical for making an informed decision when choosing a sensor

How do low-cost sensors measure particulate matter?

Most low-cost PM sensors measure particle count concentration, which is the number of particles in a specific volume of air, through a process called light scattering. The sensors have a laser that emits light into an optical chamber that particles pass through. As light from the laser passes through the chamber, particles scatter the light. This scattered light is read by a device called a photodiode. By reading the intensity and duration of pulses of scattered light, the sensor can determine the size and quantity of the particles in that volume of air. This results in a measurement of particle count concentration.

The United States National Ambient Air Quality Standards (NAAQS)[4] — the regulatory standards for PM and other air pollutants— and most health-based PM reference levels are based on particle mass concentration, which is the mass of particles in a specific volume of air (measured as micrograms per cubic meter of air, or µg/m3). That is why it is important to have a conversion equation (Chapter 11) to convert data from particle count to particle mass concentration.

4. The U.S. EPA is required to set these standards for air pollutants that are considered harmful for public health and the environment, called criteria air pollutants. A list of the standards is available at [https://www.epa.gov/criteria-air-pollutants/naaqs-table].

How do regulatory monitors work?

Most FEM and all FRM monitors measure particle mass concentration. The gold standard method for measuring particle mass concentration is a gravimetric filter (pulling air through a filter that is weighed before and after collecting PM). This is the most direct measurement of particle mass concentration, since the volume of air and mass of particles are measured directly.

Other methods used to measure particle mass concentration include measuring absorption of radiation (beta-attenuation monitor, or BAM) and measuring the change in frequency in a vibrating glass tube (tapered element oscillating microbalance, or TEOM).

There are only a few FEM, and no FRM, particle counters. These instruments have built-in calibration equations that have been tested over many years in multiple seasons and in multiple locations across the country.

How do low-cost sensors and regulatory monitors differ?

It is important to emphasize that, currently, no low-cost sensor will produce data that are eligible for use in regulatory action, regardless of its quality and performance. For an instrument to be used for regulatory activities, it must meet either the federal reference method (FRM) or federal equivalent method (FEM) requirements.[5] These rigorous requirements have not yet been met by any low-cost sensor. Low-cost sensors may be less accurate, less precise, and/or perform worse at very high PM levels or in certain environmental conditions. This is why it is important to colocate your low-cost sensor with a FEM or FRM monitor, so that you can compare the data and calibrate your sensor so that it produces data that are more similar to regulatory monitors (see Chapter 11).

Can low-cost sensors produce useful data?

Low-cost sensors can produce data that are useful for a range of non-regulatory purposes if appropriate quality assurance and quality control steps are taken (Chapter 11). For example, data from a CAMN may be used for policy advocacy, research, planning, and personal actions (such as avoiding outdoor activities when air quality is poor).

---

5. Office of the Federal Register. 2018. Protection of the Environment, Title 40 C.F.R. §81.305 Attainment. Online at [https://www.ecfr.gov/cgi-bin/text-idx?SID=6ce471d8cc33d1695ff368b16c-cc3bce&mc=true&node=se40.20.81_1305&rgn=div8].

Although not appropriate for direct regulatory activities, government agencies may still be interested in community monitoring data as a supplement to regulatory monitoring data, particularly when trying to better understand air quality conditions at the community level.

For data to be useful, it is also important that they be communicated in an accessible, understandable, and accurate fashion with limitations and caveats clearly explained (Chapter 16).

What are considerations for choosing a sensor?

Below are some details you should review and consider before selecting a sensor (either sold separately or as part of a monitor). The factors you prioritize will depend on your specific monitoring goals, resources, and capacities. However, some recommendations are provided here.

- **Method of measurement:** As described above, the primary type of low-cost PM sensor is a laser particle counter. Current PM sensors can differentiate several size bins— ranges of particle diameters— which is helpful for understanding particle composition, since particles of different sizes have different sources. The particle count data from these sensors can be converted to particle mass concentration. Some sensors provide this function by default; however, built-in conversion equations typically perform poorly. This is because the particle source, usually cigarette smoke, used to create the conversion equation is typically different from ambient PM. Therefore, it is necessary to calibrate all sensors (Chapter 11).
- **Performance:** How well does the sensor measure PM? Has the sensor been tested independently by government or academics, in the lab or in the field? Results of sensor evaluations by U.S. EPA[6] and the South Coast Air Quality Management District[7] are available online.
- **Data storage and transfer:** Some monitors can transmit data over the internet to a database maintained by the manufacturer or a third-party company. These data can be public or private. In some cases, you cannot choose which, and it is an important consideration to discuss before you decide on which monitor to purchase. If the monitor you are interested in does not offer data transfer, you will have to build your own networking and data storage infrastructure (see Chapter 10). It is also important to know whether the monitor stores the data on an SD card or internal memory. If it does, makes sure that the data are in an easily readable format. If the device uses internal memory, find out how you can access the data and if you will need a special program or additional hardware. Finally, determine

---

6. U.S. EPA evaluates air sensors for performance and ease of use. View results at [https://www.epa.gov/air-sensor-toolbox/evaluation-emerging-air-pollution-sensor-performance].

7. The district's Air Quality Sensor Performance Evaluation Center has completed evaluations for many low-cost air sensors under laboratory and field conditions. View results at [http://www.aqmd.gov/aq-spec].

what would happen if the manufacturer goes out of business. Will you still have access to previous data? Will you still be able to get new data from the monitors?

- **Data transparency and ownership:** Decide whether it is important to you to have the raw data or just the final values. As mentioned before, all data from these sensors can be considered inaccurate without local calibration to regulatory instruments. Sometimes it is easier to create a calibration equation using raw data, rather than applying your own calibration to data that have already undergone a factory calibration. If you are collecting the data solely for educational outreach and good accuracy is not important, then just having the final values is okay. However, if you are interested in community level air quality, advocacy and environmental justice, or data analysis, then you will need to perform a local calibration, which requires access to the raw data and knowledge of the calibration process. Some companies make data access easy, while in other cases accessing data can be challenging. It is important to check how easy data access is before investing in a monitoring platform.
- **Commercial availability:** Is this sensor readily purchased or is it a beta prototype of a product that isn't yet available on the market? Some companies may provide sensors to organizations free of charge in order to test them in the field. If the sensor is a beta product, what assurances are provided by the company for support, having additional sensors in stock, commercial production, and so forth?
- **Purchase cost:** Air sensors can cost anywhere from $15 to hundreds of dollars. Fully functional air monitors cost from $100 to thousands of dollars. Consider how many monitors you need, the duration of the project, and the likelihood of replacement. Also consider what you are getting for the cost. A $15 air sensor can't do anything on its own and would need to be connected to a microcontroller, which requires soldering and programming skills. More expensive monitors typically handle data upload and storage on a private or public website. The cheapest of these complete systems may be about $150-300. However, even these monitors require calibration to ensure that the data they produce are as accurate are possible.

Budget tip

Benefits to budgeting for extra monitors

You may be able to purchase monitors at a substantial discount by buying in bulk, so negotiate with the manufacturer directly. Also, you may want to purchase extra monitors to be used as replacements when monitors must be removed from the field for service. This is important for ensuring continuous data collection during that time.

- **Product lifetime and maintenance cost:** Choose a robust sensor with good support. Having a good relationship with the sensor manufacturer is beneficial. Make sure to ask them about the lifetime of their product – how long it can be in the field before needing to be replaced/upgraded, how long they will support it, and what are the costs for repair or replacement? Note that the lifetime of sensors can be significantly impacted by harsh monitoring conditions.

- **Warranty and other product support:** Does the manufacturer offer a warranty? It can be very helpful to be able to replace a sensor that goes bad soon after purchase. It is also good to have a repair warranty so that any sensors that need repair or recalibration during the warranty period can be sent back to the manufacturer.

- **Ease of installation:** How easy is it to set up the monitor? Does the monitor come with a weatherproof enclosure, or will you have to purchase and modify an enclosure separately? Can the monitor be mounted to a tripod/pole/wall/etc.? What other hardware will be required to install the monitor (see Chapter 14)?

- **Ease of maintenance:** How easy will it be to maintain the monitor? Maintenance includes cleaning out sensors using compressed air, replacing broken components, troubleshooting network connectivity issues, and returning malfunctioning monitors to the manufacturer for repair and recalibration (see Chapter 14).

It's important to understand and be deliberate about what considerations are being prioritized in your final sensor selection, as well as to have contingency plans in place around the potential risks related to this choice.

How soon do sensors become "outdated"?

Like cell phones and computers, sensor technology continues to improve and manufacturers continue to innovate. This brings up the concern that the technology will be outdated as soon as it is installed. In the case of the Imperial Air Project, new sensors have come on the market during the 5 years that the project was being implemented.

However, this does not mean that the network itself is outdated or that the data are low-quality. Rather, this emphasizes the importance of developing a well-planned, robust, and comprehensive CAMN. By spending time upfront to create a strong CAMN infrastructure (including site selection, community engagement, and capacity-building) and establish quality control processes (such as calibration, automated quality control checks, and a monitor maintenance protocol), it will be easier to switch out sensors without as much disturbance to the rest of the CAMN.

That said, it is important to be aware of how much effort it will take to upgrade your monitors. Firmware upgrades that keep monitor software up-to-date are relatively easy to install. However, rarely can new sensors just take the place of the old sensors without further additional changes. At the very minimum, a site visit is required to physically swap the sensors. Changes to the network and data processing software are also likely needed, as new variables may be recorded or variables may be recorded at different rates. For quality assurance, you should also plan to colocate the new sensor with a regulatory monitor and recalculate the conversion equation. Before upgrading, make sure you understand what you will need to do to make the upgrade successful.

Suburban areas in northern Los Angeles County threatened by smoke from the 2016 Crown Fire. Wildfire smoke drifting into densely populated areas is becoming a greater concern as wildfires become larger and more frequent. *Photo courtesy of Matthewedwards, CC BY-SA 3.0, [https://commons.wikimedia.org/w/index.php?curid=11043151].*

CHAPTER 10

Data storage and processing

Regardless of whether you decide to use a customized or plug-and-play monitor, it is important to understand how your data will be stored and processed

What does "data storage and processing" mean?

Data storage and processing refers to how air quality data from the sensors are collected, managed, and transformed into information that can be used in various formats.

For plug-and-play monitors, it is important to understand how the data storage and processing are handled by the manufacturer to decide if there are additional procedures needed for your CAMN. For example, you may want to implement additional quality assurance and control measures (see Chapter 11), such as writing custom software to help you know when your monitor isn't performing well or to automatically calibrate data before displaying them on your website or using them for analyses.

How should data from air monitors be stored?

Ideally, the air monitoring data should be stored both on an SD card in the monitor and uploaded to a database on a remote server. From there, data can then be downloaded from the database, undergo quality control checks, and be used for a variety of applications including scientific analyses and web data visualization.

If you plan to use a custom monitor, you must set up a database on a server. Some considerations for selecting a server include:

- **Processing:** A database server with a multicore processor is recommended
- **Memory:** 2-6 GB
- **Operating system:** Should be compatible with your database software
- **Reliability and support:** As with any service, make sure your provider is reputable and provides adequate customer support
- **Cost**

The server can be rented from companies that either provide on-premises servers or cloud services. For example, the largest cloud service providers at time of writing include Amazon Web Services, Google Cloud Services, and Microsoft Azure Cloud Services.

You will also need to set up a database using database software. When selecting the software, consider:

- **Scalability:** If you end up collecting more data in the future (e.g., add more monitors, increase reporting, add new monitor types), will your database be able to handle the added data?
- **Redundancy:** Are data replicated across multiple servers so that nothing is lost if a server goes down?
- **Secure encryption and other security features:** While air monitoring data are not generally considered sensitive or confidential, you may want to ensure that the data are protected from intruders.
- **Ease of use/integration:** Are there features available to ensure data are entered correctly and can be checked for errors? Does the database offer the ability to customize interfaces for administrators?
- **Cost:** Some commercial software can be quite expensive. There are also good software packages available free of charge (see inset: Options for cost-free database software).
- **Operating system:** If you plan to use an existing server, make sure the software works on that operating system.

How should data be processed?

Scripts are a series of commands that tell the computer what to do with the data in an automated way. For the CAMN, important data processing steps include:

- Applying quality control to remove bad data (see Chapter 11)
- Converting particle counts to particle mass (see Chapter 11)

Options for cost-free database software

There are many software packages that are free to the public. They may also have paid versions that provide extra features and services, but these are not generally required for setting up a CAMN database.

Examples of free database software include:

- MySQL
  - Commonly used and can meet the needs of a very large CAMN [https://www.mysql.com/]
- KairosDB
  - Flexible and can accept a lot of data points simultaneously [https://kairosdb.github.io/]
- InfluxDB
  - Database that is specifically tailored for time series data [https://www.influxdata.com/]

- Calculating metrics (see Chapter 16)
- Transmitting the data (see Chapter 10)

Any suitable programming language can be used to write the scripts. IVAN AIR scripts are written in python, R, and PHP.

Are there other data storage and processing considerations?

Additional recommendations for data storage and processing include:

- **Back up your data:** Avoiding loss of data is a top priority. Create backup copies of your database at least once a week, preferably at least once a day. Backups ideally should be saved on a different hard drive or an off-site server. This can be set up as an automated task and is usually offered as a service by server hosts.
- **Don't touch the data in your database:** Never delete, change, or update data in the database. The database needs to have a pure copy of the raw data in case data processing techniques are changed. Scripts can be developed to then pull data from the database (without altering the database itself) and process the raw data for quality control purposes, data display, etc.

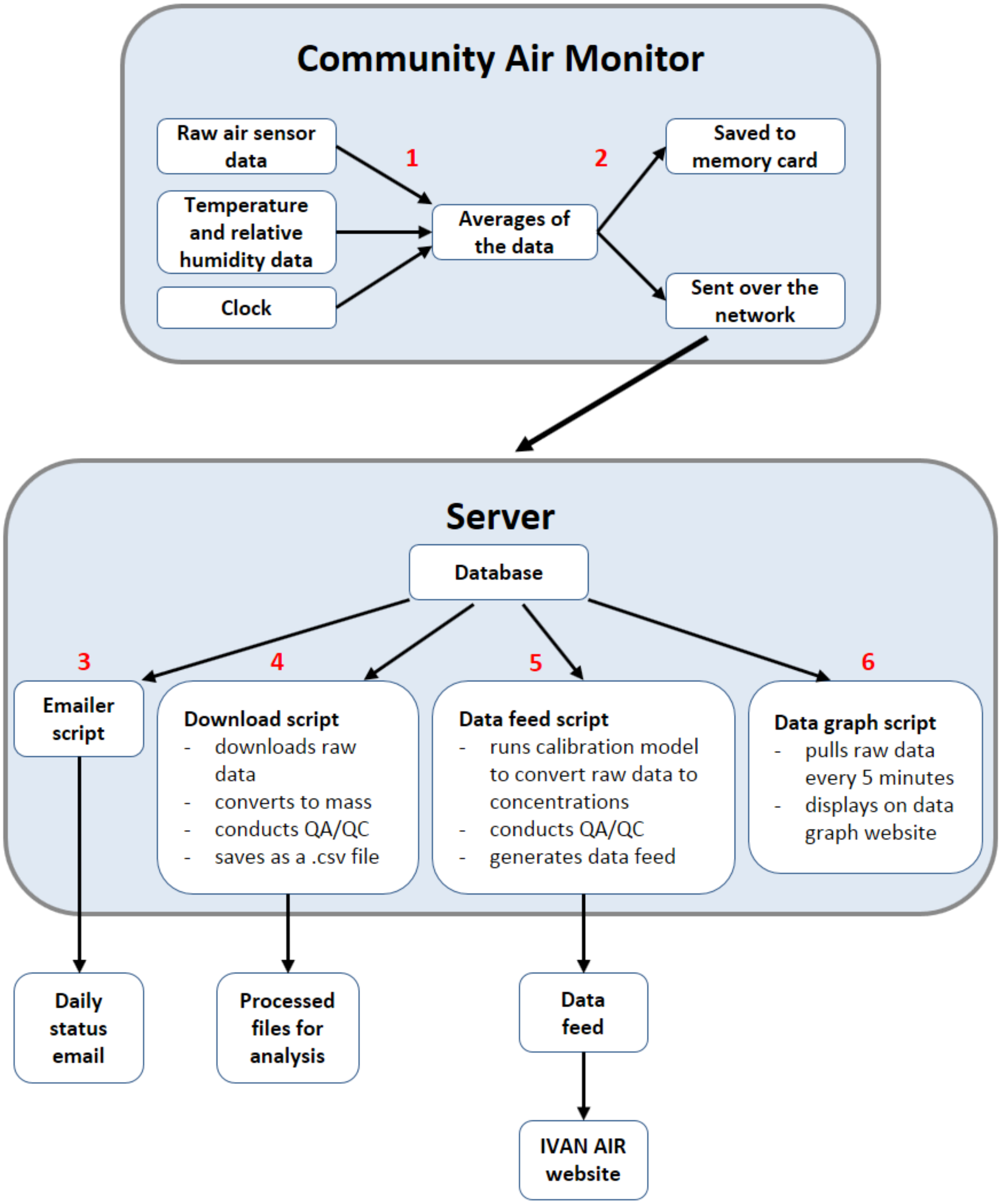


Figure 3. The flow of IVAN AIR data from the community air monitors to various endpoints, along with the processing steps taken to convert the sensor data to what is ultimately seen by various users.

IVAN AIR's data flow

Corresponding to Figure 3, the data flow steps for IVAN AIR are as follows:

1. Air sensor, temperature, and relative humidity data are collected by the microcontroller in the monitor.
2. The microcontroller saves the data to an SD card and also sends it to the server. The server runs four different scripts.
3. The emailer script sends a daily email with a status report on the monitors to let operators know how well the monitors are functioning and if any need to be serviced.
4. The data download script is used to download data from the monitors as files that can be used for analyses.
5. The data feed script provides summary data from the network that are fed into the community-operated IVAN AIR website (see Chapter 16).
6. The data graph script provides a simple graphical interface used to check monitor performance and connectivity while in the field.

» **Keep a digital log of monitor and sensor locations:** Keeping a log of current and past monitor and sensor locations is critical to ensure that the data can be processed for analysis. This is because a monitor will not always use the same sensor. For example, when you remove a sensor for recalibration, it should be replaced with another sensor to continue data collection at that location. Monitor sites themselves may also change, depending on host participation or other factors, so it is important to document this as well.

During the assembly of a monitor, you should label your sensor with an ID or take note of its serial number. This will help you to keep track of which monitoring site the sensor is being used at, how long it has been in operation, and when it was last serviced or recalibrated.

For both monitors and sensors, it is important to record time and location whenever they are sited, moved, or removed. The log should minimally contain the following information in separate columns: start date, end date, sensor number, the site's name, the site's address, and the site's latitude/longitude.

» **Keep a digital maintenance and event log:** Record the details of each time you perform maintenance on monitors. If you notice a problem with a monitor that affects data quality, log the time and date at which the problem became apparent, what you did to fix the monitor, and the time and date when the monitor was fixed.

This photo shows crop burning near El Centro, California in 1972. Today, agricultural burning continues to be a common practice in the area and a substantial source of community concern. *Photo courtesy of Charles O'Rear (NARA record: 3403717) - U.S. National Archives and Records Administration.*

What should you look for when using a monitor that already reports data to a website?

