EPA Assistance Agreement Annual Report Summary

Period Covered by the Report: May 1, 2018 to April 30, 2019
Date of Report: July 30, 2019
EPA Agreement Number: RD83618401
Title: Engage, Educate, and Empower California Communities on the Use and Applications of "Low-Cost" Air Monitoring Sensors
Investigators: Dr. Andrea Polidori (Contact PI), Dr. Philip M. Fine (PI), Dr. Jason Low (PI), Dr. Yifang Zhu (co-PI), and Hilary Hafner (co-PI)
Institutions: South Coast Air Quality Management District (South Coast AQMD), Diamond Bar, CA 91765; University of California Los Angeles (UCLA), 650 Charles Young Drive. S., Los Angeles, CA 90095; Sonoma Technology Inc. (STI), 1455 N McDowell Blvd, Petaluma, CA 94954
Project Period: May 1, 2016 to April 30, 2019 (2-yr no-cost extension until April 30, 2021)

Objectives: The overall objective of the proposed research is to provide California communities with the knowledge necessary to appropriately select, use, and maintain "low-cost" sensors and to correctly interpret sensor data. This will be accomplished by pursuing the following four specific aims: (1) develop new methodologies to educate and engage communities on the use and applications of "low-cost" sensors; (2) conduct testing to characterize the performance of commercially available "low-cost" sensors and to identify candidates for field deployment; (3) deploy the selected sensors in California communities, and interpret the collected data; and (4) communicate the lessons learned to the public through a series of outreach activities.

Progress Summary/Accomplishments (Outputs/Outcomes):

Aim 1. South Coast AQMD worked with STI (co-Principal Investigator) to revise the draft guidebook for the educational toolkit with a focus on content that encompasses the three major stages of community air monitoring: planning, deployment, and community action. Existing materials have been revised based on feedback from community member project participants, and new material has been developed as needed. South Coast AQMD worked with UCLA (co-Principal Investigator), Special Service for Groups (Asian Pacific Forward Movement), Comite Civico del Valle Inc., and other project partner organizations and agencies to conduct workshops that provided the opportunity to gather feedback from participants regarding the installation and use of their low-cost sensors. Thus far, 10 of these workshops have been conducted, out of the 14 total STAR Grant communities. In addition to the workshops, a number of surveys were deployed in order to better understand the participants' experience with the low-cost sensors. Lastly, South Coast AQMD entered into a partnership with a software company focused on building solutions for data analysis/visualization to develop an R-based, open-source, package intended to make it easier to access and explore low-cost sensor data.

Aim 3. In the past reporting period, sensors have been deployed to three more communities, bringing the total number of participating communities to 14. Two of these new communities are in Northern California in the Bay Area, and one is in the South Coast Air Basin. A total of about 400 low-cost PM sensors have been distributed on a 1-to-1 (host-sensor) basis to community members in those communities and more than 65% of those sensors have already been installed and report fine and coarse particulate matter ($PM_{2.5}$ and PM_{10}) concentration levels (see Figure below). A preliminary analysis of the data from each of these sensor networks has been conducted and was shared with the respective community during the aforementioned workshops.

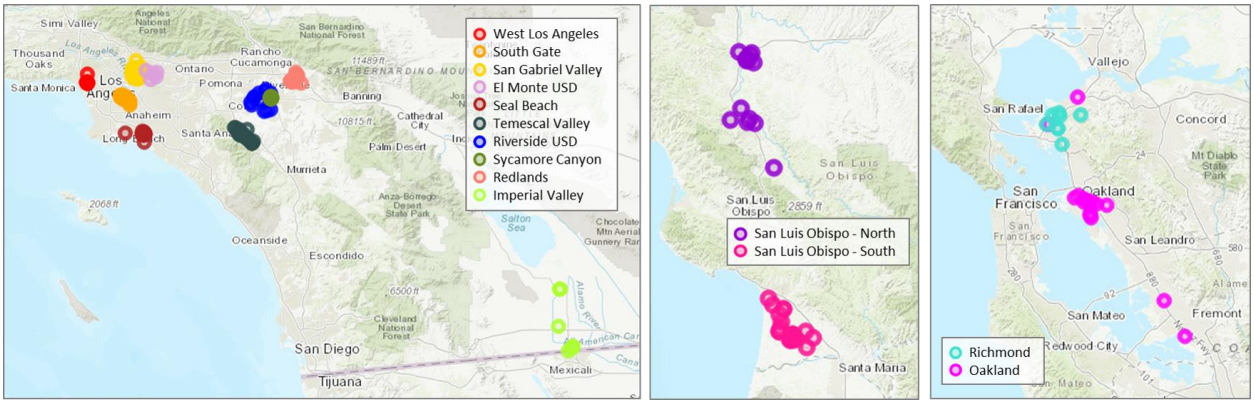

Figure. Sensor deployment in 14 California communities between October 2017 and April 2019.