Many of the monitor companies that store your data on the web will provide a data visualization service where you can easily see air quality levels throughout your network. These services can be very valuable, especially if your organization has limited IT and engineering resources. Using a monitor that reports to a website is fine, as long as there is transparency in how the data are changed and how secure your data are.

Data transparency is important, since you want to make sure that the way the raw data are processed is scientifically-valid and well-documented. Converting values or cutting out high or low values without explaining how these processes are performed can make understanding your data confusing or even cause you to lose important information. Some companies guarantee that the data from the monitors are saved "as is" on their websites.

Data security has two components: (1) public versus private data storage and (2) the ability to make backup copies of your data. Some websites only host public data or require payment to make data private. Check with the manufacturer beforehand if you are concerned about data privacy. Having the ability to make backup copies of your data is important in case the company decides to no longer support the version of monitor you have or if the company goes out of business and shuts down their servers.

CHAPTER 11

Quality assurance and control

Procedures to ensure data quality are essential to the operation of a useful and credible community air monitoring network

What's the difference between quality assurance and quality control?

Quality assurance (QA) processes involve assuring that the data from the low-cost sensor are accurate. When implementing a community air monitoring network, QA processes include comparing the low-cost sensors to reference instruments in order to calibrate the low-cost sensor, developing a conversion equation, validating your equation, and applying the equation to the monitoring data. Calibration should occur early in the development of the network and be repeated every 5-10 years to account for changes in the composition of particulate matter at the monitor site, as this can impact how the sensor measures particle count concentrations.

Quality control (QC) processes involve assuring that bad data are removed to prevent inaccurate results (i.e., data cleaning). QC processes occur on an ongoing basis and can include removing measurements that are known to be incorrect, addressing incomplete measurements, and alerting network operators when a monitor is not functioning properly.

When developing your QA/QC plan, consult with a Technical Advisory Group or other technical advisors to ensure that your protocols are adequate[8] for your desired data uses and users.

What is calibration and why is it necessary?

Calibration is the process by which a "test" instrument (such as your sensor) is first compared to a reference instrument, and then its measurements are adjusted to more closely match the reference instrument. Even FEM instruments, which are the second highest class of regulatory monitors, need to be calibrated to FRM monitors. In the case of a CAMN, the community monitors should be calibrated against a FRM monitor, or at least a FEM monitor.

Calibration fixes issues of constant bias (when the test instrument always reads higher or lower than the reference instrument) and concentration-dependent bias (where the test instrument's bias changes at high or low concentrations).

Calibration can also be used to convert measurements with one type of unit to another unit system, such as from particle count concentration to particle mass concentration.

Detailed information about the Imperial Air Project's calibration process has been published.[9] All air sensors need to be calibrated before their data can be used.

What are some considerations for colocating with reference monitors?

To calibrate your monitor, you must first colocate[10] it with a reference monitor so that you can appropriately compare their data. Colocation is the operation of monitors in the same location. Below are some considerations for colocation:

- **Reference monitors:** State and local air quality agencies and universities are good organizations to contact in order to find a regulatory-quality instrument to compare community air monitors to. It is ideal to colocate with an operating regulatory monitor. It is also important to understand the monitoring purpose for each regulatory site. Some sites monitor background conditions while others measure a particular source.

---

8 Air sensor standards have not been developed at the time of writing. However, some air sensor performance guidelines are available. See: United States Environmental Protection Agency. 2014. How to Use Air Sensors: Air Sensor Guidebook. Online at [https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook/].

9. Carvlin GN, Lugo H, Olmedo L, et al. 2017. Development and field validation of a community-engaged particulate matter air quality monitoring network in Imperial, California, USA. J Air Waste Manag Assoc. 67:1342–1352. Online at [https://www.ncbi.nlm.nih.gov/pubmed/28829718].

10. There is no consensus on the spelling of this word. It is also spelled co-locate and collocate.

- **Locations:** The ideal colocation takes place at a site that is representative of the area to be monitored. There may be multiple regulatory monitors operating within your geographic area of interest. Try to site community monitors at as many regulatory sites as possible.
- **Calibration zones:** PM can consist of many different types of particles, including dust, pollen, smoke, and liquid droplets. The composition of particles can impact how the sensor measures PM. If the particle composition varies among different areas within your geographic area of interest, then an equation should be developed for each area (i.e., calibration zone). Talk with your local air agency to find colocation sites and determine which sites would give the best coverage of the calibration zones within your region.
- **Colocation time:** If possible, permanently install a community monitor at the colocation site so your conversion equation can be kept up to date. Particle composition in an area may change over time, so the conversion equation should be updated regularly to account for this. If ongoing colocation isn't feasible, the colocation should last for a year if possible so that seasonal differences can be accounted for. If this is not possible, then the community air monitor should be colocated for one month during each season.
- **Number of community monitors:** It is ideal to operate all of the community monitors at the colocation site for at least a week. This will allow you to assess variability among the monitors, as well as identify any sensors that may not be operating well.

For more information, see inset: More resources on colocation.

More resources on colocation

The U.S. EPA has developed the following resources to help communities to evaluate low-cost sensors when conducting community air monitoring.

How to Evaluate Low-Cost Sensors by Collocation with Federal Reference Method Monitors. This instruction guide describes in plain language the steps, concepts, and considerations for colocation, data collection, data comparisons, and data conversions between low-cost sensors and federal reference monitors. Available online at [https://www.epa.gov/sites/production/files/2018-01/documents/collocation_instruction_guide.pdf].

Excel-based Macro Analysis Tool for Air Sensor Data. To be used in conjunction with the instruction guide, this tool helps users to compare data from colocated low-cost sensors and regulatory monitors. Available online at [https://www.epa.gov/air-research/instruction-guide-and-macro-analysis-tool-evaluating-low-cost-air-sensors-collocation].

How is a conversion equation developed from colocation data?

Once the colocations are completed, a conversion equation can be developed with data from the community and reference monitors. The conversion equation is developed through a statistical process called regression analysis and then applied to the data during processing (see Chapter 10).

Some considerations for developing conversion equations include:

» The community air monitor data should undergo quality control checks (see below) prior to use in developing the conversion equation.

» Try to formulate the conversion equation using the time average that you will likely use in data analyses or web visualization (e.g., hourly, daily). Correlation will be worse with shorter averaging times since there will be more variability in the data. Also, having too few data points will lead to poor correlation since the variability will not be properly captured. Therefore, if you want to use a smaller unit of time, it is important to have collected more data points.

» Include relative humidity and temperature data from the community monitor in the conversion equation, if you are collecting these.

» Develop conversion equations for areas with similar PM composition (calibration zones) and apply these equations to monitors sited within those zones.

Example: Conversion equation for IVAN AIR

In the case of IVAN AIR, the conversion is based on the following equation: BAM = Dylos + RH, where the RH is the relative humidity measured by the sensor on the custom circuit board. This equation says that the regulatory monitor (BAM or beta attenuation monitor), which is assumed to be the "real" concentration, is equal to the low-cost sensor (Dylos) including the effect of relative humidity. The equation can also be created in the following way, Dylos = BAM + RH, then reversed. This has the advantage that the residual error in the model is assumed to be due to the Dylos instead of the BAM.

Why convert particle counts to particle mass concentration?

As described in Chapter 11, most low-cost sensors measure the number of particles in the air. Because regulatory standards and most health-based PM levels are based on particle mass concentration, it is a good idea to convert the low-cost sensor data from particle count to particle mass.

The relationship between particle count concentration and particle mass concentration depends on the density and light scattering properties of the particles. To convert particle count concentrations to particle mass concentrations, particle counting sensors must be colocated with a mass-based instrument. Measurements from both instruments can be compared and a conversion equation can be developed. The differences in particle density and light scattering properties are averaged over the colocation time. However, these properties do change, and if any of those changes are large enough and become permanent then it is time for a new conversion equation.

The conversion equation should be periodically updated (about once every 5-10 years) to account for changes in PM composition. The conversion equation can also be validated after it is applied to the community monitors through a second colocation and analysis process.[11] For more information on how this was done for the Imperial Air Project, see Appendix E.

11. Carvlin, 2017.

What quality control steps should be taken?

A sensor may produce inaccurate data when it requires cleaning, maintenance, or replacement. Also, data may be missing if the sensor stopped operating due to a power outage or equipment failure. Several basic QC steps should be taken to identify and remove bad data, including:

- **Automated quality control processing:** Scripts are used to identify and flag any data points that are clearly incorrect (e.g., too low), so that they can be removed in subsequent processing. Scripts are also developed to require a certain level of data completeness (i.e., a minimum number of data points during a specified time period) before these data can be converted into air quality metrics.
- **Daily email:** The server sends an email every morning with a list of all monitors, their data completeness for the past day, and whether they have failed the automated QC check for data accuracy. This allows network operators to respond quickly to problems with the monitors.
- **Routine manual inspection:** A manual QC inspection of data from all monitors in the network is routinely performed. The purpose of this step is to catch any bad data that are not removed during the previous QC steps. Sometimes bad data have a pattern that has not been seen before, and it is important to be able to identify those times, especially if they can lead to enhanced QC or maintenance procedures.

An IVAN AIR community air monitor was colocated with a regulatory air monitor from the California Air Resources Board (CARB). The community air monitor is the smaller gray box attached to the front railing (center of photo). The surrounding equipment is part of the CARB regulatory monitor. Colocation is important for data quality assurance. *Photo courtesy of Comite Civico del Valle.*

Automated quality control processes for IVAN AIR

There are two automated QC processes used for IVAN AIR. The first accounts for incorrect data. The second accounts for incomplete data.

Incorrect data: For all particle counters, decreases in sensitivity are a common feature that occur as the sensor gets dirty. This can occur quickly, such as during a dust storm, or slowly over months, as dirt builds up inside the sensor. The latter is referred to as sensor drift, because the readings incorrectly and gradually decrease. At some point, the sensor reports values that are so low that they could not be accurate, even if measuring PM in a very clean room. For IVAN AIR, these unnaturally low values are flagged automatically, then inspected manually.

Incomplete data: When monitoring data are displayed as averages (such as an hourly or daily concentration), it is important to pay attention to how many data points are contributing to those calculations. If too many data points are missing, then the calculated average may not be representative of the actual average.

Data completeness is the percentage of valid data points compared to the total number of possible valid data points. For example, if the values for the 12 possible data points (taken every 5 minutes) in a full hour are:

10, 18, 15, **20, 25, 20, 35, 55, 40, 25, 15, 22**

Then the average is 25. However, if the numbers in bold were missing from the data, the data completeness would be 25% and the average of the remaining data points would be 14, which is lower than the actual average for that hour.

For analyses conducted with IVAN AIR data requiring higher accuracy, the Imperial Air Project used 75% data completeness. For real-time data on IVAN AIR, a requirement for a minimum of 50% data completeness was chosen so that there would be less missing data on the map. Data points may be missing for a number of reasons, such as poor network connectivity or a sensor problem.

This page left blank intentionally.

Part 4:

Network design and implementation

Chapter 12: Deciding where to put the monitors

Chapter 13: Obtaining permission to install monitors

Chapter 14: Monitor installation, operation, and maintenance

This page left blank intentionally.

CHAPTER 12

Deciding where to put the monitors

An integral part of designing a community air monitoring network is the placement of monitors, which can impact the utility and relevance of the network

Why does it matter where the monitors are placed?

Monitors that are installed in places that are meaningful to community members are more likely to:

- Increase awareness of air quality issues and the CAMN among residents
- Produce data that community members will use
- Provide data that can help protect health at locations that the community cares about (e.g., schools, senior centers)

Monitors that are installed at locations that meet recommended siting criteria are more likely to:

- Produce data that better represent the area where the monitor is located
- Be useful to researchers and government agencies

The location of monitors in a CAMN can also be important if you want to conduct specific types of analyses or generate data that can inform specific policies or programs.

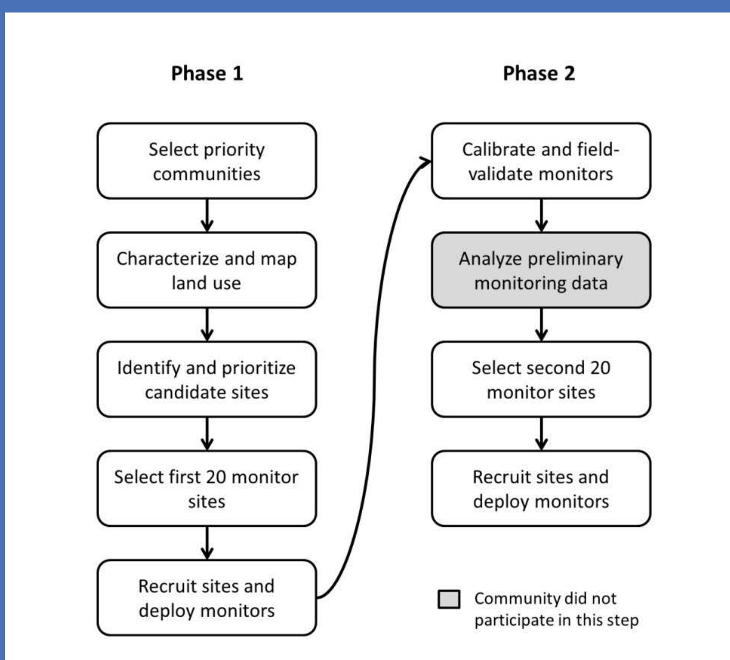
The Imperial Air Project's phased siting process

The Imperial Air Project had two overarching goals for siting monitors. First, it was important to place monitors in locations that were prioritized by the community. Second, it was important to place monitors in locations that would facilitate scientific analysis, specifically the ability to estimate air quality in areas that did not have a monitor.

To integrate both needs, a phased approach was used. In Phase 1, 20 monitors were deployed in locations that were identified and prioritized by community participants. These monitors also fulfilled certain criteria needed for the Phase 2 analysis.

In Phase 2, data from first 20 monitors were analyzed to identify locations where additional air monitoring data would be useful for scientific analysis. Locations for the remaining 20 monitors were determined based on the results.

This siting methodology combined scientific methods, community knowledge, and community-generated data to identify monitor locations to best meet the goals of the CAMN. The diagram below shows the overall site selection process.



What process should be used to select monitor sites?

Your site selection process should reflect the community's air monitoring goals, as articulated by the CSC and other community stakeholders (see Chapter 7). A recommended general process would include:

1. Define the geographic region and specific area(s) in which you will be placing monitors
2. Determine opportunities for colocation with fixed regulatory monitors
3. Recruit community members to participate in identifying sites
4. Identify potential sites in specified areas
5. Collect and assess information about the sites
6. Select sites and alternates based on your predetermined criteria

The criteria for each of these steps will depend on your air monitoring goals. You may also wish to alter or enhance this process as needed to meet those goals. For example, the Imperial Air Project used a two-step process[12] to select monitor sites to meet community priorities and research priorities (see inset: The Imperial Air Project's phased siting process).

What geographic area will the CAMN cover?

It is important to define the geographic region that your CAMN will cover, as this will form the basis for your site selection protocol and community engagement process. For example, you may be interested in one or more neighborhoods, towns, cities, or counties. Or you may be interested in a geographic region that doesn't adhere to any conventional boundaries.

Once you establish your geographic region, you may wish to define areas within that region to target the distribution of your monitors. For example, these could be cities, neighborhoods, or some other geography that you've defined based on your specific project criteria. Defining these areas can be helpful if you want to ensure that monitors are distributed equally within your region or if you wish to distribute monitors in the areas with the greatest need. For example, you may wish to focus on areas that have a specific type of pollution source, a minimum number of residents, or other some other characteristic.

If you have fewer monitors available than the number of defined areas within the region (e.g., 5 monitors and 10 cities), you will need to prioritize a subset of these areas using criteria that align with your air monitoring goals. It can be helpful to engage the CSC in this selection process (for example, see inset: Prioritizing communities for the Imperial Air Project).

---

12. Wong M, Bejarano E, Carvlin G, et al. 2018. Combining Community Engagement and Scientific Approaches in Next-Generation Monitor Siting: The Case of the Imperial County Community Air Network. Int J Environ Res Public Health.15(3). Online at [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5877068/].

Prioritizing communities for the Imperial Air Project

Because the Imperial Air Project focused on an entire county, it was important to determine if there were communities (in this case, defined as towns or cities) where siting an air monitor would be a priority.

A major objective of the first CSC meeting was for the group to select 10 priority communities. Through facilitated discussions and small group activities, the CSC:

- Reviewed and confirmed community boundaries
- Discussed concepts of community vulnerability (i.e., what makes a community at higher risk for poor health)
- Examined health and environmental data for the county
- Identified specific factors that contributed to vulnerability within Imperial County

CSC members then met in pairs to identify and rank their top 10 priority communities. These were reported back to the entire group and a ranked choice voting activity was used to identify priority communities. Because the voting results were so close, 11 communities were chosen in the end. The remaining communities were not excluded from having a monitor, but would not be guaranteed to receive one.

Why is it important to identify colocation sites first?

In the context of monitor siting decisions, colocation is the process of siting a monitor alongside or as close as possible to a regulatory monitor. This allows for the ongoing collection of monitoring data that can be directly compared to data from a regulatory monitor (see Chapter 9). Because of its importance to the ongoing quality assurance of your network (see Chapter 11), is recommended that you identify colocation sites before identifying other monitor sites. This way, you will have a better idea of how many monitors should be set aside for colocation and what geographic area may not need an additional monitor because there will already be a colocated monitor in place.

Engaging community residents is critical for deciding where to place monitors. After a two-day process to identify and gather data on possible monitor sites, community participants and the project team took a group photo to commemorate the achievement. *Photo courtesy of Comite Civico del Valle.*

Who should be engaged in the site identification and selection process?

To ensure that CAMN sites will be meaningful to community members, residents from each of the priority areas, if selecting, or your geographic region should be engaged in the identification and prioritization of potential monitoring sites. Who and how many participants you engage will depend on your specific site identification and selection process. For example, you may not need to engage anyone beyond your CSC.

However, if you have the time and resources, this may be an opportunity to outreach to new individuals, increasing awareness and engagement in your project. To recruit participants, it can be helpful to have invitation letters and factsheets describing the project and what you are asking of them.

What process should be used to identify potential monitoring sites?

When engaging participants to identify potential sites within their specific area, it is helpful to provide some background or guidelines, such as:

» **What is a site?** Choose a specific location with a building where the monitor can be placed. If there's nowhere to put a monitor, it is probably not a good option.

- **Can the site be an air pollution source?** Unless your goal is to measure emissions specifically from that source, then it is preferable not to have a monitor right where pollution is being emitted. Instead, consider choosing a site that is near the source, but more representative of the air quality in the community.

Then, to identify sites that are meaningful to the community, it can help to prompt participants to consider:

- **Where do you need air quality information?** For example, would information about air quality at a location be useful for residents to reduce their own exposure to pollution, for communities to engage in broader advocacy or policy actions, or for conducting research?
- **Where do people spend time?** Where do people live, work, learn, play, or otherwise congregate? Are there typically a lot of people at this location? Or do the people at this location typically spend a significant amount of time there?
- **Where is air pollution a concern?** For example, are there locations that are impacted by multiple pollution sources? Or do vulnerable populations (e.g., children, elderly, asthmatics) spend a lot of time there?
- **Where may having a monitor have additional impacts?** For example, would a monitor at a location (such as a city hall) lead to increased awareness or action from community members, policymakers, or the media?

Other recommendations for engaging participants in this process include:

- Providing maps of the geographic area to aid in the identification of sites
- Allowing time for participants to brainstorm sites individually
- Having participants from the same geographic area convene to share and discuss the sites that they've identified
- Not requiring consensus or limiting the number of sites at this time

In general, the process used to identify, assess, and select potential monitor sites is flexible. It should be developed according to your specific air monitoring goals, time frame, community engagement structures, and resources.

What information is needed about potential sites?

Once participants have identified potential sites, it can be helpful to collect information to assess the suitability of each site for installing an air monitor. This process, which requires a visit to each site to assess various characteristics, can be a good opportunity for participants who want experience in data collection. It can also be helpful to participants to see the site in person prior to the site selection process.

It is important to train participants on how to collect the data prior to visiting potential sites. In addition, remind participants not to trespass or otherwise intrude at a site, and provide guidance on how to respond to potential inquiries about their activities. When visiting sites, it may be helpful for participants to carry a formal letter or factsheet from your organization that explains the project and what they are doing.

Assessing the suitability of a site for air monitoring is best done in person. First, it is important to note whether the site itself is appropriate for the installation of an air monitor. Characteristics to assess include:

- **Power supply:** Unless you have the capacity to provide solar power to your monitor, there should be an accessible AC power supply, such as an outdoor electrical outlet.
- **Internet access:** Is there Wi-Fi or wired Ethernet access at the site? This isn't necessary if you are able to provide a mobile hotspot. Mobile hotspots may be necessary for sites with unreliable internet access.
- **Security:** There should be a secure location for the monitor to be installed where it would not be accidentally or purposefully tampered with.
- **Place to install the monitor:** There should be a building for the monitor to be attached to, or you should be prepared to provide a structure such as a tall tripod.

Second, assess whether the site will allow for the measurement of ambient air quality levels that are representative of the surrounding areas. For example, it is important to avoid a location that is very close to sources of pollution that might impact monitor readings (e.g., vents, outdoor grills, trash burning). Characteristics to assess include:

- **Groundcover near building:** For example, dirt, gravel, grass, pavement, etc.
- **Building height:** How many stories tall is the building?
- **Trees near building:** Are there trees close to the building? How tall are they?
- **Potential sources of pollution:** What are the nearby (for example, within 50 meters) potential sources of air pollution?
- **Potential nearby agricultural burns:** For some communities, agricultural burns may be considered exceptional events that are not representative of daily air quality conditions. In others, agricultural burns may be a concern because they occur frequently. So, those communities may not wish to exclude a site based on its proximity to potential burns.

If your project has limited time and resources to conduct this effort, the characteristics above can also be assessed after sites are prioritized and selected.

Other information that is useful for the site selection process, which doesn't require a visit to the site, includes:

- Location
- Description of the site (such as residence, grocery store, school, county office, etc.)
- Why this location was identified as a potential site to install a monitor

How should the final sites be selected?

The process for selecting the final sites should be determined when you design the rest of the site identification process. The site selection process can also include a step to prioritize the potential sites before the final selections. Depending on how community-driven you want the process to be, the participants can take the lead in the prioritization and/or final selection of the sites. Whatever process you plan to use should be shared with the participants at the beginning of their engagement for transparency.

When planning your site prioritization and selection processes, consider:

- **Who is involved:** Who will be involved in the site prioritization process? Who will be involved in the final site selection?
- **Methods for prioritization:** What method will be used to prioritize sites, and how will they be prioritized? For example: in ranked order or grouped into high, middle, and low priority.
- **Methods for selection:** What method will be used to select the final sites? If a prioritization process has happened, which sites are eligible for consideration?
- **Criteria:** What factors will be considered during the prioritization and selection processes? Can sites be disqualified?
- **Contingencies:** If these are group processes, is consensus needed? How will any disagreements be resolved? If a selected site declines participation, how will alternate sites will be identified?

Budget tip

Mobile hotspots

Consider budgeting to cover the monthly costs of maintaining mobile hotspots at each monitor site. There can be considerable data loss if Wi-Fi is unreliable, and mobile hotspots may be a flexible solution. Local colleges may have access to discounts on monthly costs of Wi-Fi hotspots.

CHAPTER 13

Obtaining permission to install monitors

Securing permission is essential before installing monitors at sites, requiring time and careful planning to successfully recruit monitor hosts

What is the role of a monitor host?

It is important to cultivate relationships with the owners and appropriate representatives of the sites where you would like to place a monitor. Beyond providing permission to install the monitor, these individuals will play a key role in the long-term sustainability of the CAMN. As monitor hosts, they provide a secure location for the monitor, supply the monitor with power and internet (if available), allow your organization access to the monitor for ongoing maintenance activities, and alert you to any concerns or changes that may impact the monitor, such as resetting the Wi-Fi password.

Given the critical role of monitor hosts, a tailored recruitment approach is recommended for each site.

What are considerations for a recruitment strategy?

For each selected site, it is helpful to consider:

- **Which representative(s) of the site should be contacted?** For sites such as schools or government buildings, there may be a chain of command to follow or formal communication channels that should be used. For homes or businesses where the resident is not the property owner, both tenant and owner should be contacted. It is important to identify who is ultimately going to make the decision to provide permission for siting. This individual or group (such as a school board) may be different from the people who you might interact with at the site to install the monitor.
- **Who is the best person to make the initial contact?** Do you know the site representative? Are they aware of your organization? If not, would it be possible to gain an introduction via an intermediary (such as a CSC member)? In some cases, it may be appropriate and beneficial to arrange a meeting with the site representatives where other individuals (such as key CSC members) may be able to provide important influence and support.
- **What is the best way to initiate contact?** Depending on the site, approaches include: formal letters, emails, phone calls, and in-person visits. Follow-up contact via phone is often necessary to prompt a response.
- **What basic information should you provide?** For the initial contact, it is important to provide essential information such as who you are, what the project is, what you are requesting from them, and the potential benefit to participation.
- **What might be potential barriers to getting permission?** It is helpful to anticipate questions, concerns, and barriers. For example, are there concerns about liability, how the data will be used, or stigma about poor air quality? Are there specific policies and regulations to follow, or permits that must be obtained prior to installation? Are there concerns about construction or site modifications that may need to be occur to install the monitor?
- **What might encourage participation?** In addition to addressing any concerns, it may be helpful to provide testimonials from other sites or other community air monitoring projects about the benefits of participation. Hearing directly from stakeholders about the importance of air monitoring information (such as for parents of asthmatic children) can also be influential. Finally, you may wish to offer a stipend to help offset any costs related to the monitor’s electricity or internet use, though these costs should be minimal.

The Brawley Union High School's maintenance staff created a custom mount for the air monitor to be placed on the school roof. This is one example of the community participation, ownership, and initiative that occurred throughout the project. *Photo courtesy of Comite Civico del Valle.*

- **What kind of follow-up might be needed?** After initial contact with the site, you may be requested to provide additional information by responding to specific questions, conducting a presentation (e.g., to a school board), providing formal documentation, and more. Additionally, once permission is provided, you may need to take time with the monitor hosts to discuss specifics of the monitor installation process and provide more information about how they may be able to use the data themselves.
- **What other materials might be helpful to prepare in advance?** It may be helpful to provide background information that the site representatives can review, such as factsheets, FAQs, and presentations. Formal letters requesting permission to site a monitor may be helpful for initial contact, as well as letters of support provided by trusted and influential individuals or organizations.

See Appendix E for examples of recruitment materials.

Are formal siting agreements or permits needed?

It is recommended that you develop siting agreements with each site to ensure that roles, responsibilities, and liability issues are clearly addressed (Appendix E). Depending on the site, the agreement may need to be customized or renewed regularly. Encroachment permits may also be required prior to monitor installation.

How long does it take to recruit monitor hosts?

It is difficult to estimate how long site recruitment will take. In general, recruitment at institutions such as schools and other government buildings can be a lengthy and intensive process. While difficult to predict a timeline, it can be helpful to plan an approach by thinking through how many different people may need to be contacted, whether there are periods of time when site representatives may not be available (such as holidays or summer break), and whether there may be a blockage or gap in the decision-making chain of command (such as a current or anticipated change in administration or personnel).

Once permission is received, begin the process of coordinating with the monitor host to install the monitor (see Chapter 14).

How often should monitor hosts be contacted after the monitor is installed?

After installing the monitor, it is recommended that you establish a process for regular communication with the monitor host in order to maintain updated contact information, sustain the relationship, provide project updates, and address any questions or concerns that may occur. Additionally, this can help to facilitate regular site visits, which are needed to inspect and maintain the monitor (see Chapter 16).

Budget tip

Offer opportunities to sponsor community monitors

If a local business hosts a monitor site, consider asking them to sponsor the monitor on an annual basis– they could get recognition by placing their name on the monitor in the data display.

CHAPTER 14

Monitor installation, operation, and maintenance

Setting up, maintaining, and repairing monitors are essential, ongoing processes necessary for producing usable data

What needs to happen before installing a monitor?

Prior to installation, it is recommended that you schedule a site visit with the monitor host in order to:

- Agree upon where to install the monitor
- Identify which tools and materials will be needed to complete the installation
- Test connectivity to the internet and assess whether a mobile hotspot will be needed

It is also important to ensure that monitoring components can be tracked, whether by their serial number or by labeling them on your own. Digital logs to track inventory, location, and monitor maintenance status should be created (Chapter 10). It may also be helpful to have a waterproof notebook for taking notes while visiting sites and installing or servicing monitors. The microcontroller should have an ID assigned when uploading to the data server.

Tools and materials needed

Depending on where you plan to install the monitor on the building, you may need:

- Power cables
- Network cables
- A tripod
- Brackets
- U-bolts
- Cable ties
- Hose clips
- Screws
- Nails
- Silicone
- Plywood
- Saw
- Drill
- Screwdriver
- Pliers

Ballast, such as sand bags or concrete blocks, may be used to weigh down a tripod if it can't be screwed down. However, monitors can fall over if this is not done properly.

Where on a building should the monitor be installed?

It is important to site a monitor away from any wind barriers, such as trees and walls, and away from nearby pollution sources, such as exhaust vents or air conditioners. The U.S. EPA[13] and the California Air Resources Board[14] have guidelines for siting and installing monitors.

It is recommended that you review these guidelines and, as appropriate, consider selecting one set to follow. For IVAN AIR, some sites do not strictly meet these guidelines. This was considered acceptable since the project team and the community felt that the benefit of measuring air pollution in these areas outweighed the costs of not meeting the exact siting requirements.

---

13. Office of the Federal Register. 2013. Title 40 Protection of Environment, Appendix D to Part 58- Network Design Criteria for Ambient Air Monitoring. Online at [https://www.gpo.gov/fdsys/pkg/CFR-2014-title40-vol6/pdf/CFR-2014-title40-vol6-part58-ap-pD.pdf].

14. California Air Resources Board. 1999. Central California Air Quality Studies, Initial Field Program Plan, Siting Criteria. Online at [https://www.arb.ca.gov/airways/Documents/plans/981220/Part4.pdf].

What does the installation process entail?

Each installation will be unique, but in general, you need to:

1. Affix a tripod or pole to the base/side of the roof of the building
2. Mount the monitor to the tripod
3. Connect the power and network cables
4. Test that the monitor is working

What should be documented during installation?

For each site, it is helpful to keep a set of notes that can be referred to and updated during the maintenance process. For example, for the installation and subsequent maintenance visits, it can help to:

- Note the time and date
- Note the name of the monitor host/site representative that was present that visit
- Take photos during and after the installation or maintenance process
- Keep track of any materials used
- Keep track of equipment needed to access the monitor in the future, such as a ladder
- Note any challenges or concerns
- Write down the Wi-Fi password
- Write down the sensor ID number if installing/swapping out a new sensor

How do you know if a sensor's readings are drifting downward?

The best way to detect when a sensor is producing lower numbers than it should (signal attenuation or sensor drift) is by regularly examining the last couple months of data from that monitor to see if there is a downward trend. It can also help to compare the data from that monitor to data from the nearest regulatory monitor (which is calibrated regularly) or other nearby monitors in your network to assess whether they are producing similar patterns.

How can you tell if the monitors are working?

Depending on your sensor, monitor set-up, and methods for data storage and processing, there are a number of ways to test that a monitor is working. For example, the sensor may have lights that indicate if it is on and functioning correctly.

If you use the same methods for data storage and processing as IVAN AIR (see Chapter 10), there should be two main tools to test the performance of the network: (1) an automatically-generated daily email and (2) the data graph web visualizer (see Figure 4). The daily email is sent to the individual(s) responsible for maintaining the monitors and ensuring data quality. It provides at-a-glance information about the overall health of the network. It can be used to check which monitors are no longer reporting, which are reporting all zeros, and which are having trouble uploading data due to poor network connectivity. The data graph tool can be used to test whether monitors are uploading after installation, as well as to keep an eye on long-term trends as part of standard maintenance.

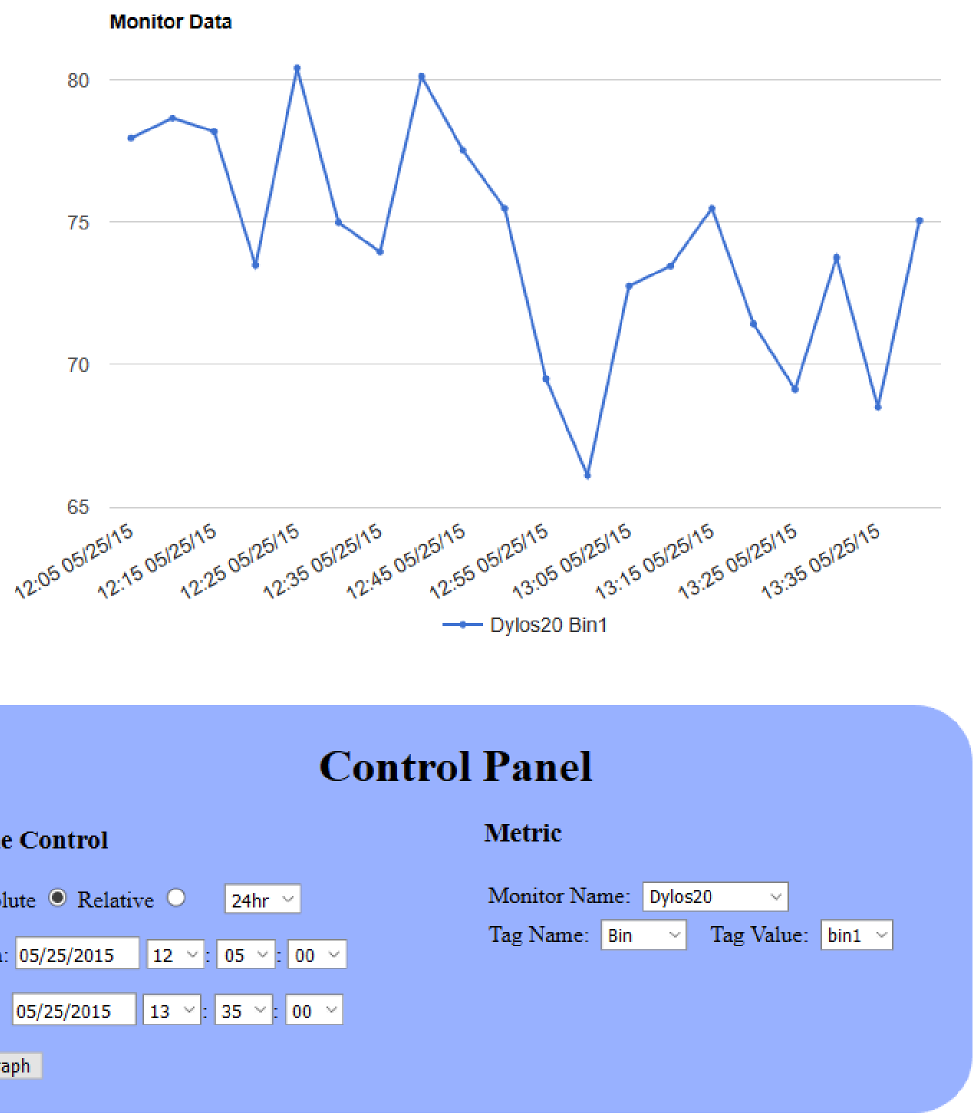


Figure 4. Screenshot of data graph web visualizer used for manual quality control checks for IVAN AIR.

How do you clean a sensor?

This will depend on the sensor you use. For IVAN AIR's sensor, quick cleaning involves blowing canned air through the fan grate. Full cleaning involves taking off the cover, blowing out all the dust with canned air, and cleaning the photodiode and laser with a lint-free cloth and isopropyl alcohol. Sensors in harsher environments are fully cleaned once every three months, whereas sensors in less harsh environments undergo full cleaning once a year.

How is routine monitor maintenance conducted?

The amount of maintenance you will have to do will depend on the conditions at the site (e.g., heat, cold, weather, sand/dust, strength of the network signal) and the sensor you choose. A recommended general maintenance process includes weekly data checks, monthly site visits for each monitor, and yearly recalibration. However, this can be adjusted based on your specific conditions, and some monitors may need more frequent maintenance depending on their site.

For data checks, the individual(s) responsible for operating the network should check on the data from each monitor once a week using whichever data visualization methods you have set up. For example, these might be your data graph or daily status emails (see Chapter 10 and Figure 4).

It is common for air sensors to build up a layer of dust over time, which gradually causes the sensor to produce numbers that are lower than they should be, also known as signal attenuation or sensor drift. This is very hard to detect early and without inspecting the data manually. If this is not detected and addressed, it can lead to the production of months of incorrect and unusable data.

For site visits, a network operator should visit the monitor once a month and visually check the site to see whether any site maintenance needs to be performed. Depending on your sensor, this could include a quick cleaning or a full cleaning. In harsher environments, the sensor may need to be fully cleaned more frequently.

An annual recalibration of each sensor is suggested if possible. If this service is available, recalibration is best done by sending the sensor back to the manufacturer. There is typically a cost associated with this service. Otherwise, colocating the monitor with a regulatory monitor could "recalibrate" it by allowing you to create and use a calibration equation (Chapter 11) to make necessary adjustments.

Examples from the field: Monitor problems encountered in Imperial

Imperial Air Project staff have investigated and addressed a range of situations when monitors were not operating as expected.

- **Wi-Fi connection that dropped frequently or would not connect:** This occurred numerous times due to a range of issues, including:
  - The router or antenna is too far away
  - Microcontroller is defective and unable to connect to Wi-Fi
  - Microcontroller does not connect to its designated wireless network and instead connects to one of multiple open network connections available
  - Air monitor host updates wireless network to require a user name and password, resulting in the need for a mobile hotspot since the microcontroller cannot enter this information
  - Temporary loss of power at the site leads to a stop in the automated connection process
  - Unintentional disconnection due to activity by site host
  - The network firewall only allows certain IP address to connect, requiring the air monitor host to add the microcontroller's IP address to the firewall
  - The mobile hotspot or Wi-Fi signal is unstable in rural areas
  - Heat damages the battery life of the mobile hotspot, requiring replacement
- **Incorrect values being reported:** Because of the desert environment in Imperial County, incorrect sensors readings were often caused by physical disturbances, such as:
  - Dust and sand in the monitor enclosure
  - Heat and direct sunlight, which affect the sensor
  - Intrusion by spiders, lizards, and other small animals

» **Monitors not working:** In one instance, the building's electrical breaker was faulty, causing the monitor's aluminum mounting plate to become extremely hot and melt the sensor. Comite Civico del Valle staff did multiple site visits and sensor reinstallations before figuring out the issue. The breaker was replaced, resolving the issue. Extreme ambient heat, especially when concentrated (such as on metal roofs), can damage the sensor as well.

Humberto Lugo of Comite Civico del Valle installs a monitor near the Salton Sea. Each monitor installation is unique and may require different tool or materials. *Photo courtesy of Zoe Meyers/The Desert Sun.*

Setting a regular maintenance schedule and keeping a log of maintenance activities can help prevent monitor failures and the need to retroactively remove bad data. It is important to note that maintenance, repair, and site set-up can require a lot of time and, for larger networks such as IVAN AIR, may require the equivalent of one full-time staff person. Finally, to prevent gaps in data, it is important to have additional sensors available to immediately replace any sensors that must be removed for recalibration or because they are no longer functioning.

What if there are problems with the monitor?

There are many problems that can occur at a monitoring site, from needing to reboot the monitor because of a power or software problem to needing to fully replace the sensor. The first step in troubleshooting a problem is using observational skills to note all the pertinent facts about the situation. Below are some general questions to ask.

Before a field visit:

- Are you getting some data or no data at all?
- How has the network signal strength been at that site?
- Have there been power outages before?

During a field visit:

- Are the lights on the monitor lit?
- Are any cables unplugged?
- What happens when you reboot the monitor?
- Does anything look frayed or damaged?

After you have completed the site visit, determine whether you can fix the problem yourself or if you need to contact the manufacturer.

Part 5:

Using and sustaining a community air monitoring network

Chapter 15: Disseminating the air monitoring data

Chapter 16: Communicating air monitoring data on the web

Chapter 17: Analyzing air monitoring data

Chapter 18: Sustaining the network

Chapter 19: Conclusion

This page left blank intentionally.

CHAPTER 15

Dissemінating the air monitoring data

To be impactful, data and information from the network must be accessible, understandable, and useful to communities and other stakeholders

How can a data dissemination plan be developed?

Data dissemination is the process of making the data and information available to target audiences. Different methods may be desirable, depending on what information is being communicated and to whom. Before developing a data dissemination plan, you should engage your CSC, technical advisory group, and other stakeholders to help identify:

- Who needs to know about the CAMN data?
- What kind of data and information would be most useful?
- How would these audiences use the data and information?
- What methods of communication are preferred and effective?
- What barriers may inhibit access to the information?

What kinds of information might be disseminated?

Some broad categories of information to consider disseminating include:

- Real-time data from each air monitor
- Datasets

- Results from analyses conducted using the air monitoring data (see Chapter 17)
- Other results from the project

What are different ways to disseminate information?

Several different dissemination approaches may be needed, depending on the types of information being communicated and the audiences you are trying to reach. Some examples include:

- **Website:** Websites can be used to display and offer access to different kinds of information, including real-time data, summary statistics, downloadable datasets, and publications (see Chapter 16).
- **Alert systems:** You may wish to also have a webpage or other mechanism where users can register to receive an email or text when PM levels are high at specific monitors.
- **Air quality flag programs:** Usually implemented in school settings, the flag program uses colored flags to communicate the current air quality to the entire school and the surrounding community. The color indicates the amount of air pollution and what actions, if any, are recommended to reduce exposure. The flags are displayed outside of a school building and are updated at least daily. You may wish to engage with existing flag programs so that they use the CAMN data as another source of air quality information, in addition to data from the regulatory monitoring network.
- **Coordination with other partners:** To share real-time data widely, you might consider coordinating with local media outlets such as radio and television stations to alert audiences when air quality is hazardous.
- **Data requests:** As awareness of your CAMN grows, you may be contacted with requests for the air monitoring data, perhaps as a dataset or in a more summarized fashion. It is important to have a plan for addressing these requests, since fulfilling them may take significant staff time. A data request form can be a helpful way to assess and keep track of requests. For example, you may require the requestor to specify exactly the data they want, when they need the data by, what they plan to do with the information, and how the results will benefit and be shared with the community. If you decide to fulfill the data request, be sure to provide the necessary supporting information, such as metadata, which supplies information about the air monitoring data. This can include quality assurance and control procedures (Chapter 11) and monitor location and maintenance logs (Chapter 10). You may also wish to ask the requestor to cite your organization and/or your CAMN in any publications or other products derived from your data.
- **Publications:** Information about the CAMN, results of analyses, and other related information may be described in publications. These can be tailored by audience and may include reports, factsheets, news articles, and scientific manuscripts.

- **Presentations:** Infomation about the CAMN, air monitoring data, and/or results from analyses might be presented at community meetings, health fairs, scientific conferences, and other events.

Using existing community resources to disseminate data, such as an existing website or school flag programs, can be a good way to reach a broader audience, strengthen the capacity of these resources, and ensure sustainability of the CAMN.

What if someone wants to display your CAMN data on their website?

There may be government, non-profit, or private organizations working to compile, aggregate, and/or display data from different low-cost sensor networks on a single website.

This can be a good way to help disseminate the CAMN data and reach broader audiences. However, it is worthwhile to understand how the CAMN data and supporting information will be shared with users, to ensure that the data can be used appropriately and effectively.

When considering these requests, it can be helpful to determine:

- What is the purpose of the website? Who are the intended audiences?
- How will data on the website be used? Will the data be available to the public, free of cost?
- Will your data undergo any further processing or QC procedures? Will this be documented?
- How will data from multiple networks be aligned and displayed?
- What kind of metadata, supporting information, and interpretation will be provided?
- How will your data be cited? Will your contact information be provided?
- What data are being requested from you and in what format? How often will the data need to be updated?

High school students conducted outreach and education about air quality and the CAMN as part of their internship with the Imperial Air Project's youth program. Youth engagement is an effective strategy for disseminating information and building local leadership. *Photo courtesy of Comite Civico del Valle.*

Potential barriers

For each dissemination approach, it is important to identify potential barriers, such as limited access to cell phones or the internet, limited literacy or language skills, and color-blindness. Use of multiple communication and dissemination methods may be one way to circumvent some of these barriers.

How to raise community awareness of the CAMN?

Once the CAMN is operational and there are mechanisms in place to disseminate the data, it is important to conduct outreach to raise awareness of the CAMN as a community resource and increase use of the data. As with the data dissemination plan, engage the CSC to:

- **Define outreach goals:** What do you want people to know about the CAMN? How do you want them to use the data (such as personal exposure reduction, policy implementation)? Are there other actions you'd like them to take (such as providing financial support for the CAMN, granting permission to install a monitor)?
- **Identify target audiences:** What is their level of knowledge and interest around air quality? What are opportunities and barriers to reaching and communicating with them? Who do they trust?
- **Determine outreach methods and messages:** What methods would be most effective for reaching each audience? What messages would be most effective with this audience to support your outreach goals? What materials might need to be developed (e.g., factsheets, brochures, posters, or promotional items such as pens and water bottles)?

Based on this feedback, develop an outreach strategy and related materials. Examples of outreach activities are listed below, and there may be some overlap with activities in a data dissemination plan.

» **Community celebrations and launch events:** Project accomplishments can be shared and celebrated at events such as ribbon-cutting ceremonies, launch events for newly installed monitors, and community gatherings. These activities can generate publicity and result in media attention and increased community awareness of the CAMN.

» **Media engagement:** Developing press releases, planning press conferences, and submitting letters to the editor will increase the likelihood that media outlets will develop news stories focusing on the CAMN and share it with the community.

» **Presentations:** Conduct presentations at schools (e.g., in classrooms) At schools (e.g., in classrooms or at PTA meetings), at public meetings, or anywhere your target audience is likely to attend.

» **Social media engagement:** Post photos and videos related to the CAMN, such as announcing the CAMN, reminding people to check CAMN data on bad air quality days, sharing facts about air quality and health, etc.

» **Tabling:** Tabling at health fairs, community fairs, and conferences can provide an opportunity to speak directly with community members, demonstrate your CAMN website on a laptop, and hand out factsheets and promotional items.

» **Train-the-trainer activities:** Training community members, including youth, to conduct outreach in their communities and among their peers can be an effective outreach strategy and can also increase awareness and capacity among the new trainers (see inset: Engaging youth and fostering leadership through the Imperial Air Project youth program).

Engaging youth and fostering leadership through the Imperial Air Project youth program

Youth can play an active role in raising awareness about air pollution and increasing use of data to protect community health. Youth are a key stakeholder in that they are more vulnerable to harmful air pollution exposures, and they are also the future leaders in the community.

The Imperial Air Project initiated a pilot Youth Environmental Health Internship (YEHI) program, which was designed to increase youth awareness and knowledge of air quality issues, civic engagement, and outreach and presentation skills. Ten high school students participated in each semester-long YEHI session. Sessions culminated with interns conducting presentations about IVAN AIR at their schools and within their communities, as well as visiting the state capitol to speak with legislators about local air quality concerns.

Through these efforts, YEHI interns were able to increase awareness about air quality issues and how to use IVAN AIR data to reduce air pollution exposures. In one case, after attending a presentation by interns, leaders from a local Native American community contacted Comite Civico del Valle to explore installing a monitor on their land.

Youth are effective at engaging and educating both peers and adults, and youth participation in outreach and education should be considered when planning dissemination strategies.

CHAPTER 16

Communicating air monitoring data on the web

There are many ways to display air quality data, so it is important to tailor your website to address the highest priorities for your community

Should you operate your own CAMN website?

Your organization (alone or in partnership with others) may currently operate a website that you would like to use to display CAMN data. Or, you may wish to create a website specifically to display CAMN data. The benefits to a community-operated CAMN website include being able to control how CAMN data are displayed and messaged, as well as building organizational capacity and sustainability. If you choose to enhance an existing website, then you are also leveraging resources and an existing web audience.

If you choose a sensor that automatically reports data to the manufacturer's website (see Chapter 9), but you wish to also operate your own CAMN website, then you will need to determine if and how the data will be available to you.

Media attended the ribbon-cutting ceremony at Brawley Union High School to celebrate the first of 40 air monitors deployed in Imperial County. The monitor is visible on the roof, and the flag is part of the school's air pollution flag program. Green, yellow, orange, or red flags are flown based on air pollution levels. The IVAN AIR website displays data using the same color coding. *Photo courtesy of Comite Civico del Valle.*

How to choose what air quality information to share?

There are many ways to measure air quality and communicate the results on a website. No single measure can provide a complete picture about air quality, so selecting those that best communicate your CAMN data is an important process. To do this, it is recommended that you:

1. Identify your community's information needs, values, and priorities.
2. Understand the options and considerations for selecting air quality measures and display methods.
3. Select the measures and displays that would be best for your community.
4. Evaluate if the information is useful and understandable.

Because CSC members serve as representatives of the broader community, they can play a useful role in describing community information needs, values, and priorities. Discussions, focus groups, and surveys are some ways to engage the CSC around these issues. While consensus among the CSC members isn't necessary, there may be enough commonalities in their responses to inform your decision-making. If no clear trends emerge, you might need to get additional input from other community members.

Leveraging an existing community website: The IVAN Network

The Imperial Air Project displays data on a website called IVAN AIR (https://ivan-imperial.org/air). IVAN AIR was built upon an existing community website and environmental monitoring platform operated by Comite Civico del Valle, called IVAN (Identifying Violations Affecting Neighborhoods).

Leveraging an established community website to display air monitoring data can be a good idea, especially if the website is a known and trusted resource by residents. Rather than displaying data on a partner's website, this method ensures community responsibility and control of data dissemination. It also ensures that resources for website development are directed back into the community, strengthening community infrastructure and capacity.

The IVAN platform is currently used by seven other communities in California. The enhancements made to the platform to display the air monitoring data in Imperial (along with the associated data management and processing infrastructures) are already being used by some of these communities to display their own air monitoring data.

If you are interested in establishing IVAN in your community, you can learn more at [http://www.ivanonline.org/].

How can community needs, values, and priorities be identified?

Rather than simply asking the CSC members to vote on specific air quality measures, it is helpful to begin by focusing on broader needs and values related to air quality. This can provide a useful lens with which to view any subsequent input about measures and display methods, as well as to identify possible contradictions (e.g., if the measure most preferred by the group does not fit the data needs articulated).

When engaging the CSC, some basic questions to ask include:

- **What do you most want air quality data for?** It may help to provide some specific examples, such as knowing when to avoid being outdoors, knowing when to reduce one's own emissions, demonstrating that a location is an air pollution hotspot, and seeing how air pollution changes over time.

» **What would be important to know about the air quality at a specific monitoring location?** For example, is it most helpful to compare it to the average air quality in the county or to a regulatory standard? Or, is it more important to know how that level of air pollution might impact health or what action one should take to protect health at that level?

» **What characteristic is most important for data from a CAMN?** Because it is unlikely that a single way of communicating data can address all priorities, it can be informative to urge the CSC to choose their top data characteristic from a group of possibilities. For example, is it most important for CAMN data to be based on the best science possible, be useful and understandable to the community, be comparable to existing data, or be accepted by regulatory agencies?

What kinds of air quality measures should be considered?

As described in Chapter 11, the data produced by the monitor will likely be converted to or provided as particle mass concentration (i.e., the mass of the particles per volume of air, expressed as $\mu g/m^3$). However, to make this information more meaningful, decisions must be made about:

» **What averaging time to use?** Consider what time scale you want to use to average your data. For example, 1 hour, 24 hours, or longer?

» **What to compare this concentration against?** Is the concentration itself enough information? Is it helpful to compare it to typical levels (e.g., for that specific monitor or for all monitors in the CAMN)? Is it helpful to compare it with existing health or regulatory guidelines or reference levels?

» **Is it helpful to use a health risk-based index?** Many countries communicate about air quality using a color-coded air quality index. The exact index can vary, but generally the color corresponds to a PM concentration range that is associated with a certain level of health risk. The U.S. EPA uses the Air Quality Index[15], and IVAN AIR uses its own index based on the U.S. EPA NowCast method[16] (see inset: The Air Quality Index and Community Air Quality Levels).

» **How frequently should this information be updated on the web?** Technically, a measure can be recalculated on an ongoing basis as new data are reported by the monitor. How often should this data be refreshed on the website?

---

15. AirNow. 2016. Air Quality Index Basics. Online at [https://airnow.gov/index.cfm?action=aqibasics.aqi].

16. United States Environmental Protection Agency. 2013. Transitioning to a new NowCast Method. Online at [https://www3.epa.gov/airnow/ani/pm25_aqi_reporting_nowcast_overview.pdf].

There are different ways to get CSC input on air quality measures. For example, you could share several examples of commonly used measures and ask the CSC members:

» What do you like and not like about the measure as a way to explain air quality?

» What is this measure useful for?

» What other information would you want?

How are measures calculated and displayed?

Once selected, the air quality measures will need to be integrated into your data processing infrastructure through a data feed script (Chapter 10). The script will pull air monitoring data from the database, apply the conversion equation, apply QC procedures, calculate the desired measures, and send the final data to the website's server. See Appendix G for a technical description of the script used to produce data on IVAN AIR.

Then, decisions must be made on how to display the measures on the web. These considerations include which format(s) to use and subsequent choices related to that format.

Data display formats can include maps, tables, charts, widgets (such as a dial or slider bar), and text. The formats can provide different ways to understand the same data. For example, displaying PM concentrations on a map provides at-a-glance information about the spatial distribution of pollution, whereas displaying concentrations on a ranked list of monitors can be more helpful for seeing and comparing actual PM concentrations.

Once formats are selected, it is important to consider details that can help the user to more easily interpret the data, including:

» **Labels:** If categorizing data, what specific wording and/or other method (such as using color coding or symbols) should be used to make it easier to distinguish between categories?

» **Color schemes:** If using colors to help distinguish variations in the results (such as between higher and lower PM concentrations), what color scheme should be used? For example, should you use colors similar to the AQI? Lighter to darker shades of the same color?

» **Supporting text:** What definitions, explanations, and disclaimers are needed to help with interpretation of the data? What explanatory or disclaimer text should be included alongside displayed data? What information should be included in a Frequently Asked Questions (FAQs) section?[17]

---

17. For examples of supporting text, see IVAN AIR's FAQs at [https://ivan-imperial.org/resources/airfaqs].

The Air Quality Index and Community Air Quality Levels

The Air Quality Index (AQI) is used by the U.S. EPA and other regulatory agencies to report the air quality for the day, tell how polluted the air is, and tell what immediate health effects might be a concern at that level of pollution.

IVAN AIR displays air quality as Community Air Quality Levels (CAL). The CAL is calculated for each monitor based on current concentrations, with the number and category updated on the website every 5 minutes.

The AQI and CAL both provide information to communities about the current air quality level and associated health risks. However, there are some differences. The CAL is calculated using U.S. EPA's NowCast method, which uses the past 12 hours of data and weights them (this means that the recent monitor readings have more influence on the calculation of the CAL than the earlier monitor readings). The AQI is calculated based on the PM concentration averaged from the past 24 hours.

Furthermore, CAL does not use categories beyond the unhealthy/red category, since it is recommended that everyone take precaution when air pollution reaches that level of risk. This also aligns with the categories used by school flag programs in Imperial County.

Community Air-Quality Level (CAL)

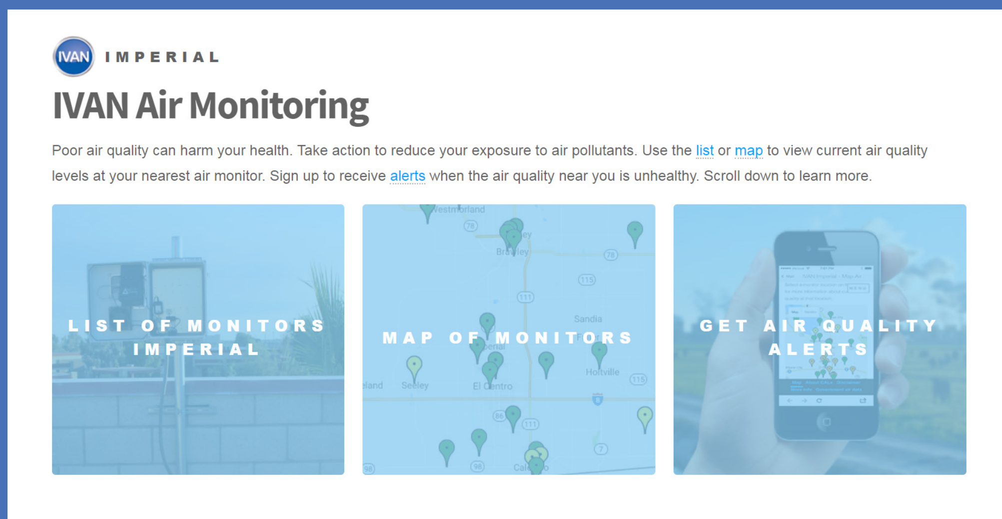
Number range	Category/Color
0-50	Low Risk/Green
51-100	Moderate/Yellow
101-150	Unhealthy for Sensitive Groups/Orange
Above 150	Unhealthy/Red

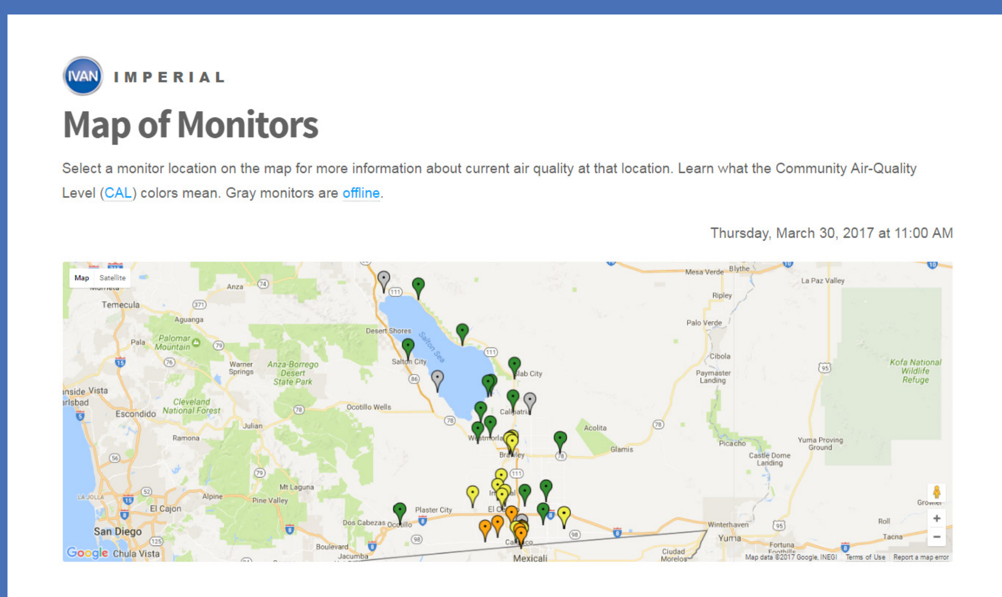
Air Quality Index (AQI)

Number range	Category/Color
0-50	Good/Green
51-100	Moderate/Yellow
101-150	Unhealthy for Sensitive Groups/Orange
151-200	Unhealthy/Red
201-300	Very Unhealthy/Purple
Above 300	Hazardous/Maroon

Displaying data on IVAN AIR

IVAN AIR (https://www.ivan-imperial.org/air) features the real-time air monitoring data in multiple ways, including a map and a list of monitors that display the Community Air Quality Level. Summary data, such as the average PM concentrations for the past 24 hours, 30 days, and 90 days are provided for each monitor. The website also includes a page where individuals can sign up to receive air quality alerts by email when PM levels are high at their selected monitors.





The choices made can impact how the data are understood and interpreted. Therefore, when considering various display options, it is important to assess:

- **Is this understandable?** Will the data be interpreted appropriately?
- **Is this useful?** Can community members use this information as intended?
- **How is it similar or different from existing information?** What are the pros and cons of these similarities or differences?

Finally, someone with web design expertise can help to create (or update, if using an existing website) the overall website design, including the desired air quality data displays and accompanying text. The actual development of the website and integration of the data should be accomplished by someone with user interface or web application development experience (this may be the same individual). Once developed, the website should be tested by community members to ensure that the air monitoring data and information are easy to access and understand.

CHAPTER 17

Analyzing air monitoring data

Analysis of the air monitoring data can range from relatively simple to very complex, depending on the questions you want to answer

What needs to happen before you begin analyzing your data?

It is important to develop your data analysis plan based on the questions you have, the information you want, how you want to use the results, and whatever constraints your organization may have with regard to time and capacity.

When developing your data analysis plan, you should assess whether your air monitoring data are appropriate or adequate for your selected analysis. For example:

- **Do you have enough data?** Do you need to collect data for longer? Do you need more monitoring locations?
- **Do you need other kinds of data?** If your analysis requires additional data, do they exist and do you have access to them?
- **Have quality assurance and quality control procedures been applied to the data?** Have the data been processed for calibration with a regulatory monitor? Have data points that are clearly incorrect (i.e., too low, too high, or otherwise indicating an instrument error) been flagged? Have the data undergone completeness checks? See Chapter 11 for more information.

What kinds of information can be answered with the air monitoring data?

Broadly speaking, questions that can be answered through relatively simple analyses include:

- For one or more monitoring sites
    - What is the air quality, on average?
    - What are the highest levels of air pollution reached every day, on average?
    - How does air quality at a specific site compare to the rest of the network?
    - How has air quality changed over time?
    - When is air quality usually the worst during the day? During the year?
    - What was the air quality like at a specific time and location? For example, before or after a known air pollution event or implementation of a specific policy.
- For all monitoring sites
    - What is the average air quality for the entire network?
    - Which monitoring locations experience the most pollution?
    - Which monitoring locations experience the least pollution?

Questions requiring more complex analyses or even a separate research project include:

- How do data from the community network compare to regulatory monitors?
- How many air pollution episodes occurred during a specific time period?
- Where did the most air pollution episodes occur?
- Where might the pollutants responsible for specific air pollution episodes have come from? What were possible sources?
- What was the air quality like at places where there are not monitors?
- What was the relationship between air pollution and health outcomes?

It is important to keep in mind that each type of analysis will have its own limitations as far as how well the results can answer certain questions. While some may not be able to provide definitive answers, the results may still be useful for informing public health planning, action, and policymaking.

Resources for analyzing air pollution data

There are free resources which can assist you or your partners in analyzing air pollution data. These include:

- Real Time Geospatial Data Viewer (RETIGO)
  - Web-based tool that allows you to plot your data as a function of time, place, or wind speed/direction
  - Developed by U.S. EPA [https://www.epa.gov/hesc/real-time-geospatial-data-viewer-retigo]
- Instruction guide and macro analysis tool for colocation evaluation
  - Excel spreadsheet that allows users to input data from low-cost and regulatory monitors for comparison. Instruction guide describes how to use the spreadsheet, as well as guidelines for colocation with a federal reference monitor.
  - Developed by U.S. EPA [https://www.epa.gov/air-research/instruction-guide-and-macro-analysis-tool-evaluating-low-cost-air-sensors-collocation]
- openair R package and manual
  - R package (collection of R functions and code) for analyzing air quality data, along with a corresponding manual. R is a free, open-source statistical programming language.
  - Developed at King's College, London [http://www.openair-project.org/downloads/openairmanual.aspx]

Where can you get assistance in conducting data analysis?

Depending on your organization's interest, availability, and experience, you may wish to conduct the analysis on your own. Or you may prefer to work with an outside entity that has the appropriate expertise, such as:

- University faculty, researchers, or graduate students
- Local, regional, state, or national government agencies
- Non-governmental organizations, particularly those with strong research capabilities
- Private consultants
- Volunteer scientists from your community

Before initiating the analysis project with an outside partner, it is helpful to clarify:

- **What is the scope of work?** What is the partner agreeing to do, for how many hours, and in what time frame? In what format will the results be provided?
- **Who "owns" the results of the analysis?** What are agreements about using and sharing the data and results? Who will the analysis work be attributed to?
- **How will results be shared?** Will results be presented at conferences, through scientific manuscripts, or in other publications such as reports or factsheets? By whom? Who will be included as authors? Will community partners be included as co-authors for scientific manuscripts and presentations?
- **Is payment involved?** How much? By when?

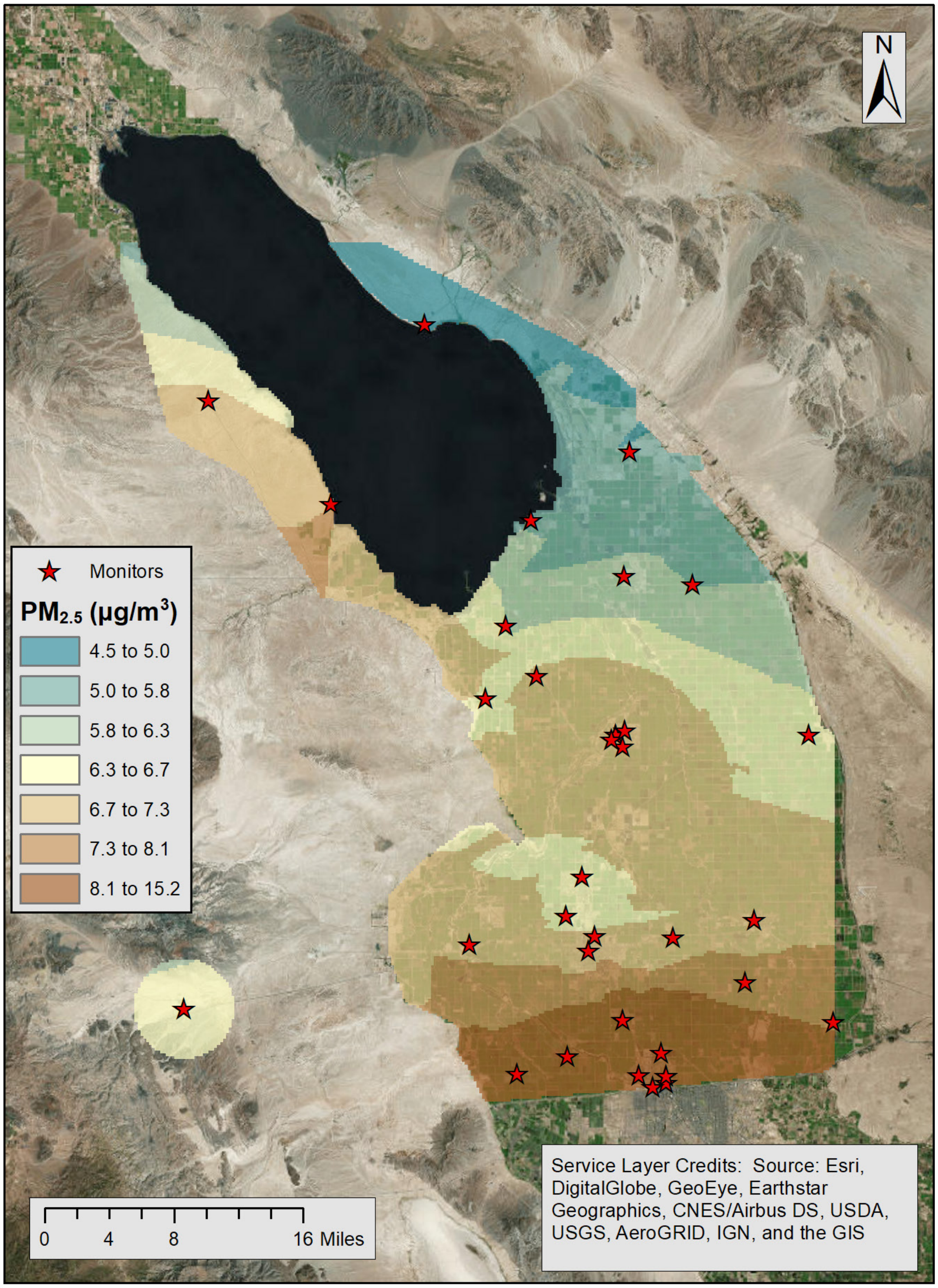
What limitations should be considered and communicated?

It is important to address known limitations of the data and analyses when communicating about your analysis results. While these limitations will depend on your specific analysis, when using community air monitoring data, it will be important to note that they are not regulatory data. When possible, try to communicate the accuracy, precision, and bias of your results. The EPA's Air Sensor Guidebook has suggestions for how to think about these statistical metrics in terms of air sensors.[18]

---

18. United States Environmental Protection Agency. 2014. How to Use Air Sensors: Air Sensor Guidebook. Online at [https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook].

Measured Average $PM_{2.5}$



CAMN data may be used for both simple and complex analyses. This example shows preliminary results of an advanced geostatistical procedure called Kriging to estimate PM2.5 throughout the county using data from IVAN AIR. Results indicate that PM2.5 is higher near the US-Mexico border and to the southwest of the Salton Sea. *Image courtesy of Graeme Carvlin.*

This page left blank intentionally.

CHAPTER 18

Sustaining the network

Once your network has been established, it is important to ensure that its operation can be sustained while maintaining or improving the level of data quality

What do you need to consider when developing a sustainability plan for your monitoring network?

Establishing a CAMN is a considerable amount of work, and it is important to estimate and plan for the cost and effort of maintaining this effort. It is best to begin considering your sustainability needs while you are still developing your CAMN, as this can help you to more smoothly transition from the development to maintenance phase.

In particular, if you are partnering with other organizations or consultants to develop the CAMN, figure out if they will have a role in the long-term operation of the network. If so, what are the details of that agreement? If not, then what steps are needed to ensure a smooth transfer of their responsibilities, capacities, and/or infrastructure to your organization or any new partners?

A sustainability plan should address:

» Organizational capacity and staffing

» Monitoring equipment and data infrastructure

» Quality assurance and control

» Data management and analysis

- Community engagement
- Cost
- Timelines

What kinds of capacities and staffing will you need?

If any core functions related to CAMN operation are conducted by external partners and you plan for these responsibilities to be transferred to your organization, ensure you have both the staff expertise and availability to take this on. For example, these activities could include assembling monitors, overseeing the database and data processing activities, compiling data to respond to data requests, facilitating the CSC, and other activities described below.

Transferring these responsibilities will require you to assess internal capacities, train staff as needed, and determine a transition period that allows some overlap between your group and your partners. If feasible, identify training and capacity-building opportunities beforehand, so that the individuals from your organization who will ultimately take on these tasks can work alongside your partners to gain hands-on experience. You can also ask your partners to document their processes and any other important details.

If it isn't possible or desired for your organization to take on these functions, identify other partners or contractors to take on these roles.

What is needed to maintain your monitoring equipment and data infrastructure?

As described in Chapter 14, ongoing maintenance of your monitors will be necessary and should be done according to your defined maintenance plan. Ongoing staff time will be needed for routine maintenance, and as sensors and other monitoring components age, components will eventually need to be replaced. You may also decide to upgrade your equipment as technology improves or older models become unavailable (see Chapter 9). It can help to plan for this eventuality, as replacing components for your entire network will have associated costs and staffing requirements. Also, if you do replace the type of sensor you are using, you will need to ensure integration with the rest of the monitor components and also conduct new calibration activities (see Chapter 11).

If any of the accounts related to your network have been set up by an external partner, such as for mobile internet services or the database server, arrange with your partner for the transfer of account ownership or to create a plan to switch to your organization's own accounts without disruption in service or loss of data.

How will you ensure continued data quality assurance and control?

Along with continuing to implement automated and manual quality control processes described in Chapter 11, monitors should ideally be recalibrated by the manufacturer once a year, which has associated costs. Additionally, since particle composition in an area may change over time, consider including regular (every 5-10 years) updates of your conversion equation as part of your sustainability plan (see Chapter 11) and identify who will do this work. If something has happened that may dramatically change pollution sources (such as rapid population growth, a ban on agricultural burning, or the introduction of new industrial facilities), then updating your conversion equation is recommended. Finally, as more data are gathered from your CAMN, you may wish to do analyses (Chapter 17) to assess how well your network is performing.

How will management, analysis, and reporting of data be conducted?

If your CAMN was developed in partnership with others, establish a plan that addresses:

» **How will the air monitoring data be managed?** Who will be responsible for ongoing review of quality assurance and control protocols, checking to ensure that all data processing steps are working as expected, and so forth?

» **How will you respond to requests for data?** What type of requests do you have the capacity to respond to? Who will be involved in evaluating the requests and determining a timeline and process to respond? How will you track requests (e.g., who made the request, what data you provided, how the data were used, what community or public health benefits the data ended up contributing to)?

» **Who will be the "owner" of the data?** How should the data or network be cited when used by your organization or others? Are there any stipulations from your funder about attributing the data to them or allowing them access to the data? Do these stipulations seem appropriate?

» **Who will have unrestricted access to data?** While you may decide to make the CAMN data available to the general public in a variety of ways (e.g., website, downloadable datasets, by request), will anyone besides your organization have unrestricted access to the raw data?

» **How will you support community awareness and access to the data?** Do you have a long-term outreach and dissemination plan (see Chapter 15) to ensure that community members continue to be aware of the data and know how to access and use it? If you use a website to disseminate data, do you have a strategy to manage and update it (see Chapter 16)?

How will you maintain engagement with the air monitor hosts, CSC, and broader community?

Among the key strengths of a CAMN are the relationships and partnerships developed with the air monitor hosts, CSC members, and others in the community. As part of your sustainability planning, consider how you will maintain these relationships.

For air monitor hosts, this may include establishing a regular check-in schedule to maintain communication and keep updated on any issues or concerns.

For the CSC, there may be specific activities for which their input or support would be helpful, such as the deployment of more monitors to expand the network, outreach activities to increase awareness and use of the CAMN, or public health or advocacy campaigns that use the CAMN data. Engage CSC members in determining the future role of the CSC, identifying the process for convening the group, and deciding if any changes to governance or membership would be appropriate for this new phase.

Finally, decide how you will continue to engage with any other individuals or organizations that play an important role in supporting the dissemination or use of the CAMN data, such as schools with air quality flag programs.

How much will it cost to sustain the network?

Maintenance activities (including overall coordination and project management), equipment, and services will have associated costs (See Appendix B). Having a good estimate of your available near and long-term financial resources will help to determine the scope and timeframes for your maintenance activities. Clarifying your CAMN maintenance goals and strategy will also inform your fundraising activities.

There are different options for financing the CAMN once it is established, including applying for grants, identifying businesses or institutions to sponsor monitors (particularly those that actually have monitors deployed at their locations), charging for access to data (such as archived datasets), and subcontracting with research partners to provide CAMN data for their studies.

Students birdwatching at the Salton Sea. There is substantial concern about the drying lake's impact on air quality in Imperial County and beyond. *Photo courtesy of Pacific Southwest Region U.S. Fish and Wildlife Service, CC BY-SA 2.0, [https://commons.wikimedia.org/wiki/File:Salton_Sea_ National_Wildlife_Refuge_ Migratory_Bird_Day_(31301235305).jpg].*

CHAPTER 19

Conclusion

The Imperial Air Project offers a flexible model for a scientifically-rigorous, community-led air monitoring network that enhances community capacity, strengthen partnerships, and protects community health

The foundation of the Imperial Air Project model is the combination of community ownership with scientific rigor. This model is flexible and can be tailored to fit the needs of your community. Importantly, the model is not dependent on a specific sensor technology or the pollutant measured. Instead, it provides a framework for an equitable, community-led, scientifically-guided process to develop and implement a CAMN to improve the health of all residents.

At its core, the model's success comes from:

- **Planning** that is intentional, equitable, and includes all of the values below
- **Inclusiveness** of diverse perspectives, peoples, and needs
- **Rigor** in the participatory process, scientific method, and data
- **Communication** among partners, with community participants, and with other stakeholders that is honest, open, clear, and respectful
- **Transparency** in project aims and activities, decision-making processes, data collection and processing methods, and communication of data and results
- **Sustainability** by emphasizing relationships, resource-sharing, capacity-building, and results that leave lasting benefits in the community

The Imperial Air Project model can be adapted in a variety of contexts. It may be woven together with additional community air monitoring models and guidelines developed by other communities, government agencies, or academic institutions to create a final plan that best fits your community's needs. But, regardless of the model chosen, a successful CAMN will require long hours and a devoted project team.

Below are some questions to consider in adapting the Imperial Air Project model in your community:

- **Goals:** What are the main goals of creating a CAMN for your community? What specific air quality concerns you would like to address? How will your organization and the broader community use the data?
- **Staffing and partnerships:** Who has or can gain the skills, capacities, resources, and funding necessary to create a CAMN in your community?
- **Relationship-building:** How can creating a CAMN help build and strengthen relationships within and across diverse organizations and groups of residents in your community?
- **Capacity-building:** What kinds of skills-building, hands-on training, and educational and employment opportunities can the creation of a CAMN offer for your community?
- **Impacts:** How can a CAMN complement or add to existing efforts by government regulatory agencies and others to both monitor air quality and share this information to improve community health?

The success of the CAMN can be measured in many ways, and community members (like those in the CSC) should have an early role in defining what the successful development and implementation of a CAMN should look like.

Definitions of success should reflect the goals of the project, and they can extend beyond simply whether the CAMN is operational. Success can also be measured by how many community members participated or remained involved in the project, whether project team members have gained knowledge and skills or taken on new roles, and how the CAMN data are being used. Evaluate your progress and document your achievements throughout the project to provide an opportunity for course-correction, reflection, and celebration.

The process to implement a CAMN can be lengthy, with much of the hard work and incremental accomplishments hidden from view of community stakeholders. Therefore, it is also important to share and celebrate your achievements with the community throughout the process. This can be done in a number of ways, including ribbon-cutting ceremonies for newly installed monitors, holding community gatherings to share when important milestones are reached, and organizing events to launch the CAMN website.

Remember to also celebrate those who have contributed to the success of the CAMN, including CSC members, air monitor hosts, other community participants, and project team members. Presenting certificates of appreciation to participants, recognizing the contributions of the CSC and project team members at events, and acknowledging all project team members in presentations or publications are ways to honor the people whose hard work, support, and dedication have contributed to the CAMN's success.

Regardless of how your successes will be defined and celebrated, by embarking on this journey to establish a CAMN, you are contributing to a better future for your community.

The first community air monitor, located at Brawley Union High School, was celebrated with a ribbon-cutting ceremony that included project team members, CSC members, students, and local officials. The high school band played for attendees, and the crowd was greeted by local representative State Assemblymember Eduardo Garcia. *Photo courtesy of Comite Civico del Valle.*

This page left blank intentionally.

Resources cited

Below are the resources cited in the guidebook. For more information about the Imperial Air Project or this guidebook, contact info@trackingcalifornia.org or go to [www.trackingcalifornia.org/imperial-air-monitoring]. Real-time air monitoring data from IVAN AIR can be viewed at [www.ivan-imperial.org/air].

RESOURCES DEVELOPED BY IMPERIAL AIR PROJECT

- English PB, Olmedo L, Bejarano E, Lugo H, Murillo E, Seto E, Wong M, King G. Wilkie A, Meltzer D. 2017. The Imperial County Community Air Monitoring Network: A Model for Community-Based Environmental Monitoring for Public Health Action. Environ Health Perspect. 125:074501. Online at [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5744720/].
- Carvlin GN, Lugo H, Olmedo L, Bejarano E, Wilkie A, Meltzer D, Wong M, King G, Northcross A, Jerrett M, English PB, Hammond D, Seto E. 2017. Development and field validation of a community-engaged particulate matter air quality monitoring network in Imperial, California, USA. J Air Waste Manag Assoc. 67:1342–1352. Online at [https://www.ncbi.nlm.nih.gov/pubmed/28829718].
- Wong M, Bejarano E, Carvlin G, Fellows K, King G, Lugo H, Jerrett M, Meltzer D, Northcross A, Olmedo L, Seto E, Wilkie A, English P. 2018. Combining Community Engagement and Scientific Approaches in Next-Generation Monitor Siting: The Case of the Imperial County Community Air Network. Int J Environ Res Public Health.15(3). Online at [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5877068/].
- IVAN Imperial. IVAN Air Monitoring. Online at [https://www.ivan-imperial.org/air].
- IVAN Imperial. Air Monitoring Q&A. Online at [https://www.ivan-imperial.org/resources/airfaqs].

RESOURCES ON COMMUNITY AIR MONITORING

- United States Environmental Protection Agency. Air Sensor Toolbox for Citizen Scientists, Researchers and Developers. Online at [https://www.epa.gov/air-sensor-toolbox].
- United States Environmental Protection Agency. Evaluation of Emerging Air Pollution Sensor Performance. Online at [https://www.epa.gov/air-sensor-toolbox/evaluation-emerging-air-pollution-sensor-performance].
- United States Environmental Protection Agency. 2014. How to Use Air Sensors: Air Sensor Guidebook. Online at [https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook].
- United States Environmental Protection Agency. Instruction Guide and Macro Analysis Tool: Evaluating Low-Cost Air Sensors by Collocation with Federal Reference Monitors. Online at [https://www.epa.gov/air-research/instruction-guide-and-macro-analysis-tool-evaluating-low-cost-air-sensors-collocation].
- California Air Resources Board. Community Air Monitoring. Online at [https://ww2.arb.ca.gov/capp-resource-center/community-air-monitoring].
- South Coast Air Quality Management District. Air Quality Sensor Performance Evaluation Center (AQ-SPEC). Online at [http://www.aqmd.gov/aq-spec].

TECHNICAL RESOURCES

- United States Environmental Protection Agency. 2018. Excel-based Macro Analysis Tool for Air Sensor Data. Online at [https://www.epa.gov/air-research/instruction-guide-and-macro-analysis-tool-evaluating-low-cost-air-sensors-collocation].
- United States Environmental Protection Agency. 2018. How to Evaluate Low-Cost Sensors by Collocation with Federal Reference Method Monitors. Online at [https://www.epa.gov/sites/production/files/2018-01/documents/collocation_instruction_guide.pdf].
- United States Environmental Protection Agency. Real Time Geospatial Data Viewer (RETIGO). Online at [https://www.epa.gov/hesc/real-time-geospatial-data-viewer-retigo].
- Carslaw DC. 2015. The openair manual — open-source tools for analyzing air pollution data. Manual for version 1.1-4, King's College London. Online at [http://www.openair-project.org/PDF/OpenAir_Manual.pdf].

BACKGROUND INFORMATION

» United States Environmental Protection Agency. National Ambient Air Quality Standards (NAAQS) Table. Online at [https://www.epa.gov/criteria-air-pollutants/naaqs-table .

» Office of the Federal Register. 2018. Protection of the Environment, Title 40 C.F.R. §81.305 Attainment. Online at [https://www.ecfr.gov/cgi-bin/text-idx?SID=6ce471d8cc33d1695ff368b16ccc3bce&mc=true&node=se40.20.81_1305&rgn=div8].

» Office of the Federal Register. 2013. Title 40 Protection of Environment, Appendix D to Part 58- Network Design Criteria for Ambient Air Monitoring. Online at [www.gpo.gov/fdsys/pkg/CFR-2014-title40-vol6/pdf/CFR-2014-title40-vol6-part58-appD.pdf].

» California Air Resources Board. 1999. Central California Air Quality Studies, Initial Field Program Plan, Siting Criteria. Online at [www.arb.ca.gov/airways/Documents/plans/981220/Part4.pdf].

» AirNow. Air Quality Index Basics. Online at [https://airnow.gov/aqi/aqi-basics].

» United States Environmental Protection Agency. 2013. Transitioning to a new NowCast Method. Online at [https://www3.epa.gov/airnow/ani/pm25_aqi_reporting_nowcast_overview.pdf].

This page left blank intentionally.

Project contributors

Imperial County Community Air Monitoring Project Team

Tracking California

formerly the California Environmental Health Tracking Program, a collaboration of the Public Health Institute and the California Department of Public Health

Natalie Collins*
Paul English (Principal Investigator)
Catalina Garzón-Galvis
Justin Howell
Galatea King*
Daniel Madrigal
Dan Meltzer*
Jhaqueline Valle Palominos
Alexa Wilkie
Michelle Wong (Co-Investigator)

Comite Civico del Valle

Esther Bejarano
Mariana Claustro
Israel Cruz*
Humberto Lugo
Eduardo Murillo
Luis Olmedo (Co-Investigator)
Christian Torres

University of Washington

Graeme Carvlin*
Katie Fellows
Edmund Seto (Co-Investigator)
Jeff Shirai

Consultants

Michael Jerrett, University of California, Los Angeles
Tyler Lopez
Amanda Northcross, George Washington University
Carlos Zamora, Z Data Solutions

** = former affiliation*

Community Steering Committee

(Past and Present Members)

Ray Askins
Astrid Calderas
Claudia Cristerna
Jose Flores
Edie Harmon
John Hernandez
Leticia Ibarra
Arturo Medina
Anita Nicklen
Frances Nicklen
Elizabeth Swerdfeger
Bianka Velez
Jose Luis Velez
Carolina Villa
Elizabeth Villa
Juan Zarate
Patricia Zarate

Technical Advisory Group

Bay Area Air Quality Management District

David Holstius

California Air Resources Board, Cal/EPA

Alvaro Alvarado
Fernando Amador
Michael Benjamin
Ranjit Bhullar
Yanju Chen
Donald Hammond
Lizzy Melgoza
Nico Schulte
Qunfang (Zoe) Zhang

California Department of Toxic Substances Control

Roger Vintze

Imperial County Air Pollution Control District

Miguel Coronel
Michael Green
Monica Soucier

Imperial Irrigation District

Kelly Bishop
Katie Burnworth
Jessica Lovecchio

Office of Environmental Health Hazard Assessment, Cal/EPA

Vanessa Galaviz

U.S. Environmental Protection Agency

Dave Fege
Priyanka Pathak
Dena Vallano
Jennifer Williams

Independent Consultant

Joel Craig

Air Monitor Hosts

Schools

Brawley Union High School

Calipatria High School

Frank Wright Middle School

Grace Smith Elementary

Heber Elementary School

Holtville High School

Kennedy Middle School

Meadows Union School

Miguel Hidalgo Elementary

Seeley Elementary School

TL Waggoner Elementary

Westmorland Elementary School

Wilson Jr High School

Residents

Hector Acevedo, Jr.

Hector Acevedo, Sr.

Ray Askins

Armando Atondo

Jose A. Dominguez

Suzy Fallavollita

Jose Antonio Garcia

Clifford Haskins

Lugo Family

Martinez Family

Gerry Merten

Vivian Perez

Gregorio Ponce

Concepcion Rubio

Mary D. Salazar

Daniel Tirado

Martha Villasenor

Other Entities

Alvarez Tax Service

Calexico Housing Authority East

Calexico Housing Authority West

California Air Resources Board

Comite Civico del Valle Inc.

Imperial Irrigation District

Torres-Martinez Desert Cahuilla Indians

This page left blank intentionally.

APPENDIX B

Example budget line items

The following line items can be considered as you develop the budget for your Community Air Monitoring Network.

A. Personnel

Each role may be filled by one or more individuals. In some cases, an individual may be able to fill or share multiple roles, and some roles may be filled by consultants. Identify percentage of each person's time over course of the project.

1. Salaries

- **Project manager:** This person provides oversight to the entire project, serving as a lead coordinator on project activities and main liaison with any partners. The role can include collaborating with any scientific partners on goals of project and leading the engagement of community in actions resulting from the project.
- **Project administrator:** The project may need a different person to coordinate all the project meetings, ensure completion of project deliverables, etc.
- **Health educator or promotor/a:** One or more people to serve as lead community outreach person for the project, with responsibilities that include: working with Community Steering Committee (CSC), planning and facilitating CSC meetings, recruiting air monitor hosts, engaging other community members, developing materials, and conducting outreach.
- **Air monitoring technician:** Responsible for the operation of the monitors, including monitor assembly, installation, operation, maintenance, and repairs.
- **Air monitoring science expert:** Develops conversion equation and establishes requirements for quality control protocols and calculation of summary statistics, to be applied to data processing scripts. This role is more likely to be filled by a consultant.
- **Data scientist/analyst:** Writes scripts specifically for taking data and manipulating it; oversees data collection, storage, processing, and reporting activities; ensures ongoing quality assurance and control; conducts analyses; and fulfills data requests.

- **Software developer(s):** The need here will vary depending on whether you plan to develop your own data infrastructure and/or website to display your data (versus using infrastructure provided by the monitor manufacturer or partners, for example). You may need a back-end developer for storage and retrieval of data (including database engineering, web services development, data processing) and front-end developer for the display of data (including user interface/web application development, as well as web and user experience design). This could be the same person, but often the skill sets vary.

- **Bookkeeper /administrator:** Manage all income and expenditures, establish consultant contracts, complete financial reports to funder, etc.

2. Fringe benefits: Compensation provided to employees in addition to salaries, such as medical and dental insurance, vacation and sick pay, transportation benefits, educational assistance, etc.

B. Consultants

The need for these roles will depend on what staff expertise is available in house. Estimate hours needed, at average hourly rates for that type of consultant. Some possible consultant roles are listed below.

- Back-end software developer
- Front-end software developer
- Web designer
- Air monitoring science expert
- Data scientist/analyst
- Facilitator for CSC meetings
- Health education and communication consultant

C. Equipment and Supplies

1. **Air Sensors:** Per sensor cost multiplied by the number of sensors anticipated. Consider purchasing additional sensors for maintenance/replacement purposes.

2. **Microcontroller:** Per monitor, if using a custom-designed monitor.

3. **Enclosures:** Per monitor, if using a custom-designed monitor.

4. **Other monitor components:** As needed, such as temperature and humidity sensor, mobile hotspots, fans, and any equipment needed for monitor installation.

5. **Computers and server for central data storage and management:** A project-specific server, either on-site or in the cloud, will be needed to store data from the monitors, process the data in real-time to create air pollution surfaces, and potentially push the data to other data repositories.

D. Travel

Consider budgeting for travel for the following activities:

1. **CSC and other meetings:** Travel should be budgeted for staff to participate in project meetings, CSC meetings, and other community events. Consider paying mileage (it is easiest to use the federal mileage rate for any year) or public transportation costs; lodging; tolls/parking; and a per diem for food if meals are not provided.

2. **Site visits for monitor installation, maintenance, and repair:** Obtaining permission at schools or other monitor sites to install monitors can take several visits. Once installed, each monitor will need to be visited every 3-6 months or even more frequently. Estimate mileage.

3. **Professional development and training:** Budget for travel to any technical or other training opportunities attended by project staff. This may include airfare and lodging to visit technical experts or attend training seminars.

4. **Conferences and meetings:** Consider budgeting for lead staff to attend and present the project findings at regional or national scientific conferences, environmental justice meetings, and other public health events to share lessons learned about the project.

5. **Consultant travel:** Transport and hotel costs for any consultants who will need to visit the project in person.

6. **Community participant travel:** Reimbursement of CSC members and other community members participating in CSC meetings and other project-sponsored community events. This includes mileage or public transportation costs, tolls/parking, lodging, and a per diem for food if meals are not provided.

E. Miscellaneous Costs

1. **General office costs:** include printing costs for meetings, health education, and promotional materials for the project.

2. **Computer workstations**

3. **Communications:** costs of communication, internet and email, and other IT support.

4. **Wireless internet service:** for Wi-Fi hotspots.

5. **Expenses for Community Steering Committee meetings and other community events:** facility rental, meeting technology and equipment, translation of materials, simultaneous interpretation equipment and services, food, stipends for community participants, and reimbursement for childcare.

6. **Conference, professional development fees**

F. Organizational overhead (indirect rate)

There are ongoing expenses of operating an organization, such as rent, utilities, telephone, insurance, etc. This is generally calculated as a percentage of total budget.

APPENDIX C

Outreach and recruitment materials

Invitation to Participate on the Community Steering Committee

[insert date]
Dear [insert name],

We would like to formally invite you to become a member of Community Steering Committee for the Imperial Community Air Monitoring Project, a collaborative project between the California Environmental Health Tracking Program, Comité Cívico Del Valle, and the University of Washington. We believe that your knowledge and commitment to improving environment and health in Imperial County would greatly benefit this important research project, which aims to:

- Use a community process to map environmental hazards and community assets in 10 impacted communities within Imperial County
- Use mapping results to establish a community air quality monitoring network, placing 40 air monitors in the best locations to identify air pollution hot spots near vulnerable populations
- Collect, analyze, and publicly disseminate data from the air monitors to inform residents about local air quality
- Use mapping and air monitoring results to design and implement public health campaigns and other activities to address key community concerns

We hope you or someone from your organization can participate in this community input process to provide essential guidance in our efforts to improve air monitoring- and ultimately air quality and health- in Imperial County. Participating in the Steering Committee will also provide you with opportunities to identify and select public health campaigns that will address key community concerns.

We ask that members of the Steering Committee participate throughout the course of the project (four years). The time commitment for this period includes attending six meetings in Imperial County, plus some light email communication.

The first meeting is scheduled for [insert date and time] and will be located at [insert location]. We will provide food, a participation stipend, and reimbursement of travel costs for all participants.

We are attaching a project overview that may be helpful. Feel free to contact us directly with any additional questions or concerns.

Thank you for considering working with us on this exciting project, which has the potential to improve air quality and health in Imperial County. We look forward to hearing from you soon.

Sincerely,

Paul English, PhD, MPH
California Environmental Health Tracking Program
Principal Investigator, Imperial Community Air Monitoring Project

Cc:

Luis Olmedo
Comité Cívico Del Valle
Co- Investigator, Imperial Community Air Monitoring Project

Edmund Seto, PhD
University of Washington
Co- Investigator, Imperial Community Air Monitoring Project

Imperial Air Project General Factsheet

CALIFORNIA ENVIRONMENTAL HEALTH TRACKING PROGRAM

Imperial County Community Air Monitoring Project

An Impacted Community

Imperial County, California, is a primarily Latino county with some of the highest rates of unemployment and poverty in the nation. Along with numerous environmental concerns cited by residents, including water contamination and pesticide use, air pollution is a major concern. For decades, the county has exceeded the state standard for PM_{10} for periods lasting over six months, and the county consistently has one of the highest asthma hospitalization and emergency room visit rates in the state for school-aged children.

Limited Data for Action

With a limited number of air pollution monitors in a county that spans over 4,000 square miles, the county's air quality monitoring network has limited ability to measure air pollution hotspots of greatest community concern. While Imperial County has a historically active and committed population, this lack of information is an impediment to assessing and informing policies and practices to reduce exposures and improve health.

New Air Monitoring Project in Imperial County

In partnership with Comité Cívico del Valle (CCV), a local community organization and long-time collaborator, along with the University of Washington and other partners, the California Environmental Health Tracking Program (CEHTP) received a grant from the National Institutes of Health to conduct a 4-year community-based air monitoring research project in Imperial County, CA.

Community-Driven Research

The project will engage members from impacted communities to design a Community Air Monitoring Network and to develop strategies to use data from the Network for public health action. A Community Steering Committee will play a key role in project design, implementation, and decision-making. Additional community members will engage in data collection, placing air monitors, results interpretation, and dissemination.

Neighborhood Mapping

Participants from 11 neighborhoods of concern will define and map local hazards and assets to inform the placement of air monitors for the Network, highlight factors contributing to community vulnerability and resilience, and delineate cumulative exposures.

Community-Operated Air Quality Monitoring Network

The Network will consist of 40 low-cost, portable air monitors placed throughout Imperial County. The project will use an innovative approach to determine the locations of the monitors, incorporating community-generated data and community input, along with requirements for scientific rigor. Community members will set up and maintain the monitors, which will remain in the community after the project.

PUBLIC HEALTH INSTITUTE®

COMITE CIVICO DEL VALLE, INC

SCHOOL OF PUBLIC HEALTH
UNIVERSITY of WASHINGTON

CEHTP

Reporting Real-Time Air Monitoring Data

The Network will relay data to the internet for immediate information on air pollution levels. The data will be publicly displayed on IVAN Online (Identifying Violations Affecting Neighborhoods, www.ivan-imperial.org), a community-based environmental reporting website. Data will also be available on the CEHTP web portal (www.cehtp.org).

Identifying Hot Spots

Project researchers will combine data from the Network with data from existing state and federal air monitors to create highly detailed maps of air pollution by location and time. Using advanced analytical methods (such as state-of-the-art dispersion and land use regression modeling), the project will result in the most accurate and detailed picture of air quality (PM_{10} and $PM_{2.5}$) throughout the county, enabling identification of hot spots near vulnerable populations.

Translating Research Results into Action

Community participants, the steering committee, and project staff will examine mapping activity results and data from the Network to discuss key findings and issues of concern. Together, the group will develop and implement a public health action plan for reducing exposures and improving health. The group will also discuss strategies for sustainability after the project's completion.

Community Steering Committee Members

Ray Askins	Community Advocate	Rosie Nava	Family Tree House
Alejandro Bejarano	Community Advocate	Anita Nicklen	Community Advocate
Joe Beltran	Community Advocate	Frances Nicklen	Community Advocate
Astrid Calderas	Community Advocate	Vincent Orfiano	Community Advocate
Edie Harmon	Community Advocate	Elizabeth Swerdfeger	Community Advocate
John Hernandez	Our Roots Multi-Cultural Center	Carolina Villa	Seeley Citizens United
Leticia Ibarra	Clínicas de Salud del Pueblo, Inc.	Elizabeth Villa	Community Advocate
Arturo Medina	Community Advocate	Juan Zarate	Community Advocate

Project Partners

California Environmental Health Tracking Program • Comité Cívico del Valle • University of Washington
George Washington University • University of California Los Angeles • Z-Data Solutions

For More Information

To learn more about this project, please contact CEHTP at tracking@cdph.ca.gov or (510) 620-3038, or Comité Cívico del Valle at comitecivico@sbcglobal.net or (760) 351-8761.

The California Environmental Health Tracking Program is a project of the Public Health Institute. This project is funded by the NIH National Institute of Environmental Health Sciences, grant number 5R01ES022722-02.

April 2015

Methods Summary: Use of Community-Based Mapping and Monitoring to Reduce Air Pollution Exposures

Principal Investigator: Paul English, Paul.English@cdph.ca.gov

Goals of community-engaged air pollution monitoring

The broad goal of this study is to develop a community-engaged research process to better understand air pollution patterns in Imperial Valley in order to reduce air pollution exposures and improve the health among residents. The project will use innovative technologies to collect data on environmental hazards, measure air quality, and disseminate data.

Specifically, our goal over the next 2 years will be to deploy a network of approximately 40 low-cost air quality monitors in Imperial County. These monitors will complement existing air quality monitoring conducted by regulatory agencies in the region. Our focus will initially be on measuring PM2.5 and PM10, however we are also considering NO2. The selection of monitors has not been completed yet, as we would like to allow for ample discussion with community partners to understand their monitoring needs. However, our motivation to use new low-cost monitors is informed by prior development and evaluations of this technology (Northcross et al., 2013 and Holstius et al., 2014). The monitors will be deployed and operated by the community. And, the monitors will transmit data over the Internet to a server, which can facilitate data dissemination for multiple purposes, including air quality modeling to identify hotspots of exposure that may affect vulnerable populations. We may also find that using monitors that have a display that shows their measurements in real-time may be valuable for community-engaged research.

Community process to identify priority neighborhoods

The first step of the project is to facilitate a community process to identify the neighborhoods within Imperial County that should be prioritized for localized air monitoring. CCV will recruit 5-10 community organizations based in Imperial County to guide the project and serve on the Community Steering Committee (CSC). Monitoring needs will be discussed, so as to help finalize our technical requirements for monitoring.

Neighborhood asset and hazard mapping

In the first project year, after attending a training meeting, community residents from each neighborhood of concern will use smartphones and other methods to conduct asset/hazard mapping for their specific neighborhood. Assets could include locations such as green space, community clinics, day care centers, and community centers. Hazards could include point sources of PM, noise hazards, busy roadways, unpaved roads, agricultural burning sites, illegal dumping, and water contamination.

Community-engaged process to design an air quality monitoring network

Traditionally, decisions on where to site monitors in a network have not involved community participation or input. A major innovation of our project is that we will engage the community in how we design our air quality monitoring network. Toward the end of the first project year, we will deploy an initial set of 20 monitors. We will randomly select deployment sites from the list of candidate sites, stratified on factors identified from the community hazard and asset mapping discussions (e.g. land use, distances to agricultural burning, distance to border, proximity to Salton Sea). Based on data from these initial monitors, we will develop a land use regression model that incorporates community-identified factors as independent variables. The model will inform the placement of the remaining 20 monitors in year two. In total, 40 new monitors will be sited in Imperial.

Quality assessment of the monitoring data

At 10 of the pilot study locations, we will co-locate gravimetric samplers with the low-cost monitors for a period of 7 days in different seasons to capture temporal variations in air pollution sources. These measurements will serve to validate our low-cost monitors and enable locale-specific calibration. Also if feasible, we would like to co-locate monitors at, or near to, at least one existing regulatory monitoring site throughout the duration of the study. This would allow for ongoing calibration of our monitoring network against data from Federal Reference or Equivalent Method (FRM/FEM) instruments and possibly enable the development of region-specific correction factors to convert data from low-cost instruments to mass concentrations.

Air quality monitoring data analysis and modeling

Because our low-cost monitors are particulate counters, we will need to model the relationship between PM counts and PM mass in order to compare the data with the state and federal monitors, which measure mass concentrations. Data collected from our quality assessment will be analyzed using multivariate regression methods to determine a relationship between particle counts and mass concentrations.

Using these models, period (e.g., hourly) average and daily average and maximum levels of PM10 and PM2.5 from the monitored sites will be compared to the state (for PM10) and federal (for PM2.5) standards. We will also produce a modeled air pollution surface map for each day. This may be produced using land use regression as described above, however, more advanced methods, including dispersion modeling or data-adaptive semi-parametric algorithms that optimizes the use of multiple candidate models to cross-validation to arrive at robust predictions of an air pollution surface map.

Data dissemination

One of the end results of our mapping and monitoring activities will be large amounts of data on environmental quality and concerns for Imperial. These data will be made available to the public via the Internet and will be discussed at a community meeting. Prior to the release of data, project health educators will work closely with scientists and community partners to develop and test lay-friendly explanatory text to accompany the data to ensure that they are understood and appropriately interpreted by the public.

References

Northcross, A. L., Edwards, R. J., Johnson, M. A., Wang, Z. M., Zhu, K., Allen, T., & Smith, K. R. (2013). A low-cost particle counter as a realtime fine-particle mass monitor. Environmental Science: Processes & Impacts, 15(2), 433-439.

Holstius, D. M., Pillarisetti, A., Smith, K. R., & Seto, E. (2014). Field calibrations of a low-cost aerosol sensor at a regulatory monitoring site in California. Atmospheric Measurement Techniques Discussions, 7(1), 605-632

APPENDIX D

Hardware components used for the IVAN AIR community monitor

Below are the components used in the community monitor for IVAN AIR at the time of writing. Specific hardware may not be available at the time of reading. Depending on your sensor selection and data display needs, your equipment requirements may be different.

- **Air quality sensor: Dylos 1700**

  The Dylos 1700 air quality sensor measures the number of particles in the air. The Dylos measures four particle bins, particles greater than 0.5µm, 1.0 µm, 2.5 µm, and 10 µm in diameter. The units are number of particles per 0.01 cubic feet (#/0.01 ft3). The Dylos is plugged into a custom circuit board that sits on top of the microcontroller. The Dylos sends a data packet containing the four bin sizes over a serial connection to the microcontroller once every 10 seconds. Cost ~$750.

- **Temperature and humidity sensor: Honeywell HIH6130**

  The Honeywell HIH6130 samples temperature and humidity once every 10 seconds. The data are sent to the microcontroller. Cost ~$10.

- **Custom circuit board and microcontroller: Arduino Yun**

  The custom circuit board converts the Dylos serial data stream to TTL (which the Arduino Yun can understand), integrates the temperature and humidity sensor, and provides feedback through power/Wi-Fi/data connection status lights.

The Arduino Yun has two microprocessors, an Atheros AR9331 and an Atmel ATMega32u4 (32u4), as well as Wi-Fi and Ethernet capability. The Dylos and temperature/humidity data are read by the 32u4 chip and sent directly to the AR9331 chip. The AR9331 chip is running a variant of Linux. A python script on the AR9331 reads in the data and produces five minute averages. Once every five minutes a data packet is sent from the Yun over the internet to a database on a remote server.

The Arduino Yun is no longer being actively supported. The Arduino Yun Rev2 is now being used in new monitors. Cost ~$60.

» **Cellular modems: T-Mobile 4G LTE HotSpot Z915 and ZTE Falcon Z-917**

Cellular and Ethernet connections have been more reliable than Wi-Fi for the Imperial Air Project. This seems to be particularly true with the Yun, even after adding an external Wi-Fi antenna. The cellular modems used for IVAN AIR were purchased from T-Mobile. Cost ~$80.

» **Enclosure and fan: L-com NB141207-20F**

The enclosure is a NEMA-6 rated fiberglass 14”x12”x7” box with built-in AC power and cooling. It was purchased from L-COM. Cost ~$275.

APPENDIX E

Assessing the performance of your conversion algorithm

Below is a discussion of statistical parameters to use for checking calibration model performance. For a basic introduction, consult a biostatistics textbook. For more detail, see Carvlin et al. 2017.

The metrics used to impactful the performance of the conversion algorithm include the R2, the slope, the intercept, and the root mean squared error (RMSE). It is important to look at all four parameters.

The R2, also known as the coefficient of determination or the correlation, is a measure of the linearity of the data. A “good” correlation depends on the type of model and input data, but in the case of a conversion equation, an hourly R2 of 0.7 to 0.85 is good and an hourly correlation above 0.85 is very good. As the time averaging period increases, the correlation will go up since the variability decreases. A good correlation for a daily R2 might be 0.8 to 0.9.

In addition to R2, you must also look at the slope and intercept. These parameters help describe the bias in the model. Bias is the difference between the “truth”, the regulatory instrument’s reading, and the community monitor’s reading. The slope should be close to 1 and the intercept should be close to 0. It is okay if these parameters are not ideal before the conversion equation is applied; this just means that the monitor is biased before conversion.

RMSE tells you how accurately your model predicts the true value on average. The reason to include RMSE along with R2 is that RMSE is less easily biased by outliers and nonlinearity in the data.

This page left blank intentionally.

APPENDIX F

Monitor host recruitment materials

Factsheet for air monitor hosts

CALIFORNIA ENVIRONMENTAL HEALTH TRACKING PROGRAM

Imperial County Community Air Monitoring Project

Factsheet for Air Monitor Hosts

We would like to invite you to host one of the air monitors that will form the Imperial County Community Air Monitoring Network. Please review this factsheet for more details about becoming an air monitor host. For more information, please contact Comité Cívico de Valle at comitecivico@sbcglobal.net or (760) 351-8761.

COMITE CIVICO DEL VALLE, INC

SCHOOL OF PUBLIC HEALTH
UNIVERSITY of WASHINGTON

What are you monitoring?

We are monitoring particulate matter (PM) pollution, which consists of solid and liquid particles in the air. Particles can consist of materials such as dust, dirt, soot, smoke, salt, acids, and metals. PM can negatively impact health and is linked with asthma, cancer, heart disease, poor birth outcomes, and premature death.

Why was my property selected?

As part of this project, 40 individuals representing 11 cities in Imperial County participated in a two-day meeting to identify and map possible air monitoring sites within their communities. Participants identified and ranked sites where they felt having an air monitor would best serve the community.

What are you asking me to do?

The time commitment and responsibilities for air monitor hosts are minimal. We are asking for your permission to install and operate an air monitor on your property, which will require a trivial amount of electricity and internet access from you. Also, we request permission to check on the monitor about four times a year, which we will schedule with you in advance. Project staff will be entirely responsible for the installation and maintenance of the air monitor.

Where will the air monitor be installed?

In general, the monitor can be installed in any safe, outdoor location as long as it about 10 feet off the ground and has access to an electrical outlet and wireless internet. In other studies, monitors have been installed on roof tops, on poles, and under the eaves on the sides of buildings. Project staff can work with you to identify potential locations that meet both your needs and monitor siting criteria.

How long will installation take?

Depending on the final location of the monitor, we expect the installation itself to take 2-4 hours. We can provide a better assessment once the location has been selected.

1

How big are the air monitors?

The monitors are small and lightweight (about 7 inches tall and less than 2 pounds). They will be installed with a protective casing (about 14 inches tall and 12 inches wide, weighing less than 13 pounds). For some installations, monitors may be placed on a tripod.

project air monitor and protective casing

How long will the air monitors be in place?

The plan is for the community air monitoring network to serve as a community resource and continue to operate beyond the official project end date of October 2017. If you have any concerns about hosting an air monitor at any point, please let us know.

Will I have access to the data collected by the air monitor?

Yes. The information from your monitor will be publicly available via a user-friendly website once all of the monitors for the network have been installed and tested, likely in early 2016. In the meantime, we will mail you a monthly report with a preliminary summary of the air quality data collected by your monitor. This can give you an idea of the type of information that you will be able to access once the air monitoring network is fully operational.

How is this data different from what is currently available?

Air quality data is currently available for Imperial County through such websites as imperialvalleyair.org and airnow.gov. These data are derived from four regulatory monitors located in the county. Because the data are specifically collected for regulatory purposes, they are not able to provide much information about air quality at the neighborhood-level. This project aims to supplement this existing information by providing neighborhood-level PM data.

How can the data from the air monitors be used?

Data generated by the network will include real-time air quality measurements for each air monitor, maps showing air pollution hotspots throughout the county, air quality trends over time, and other summary data. This information can be used for public health action, planning, and policy. For example, the data could:

- inform asthma management at the individual and community level
- facilitate air pollution research
- support outreach, education, and advocacy efforts
- guide programs and policies to reduce air pollution and improve health

The ultimate goal of the project is for the network to provide information that will lead to the improved health of residents throughout the county.

The California Environmental Health Tracking Program is a program of the Public Health Institute. This project is funded by the NIH National Institute of Environmental Health Sciences, grant number 5R01ES022722-02.

Monitor host recruitment letter template

Superintendent [name and title]
[school name]
[Address]
[City, state, ZIP]

April 13, 2015

Dear Superintendent [NAME],

I am writing to ask your support for an important public health project- initiated in response to community concerns about air quality- which aims to install air monitors at different locations across Imperial County, including public schools. Poor air quality is linked to many health issues, including asthma, cancer, heart disease, poor birth outcomes, and premature death. However, air quality data at the neighborhood-level is not readily available. The Imperial County Community Air Monitoring Project aims to improve the health of residents by providing better information about air quality in their communities.

We have just completed a process with county residents to learn where they would like the air monitors to be placed within their specific communities. Among the selected sites were included 11 schools throughout the county, with several of them located in your district: [NAMES OF SCHOOLS]. With your support, we hope to outreach to principals at these schools to obtain permission to install air monitors. Project staff will be responsible for installing and maintaining the monitors. From the schools, we only require use of an electrical outlet and wireless internet, as well as access to the monitor a few times a year.

We are requesting your assistance in notifying school principals and expressing your support of the project. With these monitors, residents, government officials, and others will have better information to guide actions and policies to reduce air pollution and improve health. In particular, parents of asthmatic children will be able to make more informed asthma management decisions by having real-time data about air quality in their communities.

This project is a collaboration of the California Environmental Health Tracking Program, Comité Cívico del Valle, and the University of Washington. For more information, attached are an overview of the project and a factsheet with more details about hosting an air monitor. Our partners at Comité Cívico del Valle are leading the site recruitment effort and will be following up with you and the individual schools directly. Thank you for your time and consideration. Please feel free to contact me if you have any questions or concerns.

Sincerely,

Paul English, PhD, MPH

Principal Investigator
Imperial County Community Air Monitoring Project
California Environmental Health Tracking Program

Air Quality Monitoring Equipment Installment Agreement

COMITE CIVICO DEL VALLE

Imperial County Community Air Monitoring Project

Air Quality Monitoring Equipment Installation Agreement

I,_______________________________________, voluntarily grant permission to the Comite Civico Del Valle (CCV) to install Dylos Air Quality Monitoring Equipment (monitor) at a mutually agreed upon location at the following property : ____

As part of the installation, I agree to the following conditions:

- I grant permission for the monitor to use the property's electricity and internet service. If the property does not have internet, I understand that an internet hotspot device will be installed along with the monitor. Air quality measurements collected by the monitor will be transmitted to CCV and its research partners via the internet connection.
- I will provide CCV staff and research partners with access to the monitor for periodic inspection, maintenance, repair, or replacement. I will also provide access for occasional brief tours of the monitor, which will be led by CCV or its research partners. I understand that CCV will contact me to notify me and to schedule these visits.
- I will notify the CCV immediately if I observe any type of equipment malfunction, installation problems, potential weather damage, vandalism, or theft of the monitor. I understand that I am not responsible for any damage or theft.

I acknowledge that I have been advised and understand that:

- CCV is a non-profit organization and not a governmental agency
- The purpose of installing monitor is to collect and report air quality data to CCV and its research partners.
- Data from this and other project monitors will be made publicly available via a community-based website (ivanair.org) coordinated by CCV. The monitoring data will also be shared with interested entities, such as governmental agencies, universities, elected officials, health organizations, equipment manufacturers, and the media.

1

- The Dylos Air Quality Monitoring Equipment is not dangerous to my health or safety. It is low voltage and low current device.
- The property's residents and/or staff are not required to provide any personal information.
- This agreement is voluntary for 3 years and will be extended if needed.
- I may stop participating at any time. If I end my participation, I will provide a minimum 30 days notice to CCV, who will be required to remove all equipment and electrical connections.
- I acknowledge that I am at least 21 years of age.
- CCV will hold me harmless and will be responsible for all loss or liability that results from installation or use of the monitor, except to the extent resulting from my gross negligence or willfull misconduct.

Name: ______________________________

Signature: ______________________________ **Date:** __________

Address: ____________________ **Telephone:** ____________________

____________________ **Email:** ________________

Additional Information

Property Type:
[ ] School
[ ] Residence
[ ] Business
[ ] Other (please describe)____________

Affiliation with Property:
[ ] Property owner
[ ] Representative of property owner
[ ] Renter
[ ] Other (please describe)____________

Comite Civico del Valle Representative

Name: ______________________________ **Title:** ____________

Signature: ______________________________ **Date:** ____________

Comite Civico del Valle ● 699 E Street ● Brawley, CA 92227 ● (760) 351-8761 or (760) 550-3650

2

APPENDIX G

Description of data feed script to generate IVAN AIR data

Below is a technical description of the data feed script that produces the summary data that is shown on the IVAN AIR website.

The data feed is updated once every 5 minutes. The script produces a .csv file for each Dylos sensor that contains data on PM mass concentrations and AQI for 4 different time scales.

First the script downloads the 5-minute data and performs two basic QA/QC procedures: (1) Data where Dylos bin1 is <= 30 are set to a null value (2) Drop datapoints that are missing either Dylos bin1 (used for PM2.5) or Dylos bin3 (used for PM10). The first procedure removes any abnormally low readings, which occur when the Dylos sensor has become dirty. The second procedure makes sure that PM2.5 and PM10 are reported together. This is needed to calculate a proper community air quality level (CAL), which takes the higher value of either PM2.5 or PM10.

Afterwards, the 5-minute data are run through an interpolation algorithm. This fills in any small gaps in the data. The interpolated 5-minute data are then averaged to either 1-hour data (for current/24-hour statistics) or 1-day data (for 30/90 day stats). The averaging is subject to a data completeness requirement of 50%. This means that any hours/days with less than 50% of the data are set to a null value. These data averages are then converted from Dylos count to mass concentration. Mass concentrations less than 1 µg/m3 are set to “<1”.

NowCast values are used for the 1-hour and 24-hour statistics. NowCast is a technique developed by the EPA that provides an estimate of the 24-hour PM mass concentration by weighting the last 12 hours of data. This enables the use of the AQI color scheme with less than 24 hours' worth of data. Mass concentrations are converted to AQI values and colors using the EPA's AQI scheme. AQI values that would be in categories above red using the EPA's scale are set to red. The CAL is the higher of the PM2.5 and PM10 AQIs, just like EPA composite AQIs. Summary statistics are then calculated for the PM2.5 and PM10 mass concentrations and the AQIs. Monitors that do not meet the QA/QC or data completeness checks for any particular statistic have that value set to null and their AQI color set to grey to indicate that data are not available.

Glossary

Air monitor *(pg 45)* – An instrument used to measure one or more physical properties of the air that integrates one or more air sensors with a microcontroller and other components needed to process the data and make it available in a format that is readable to humans.

Air monitoring *(pg 3)* – Measuring changes in at least one physical property of the air within a specific geographic area over a given period of time.

Air pollution *(pg 3)* – Emissions that are released into the air by human activities, such as agriculture or manufacturing, as well as natural events such as wildfires and dust storms, which are known or suspected to be associated with a certain amount of health risk.

Air pollution control district *(pg 126)* – See air quality management district.

Air pollution level *(pg 100)* – The amount of a given pollutant in the ambient air in a specific area at a given time.

Air quality *(pg 3)* – The condition of the air as determined by measuring the concentration of air pollution.

Air quality flag program *(pg 94)* – A program that uses color-coded flags to communicate current air quality levels. The color of the flag indicates the amount of air pollution in the air and what actions, if any, are recommended at that level to reduce exposure to this pollution.

Air quality index (AQI) *(pg 104)* – A color-coded system for indicating and displaying air quality levels in which each color corresponds to an amount of air pollution that is associated with a certain level of health risk. In the U.S. EPA's Air Quality Index, the color green stands for "good," yellow stands for "moderately" healthy, orange stands for "unhealthy for sensitive groups," and red stands for generally "unhealthy."

Air quality level *(pg 20)* – The extent to which the amount of a pollutant in the ambient air in a specific area at a given time is known or suspected to be associated with a certain amount of health risk.

Air quality management district *(pg 8)* – A local regulatory agency responsible for ensuring that local air quality is in compliance with state and federal regulatory standards. Also referred to as an air pollution control district or air district.

Air sensor *(pg 45)* – A component inside of an air monitor that measures a physical property of the air and reports its measurement.

Alert system *(pg 94)* – A mechanism by which users of an air monitoring network can register to receive automated notification via email or text when air quality at specific monitors is not good.

Ambient air quality *(pg 11)* – A measurement of general levels of air pollution in a specific geographic area (as opposed to measuring air pollutants emanating from a specific source).

Beta-attenuation monitoring *(pg 50)* – A method used to measure the absorption of radiation by particles caught on a filter in order to generate a measurement of the mass of particles in the volume of sampled air.

Calibration *(pg 62)* – A process of comparing the data collected by an air monitor to that collected by a reference instrument, such as a regulatory monitor, and then adjusting its measurements to more closely match the reference instrument.

Calibration zone *(pg 63)* – A geographic area where the physical composition of particles in the air is similar enough to accurately compare data collected across several air monitors in that area.

California Air Resources Board (CARB) *(pg 84)* – A state regulatory agency responsible for ensuring that human activities within California are in compliance with state and federal air quality standards.

Cellular modem *(pg 47)* – A device that allows an air monitor to upload data to a server using a cellular connection if internet at the site is unreliable or not available. Also referred to as a cellular hotspot or mobile hotspot.

Colocation *(pg 62)* – The siting and operation of an air monitor alongside or as close as possible to a regulatory monitor, which allows for the comparison of data collected by both monitors. May also be spelled as co-location and collocation.

Colocation time *(pg 63)* – The amount of time that an air monitor is located alongside or as close as possible to a reference instrument such as a regulatory monitor.

Community air monitoring *(pg 8)* – A process that engages residents of a community where air monitoring is taking place in collecting and making available information about local air quality levels.

Community air monitoring network (CAMN) *(pg 11)* – A collection of air monitors at fixed locations throughout a community or region that is established and operated by a community-based organization, aims to measure ambient air quality, and collects data that are then made available in real-time to the public.

Community air quality levels (CAL) *(pg 104)* – An air quality index used by the Imperial County Community Air Monitoring Network to provide information about general air quality levels and their related health risk.

Community-based organization *(pg 9)* – For the purposes of community air monitoring, an organization whose core function is to serve the community in which it resides and whose staff live in the community.

Community steering committee (CSC) *(pp 33-35)* – An advisory group comprised of community leaders, advocates, youth, and other concerned residents that provides guidance and decision-making in the implementation of activities for establishing and maintaining a community air monitoring network.

Concentration-dependent bias *(pg 62)* – A situation in which the readings from a low-cost air sensor vary at high or low concentrations when compared to a reference instrument.

Constant bias *(pg 62)* – A situation in which the readings from a low-cost sensor are always higher or lower than a reference instrument.

Conversion equation *(pg 64)* – An equation developed through the use of statistical methods that is used to convert one unit of measurement of the amount of particles in a given volume of air (such as particle count concentration) to another unit of analysis (such as particle mass concentration).

Correlation *(pg 64)* – A statistical measure of the interdependency between two or more variables.

Custom monitor *(pg 46)* – An air monitor whose physical assembly is conducted by or on behalf of the monitor operator to include specific hardware and software components.

Data *(pg 3)* – Information that can be expressed as a number and recorded or processed by a computer.

Data completeness *(pg 67)* – The percentage of valid data points when compared to the total number of possible valid data points.

Data display *(pg 103)* – A visual representation of a set of data points, such as a map or chart.

Data dissemination *(pg 93)* – The process of making the data and information collected by an air monitoring network available to the public and/or target audiences.

Data feed *(pg 59)* – A summary of the data collected by an air monitor that can be transmitted via computers and uploaded onto a website.

Data graph *(pg 86)* – A simple graphical representation of the data collected by an air monitor that can be used to check monitor performance and connectivity.

Data infrastructure *(pg 7)* – A digital system for sharing, storing, and communicating data using computers.

Data ownership *(pg 52)* – The extent to which an organization or individual has legal rights or control over a set of data and the way it is generated, stored, and shared.

Data point *(pg 64)* – A discrete unit of information that can be recorded as a number or point in a graph or chart.

Data processing *(pg 55)* – Collecting, managing and transforming air quality data collected by air sensors into information that can be used in various formats.

Data request *(pg 94)* – Asking to obtain access to a set of data for a specific purpose, such as an analysis.

Data security *(pg 60)* – A set of measures taken to protect and preserve the data that air monitors collect, which can include encryption, storing data on a remote server, and making backup copies.

Data storage *(pg 51)* – Preserving air quality data collected by low-cost air sensors by automatically saving it onto an SD card in the air monitor and/or uploading it to a database on a remote server.

Data transfer *(pg 51)* – Copying or transmitting data from one computer to another or to a remote server.

Data transparency *(pg 52)* – The disclosure of and clear communications about the methods used to collect the data and its limitations, supporting the appropriate use of the data and methods by others.

Data visualization *(pg 55)* – The process of generating a visual representation or user-friendly interactive display of air quality levels, such as a graph or customizable map.

Database *(pg 51)* – A collection of digital information that is organized so as to be easily retrieved and updated.

Database software *(pg 56)* – Software designed to create a database and manage the information stored in it.

Dataset *(pg 12)* – A collection of separate sets of information that can be treated as a single unit by a computer

Enclosure *(pg 47)* – A box covering an air monitor that protects the internal components of the monitor from damage by natural elements and physical tampering. Also known as a monitor box.

Encryption *(pg 56)* – The process of converting data into a code in order to prevent unauthorized access.

Exposure *(pg 5)* – Coming into contact with a chemical or other substance by breathing, swallowing, touching, or otherwise ingesting that substance.

Federal Equivalent Method (FEM) *(pg 50)* – A method for measuring the concentration of an air pollutant in the ambient air that has been designated as equivalent to that used by federal regulatory agencies.

Federal Reference Method (FRM) *(pg 50)* – A method for measuring the concentration of an air pollutant in the ambient air that is used by federal agencies responsible for enforcing air quality regulations.

Fenceline monitoring *(pg 12)* – Monitoring to measure air pollution coming from a specific source.

Firmware *(pg 54)* – A software program or set of instructions programmed on a hardware device.

Grab sampling *(pg 12)* – Monitoring to measure air pollution during specific times/events at specific locations. This is often used when technology for continuous monitoring is not available or affordable.

Gravimetric filtration *(pg 50)* – Pulling air through a filter that is weighed before and after collecting particulate matter to generate a measurement of the mass of particles in a specific volume of air.

Health risk *(pg 102)* – The magnitude of the association between a behavior or exposure to a hazard and the development of a disease or health condition.

Hot spots *(pg 41)* – Specific areas where the measured concentrations of air pollutants are significantly higher than the average levels of these pollutants in a broader geographic area over a given period of time.

Imperial Air Project *(pg 4)* – Also known as the Imperial County Community Air Monitoring Project, this project engaged community members in establishing a network of 40 particulate matter monitors in Imperial County to provide real-time air quality data and make it available on the IVAN AIR website.

Indoor air monitoring *(pg 12)* – Monitoring that takes place inside of a home or other building. This can help distinguish between inside and outside air quality or identify potential indoor sources of pollution.

IVAN *(pg 14)* – Identifying Violations Affecting Neighborhoods (IVAN) is a community-based environmental violations reporting system developed by environmental justice organizations in California in collaboration with the California Department of Toxic Substances Control.

IVAN AIR *(pg 14)* – A community website and environmental reporting platform used to make publicly available the data collected by a network of 40 particulate matter monitors in Imperial County.

IVAN community *(pg 101)* – A community or geographic area in California which has created or maintained a website connected to the IVAN network that makes environmental reporting data publicly available.

IVAN network *(pg 101)* – A data management and environmental reporting platform used to collect and display data from the community air monitoring network in Imperial County among other communities.

Light scattering *(pg 49)* – A method that uses a laser emitting light with an optical chamber that particles pass through to generate a measurement of the size and amount of particles in a specific volume of air.

Mass *(pg 49)* – The quantity of matter in a body independent of its volume or any forces acting on it.

Metadata *(pg 94)* – In the context of community air monitoring, data that provides information about the air monitoring data, such as quality assurance and control procedures or monitor location and maintenance logs.

Metric *(pg 56)* – A system or standard of measurement.

Microcontroller *(pg 47)* – A component of a monitor that takes in the data from an air sensor, performs some functions on them, and outputs a value in a human-readable format.

Mobile hotspot (pg 42) – See cellular modem.

Monitor assembly (pg 46) – The process of building and connecting the various internal components of an air monitor needed to collect, store and share data, such as an air sensor and a microcontroller.

Monitor deployment *(pg 7)* – Installing a recently assembled air monitor at a specific location and testing its operations to make sure that it is functioning properly.

Monitor host *(pg 79)* – The owners and appropriate representatives of a site that is being considered for the placement of an air monitor.

Monitor installation *(pp 83-85)* – Setting up the hardware and software components needed to operate an air monitor and ensuring that it is properly collecting, storing, and sharing data.

Monitor maintenance *(pg 87)* – Ensuring that the hardware and software components of an air monitor are continuing to function properly after it is installed.

Monitor operation *(pg 7)* – Performing the actions and processes necessary to ensure that an air monitor is functioning properly.

Monitor siting *(pg 73)* – Selecting locations for and obtaining the necessary permissions to install the monitors in a community air monitoring network.

National Ambient Air Quality Standards (NAAQS) *(pg 49)* - Thresholds for legally allowable levels of outdoor air pollutants set by the U.S. EPA and mandated by the Clean Air Act that are known or suspected to be associated with a certain amount of health risk.

Network connectivity *(pg 53)* – The means and extent to which people in a specific location can connect to the internet via computers, wireless devices, and other communications technologies. Also, wireless connectivity or internet connectivity.

Network operator *(pg 61)* – An organization or individual designated to manage the operation of a community air monitoring network and its data infrastructure; a provider of wireless communications services.

Operating system *(pg 56)* – Software that manages a computer's basic functions and allows a user to run other applications on it.

Particle *(pg 29)* – A discrete unit of solid or liquid compounds suspended in the air, such as dust, soot, or smoke.

Particle composition *(pg 51)* – The different types of particles comprising any given sample of particulate matter, including dust, pollen, smoke, and liquid droplets.

Particle count concentration *(pg 49)* – The number of particles in a specific volume of air.

Particle mass concentration *(pg 49)* – The mass of particles in a specific volume of air, typically measured as micrograms per cubic meter of air, or µg/m3.

Particle source *(pg 51)* – A determination of where a specific particle originates from.

Particulate matter (PM) *(pg 3)* – A mixture of very small particles and liquid droplets suspended in the air, also known as PM. Particulate matter equal to or less than 2.5 micrometers (PM 2.5) in size and equal to or less than 10 micrometers in size (PM 10) has the greatest known or suspected associated health risk.

Personal monitoring *(pg 12)* – Using a wearable monitor that collects information about air quality that an individual is exposed to as they go through their day.

Photodiode *(pg 49)* – A device that produces a reading of the intensity and duration of pulses of scattered light in an optical chamber in an air sensor. This is used to generate a reading of the size and amount of the particles in that volume of air.

Plug-and-play monitor *(pg 46)* – Low-cost air monitors that have been preassembled to contain various combinations of hardware and software components, such as weatherproof enclosures, built-in Wi-Fi or cellular connections, and/or software for sending data to a specific web database.

Potential site *(pg 44)* – A location that is being considered for the placement of an air monitor.

Priority area *(pg 75)* – A geographic area that has been prioritized for the placement of air monitors.

Public health action *(pg 21)* – An action taken to protect or promote public health based on air monitoring data, such as keeping schoolchildren indoors on days with unhealthy air quality levels.

Quality assurance (QA) *(pg 61)* – A process for assuring that the data being collected by an air sensor is accurate, such as comparing the data collected by the sensor to that collected by a regulatory monitor.

Quality control (QC) *(pg 61)* – A process for assuring that bad data are removed to prevent inaccurate results, such as addressing incomplete measurements and alerting network operators when a monitor is not functioning properly. Also referred to as data cleaning.

Raw data *(pg 52)* – Data collected from a specific source that has not yet been processed.

Reading *(pg 47)* – A discrete instance of collecting information from an air monitor.

Real-time data *(pg 4)* – Information that is shared immediately or very close to the time when it is collected.

Rebooting *(pg 90)* – Resetting a monitor to fix a problem with its software or access to electricity.

Reference instrument *(pg 61)* – An air monitor that meets rigorous scientific and regulatory standards for collecting data that a low-cost monitor can be compared to in order to confirm data quality.

Reference level *(pg 49)* – The level above which the concentration of an air pollutant is known or suspected to be associated with a certain amount of health risk.

Reference monitor *(pg 62)* – A regulatory-quality instrument, it can be used to compare community air monitors to for calibration and validation procedures that ensure data quality.

Regression analysis *(pg 64)* – A set of statistical processes used for predicting the magnitude and direction of change of one or more variables when compared to another variable.

Regulatory agency *(pg 14)* – A government body formed or mandated by law to ensure compliance with a set of regulations established to carry out that law.

Regulatory monitor *(pg 36)* – An air monitor that conforms to rigorous protocols determined by state and federal agencies that regulate air quality for generating air quality data.

Regulatory monitoring (pg 51) **–** An air monitoring process carried out by state and federal agencies that regulate air quality to monitor compliance with and enforce existing regulatory standards.

Regulatory standard *(pg 3)* – A threshold established by a regulatory agency, as mandated by law, for determining the legally allowable amount of an air pollutant in the ambient air.

Remote server *(pg 55)* – A server that allows access to files or data on a computer from a distant location.

Script *(pg 57)* – A series of commands that tell a computer or microcontroller what to do with data in an automated way.

Sensor cleaning *(pg 87)* – Removing dust that has accumulated in an air sensor by blowing canned air through the fan grate or wiping the photodiode and laser with a lint-free cloth and isopropyl alcohol in order to maintain its proper functioning.

Sensor drift *(pg 67)* – See Signal attenuation.

Sensor selection *(pp 51-53)* – Choosing the type of air sensor most suitable for fulfilling the intended purpose of a monitoring project or network.

Signal attenuation *(pg 85)* – A gradual decline in the numerical readings captured by an air sensor that is usually caused by the accumulation of dust or other mechanical or maintenance issues.

Signal strength *(pg 90)* – The strength of the internet connection at an air monitor site at any given time.

Site *(pg 73)* – A specific location or building where an air monitor can be placed. Also referred to as a monitor location.

Site identification *(pp 74-76)* – Identifying potential locations to place air monitors in a network.

Site selection *(pg 73)* – A process for deciding how and where to place air monitors in a network.

Site visit *(pg 54)* – A visit to an air monitor site to inspect, maintain, and ensure the proper operation of the monitor. Also referred to as a field visit.

Siting agreement *(pg 81)* – A written agreement between the operators of a monitoring network and the owners or appropriate representatives of an air monitor site that clearly delineates roles, responsibilities, and liability issues in installing, operating, and maintaining the monitor.

Siting criteria *(pg 84)* – Specific considerations that are deemed important to and consistently followed in selecting the placement of air monitors in a network.

Size bins *(pg 51)* – The ranges of particle diameters that can be measured by a given air monitor.

Spatial analysis *(pg 29)* – A set of statistical processes for assessing the geographic distribution of one or more variables and generating a visual representation of this distribution as in a map or chart.

Summary statistics *(pg 94)* – A brief visual or numerical depiction of the values in a data set, such as a chart or graph.

Tapered element oscillating microbalance (TEOM) *(pg 50)* – A method of measurement that tracks changes in the frequency of a vibrating glass tube in order to measure the mass of particles in a specific volume of air.

Technical advisory group (TAG) *(pp 36-37)* – An advisory group comprised of government, academic, and/or private sector representatives that provides guidance on technical and scientific aspects of establishing and maintaining a community air monitoring network.

Temperature and humidity sensor *(pg 47)* – A sensor that measures and records temperature and humidity that can be included along with an air sensor as a component in an air monitor.

Temporary stationary monitoring *(pg 12)* – Monitoring in a fixed location temporarily. This may be useful to assess air quality during a specific time period, such as during the construction of a building.

User interface *(pg 106)* – The means and mode of interaction between a human user and a computer.

Validation *(pg 65)* – A process for assuring that the conversion equation used for a network of air monitors is generating accurate information.

Vulnerability *(pg 74)* – A constellation of factors or variables present in a community or population that could place it at higher risk for poor health outcomes.

Vulnerable populations *(pg 76)* – Groups of people who are especially sensitive to air, environmental, or other hazards, such as children, the elderly, and those with existing conditions or illnesses, such as asthma.

This page left blank intentionally.

This page left blank intentionally.

TRACKING CALIFORNIA

INFORMING ACTION FOR HEALTHIER COMMUNITIES

PUBLIC HEALTH INSTITUTE

www.trackingcalifornia.org/community-air-monitoring-guidebook