Sensors are accompanied by copies of the sensor installation guide in English and Spanish, developed by South Coast AQMD and continually revised based on participant feedback. The Bay Area Air Quality Management District (BAAQMD) has held in-person meetings and supported the distribution and deployment of sensors in the two communities recruited in Northern California. South Coast AQMD led workshops with and distributed sensor to the final newly recruited community – in Temescal Valley.

Publications/Presentations:

There have been 3 peer-reviewed articles published in scientific journals and 16 podium/poster presentations at conferences, and 2 articles are under peer-review:

Feenstra, B., Papapostolou, V., Hasheminassab, S., Zhang, H., Der Boghossian, B., Cocker, D., and Polidori, A. Performance Evaluation of Twelve Low-cost PM2.5 Sensors in an Urban Ambient Air Environment. *[submitted to Atmospheric Environment - in review],* **2019**.

Collier-Oxandale, A., Feenstra, B., Papapostolou, V., Zhang, H., Kuang, M., Der Boghossian, B., Polidori, A. Field and Laboratory Performance Evaluations of 28 Gas-Phase Air Quality Sensors by the AQ-SPEC Program. *[submitted to Atmospheric Environment - in review],* **2019**.

Williams R, Duvall R, Kilaru V, Hagler G, Hassinger L, Benedict K, Rice J, Kaufman A, Judge VR, Pierce G, Allen G, Bergin M, Cohen RC, Fransioli P, Gerboles M, Habre R, Hannigan M, Jack D, Louie P, Martin N, Penza M, Polidori A, Subramanian R, Ray K, Schauer J, Seto E, Thurston G, Turner J, Wexler AS, Ning Z. Deliberating performance targets workshop: potential paths for emerging air sensor progress. *Atmospheric Environment*. 2(X). **2019**.

Jia, S. An Analysis of Effects of Woolsey Wildfire on UCLA University Village Air Quality using low-cost sensors. UCLA. ProQuest ID: Jia_ucla_0031N_17934. Merritt ID: ark:/13030/m50s4ngz. Retrieved from https://escholarship.org/uc/item/8s65z1fw, 2019. (Master's Thesis)

DeWinter, J., Hafner, H. R., Papapostolou, V., Polidori, A. Community-Based Air Quality Monitoring with Low-Cost Sensors: Developing a Toolkit, Best Practices, and Lessons Learned. American Geophysical Union, Fall Meeting 2018, December 2018, Washington D.C. (Poster presentation)

Feenstra, B., Papapostolou, V., Pikelnaya, O., Polidori, A., Doraiswamy, P., Gupta, P. Lessons learned and analysis from a year-long deployment of a network of low-cost particulate matters sensors. American Geophysical Union, Fall Meeting 2018, December 2018, Washington D.C. (Poster presentation)

Papapostolou, V. Air Quality Sensing & Monitoring in Citizen Science. Brown Bag Lunch Meeting Presentation at the South Coast Air Quality Management District. October 2018. (Podium Presentation).

Papapostolou, V., and Hafner, H. Community Sensor Training: Best practices and lessons learned for Engaging Communities in Air Quality Monitoring. Air Sensors International Conference. September 2018, Oakland, California. (Pre-Conference Training Session and Panel Discussion).

Feenstra, B. Development of a cloud-based application to ingest, validate, analyze, and map data from a large PM sensor network. Air Sensors International Conference. September 2018, Oakland, California. (Podium Presentation).

Papapostolou, V. South Coast Air Quality Management District – Air Quality Sensor Performance Evaluation Center. Air Sensors International Conference. September 2018, Oakland, California. (Podium Presentation).

Papapostolou, V. Air Quality Sensing & Monitoring in Citizen Science. Brown Bag Lunch Meeting Presentation at the South Coast Air Quality Management District. October 2018. (Podium Presentation).

Feenstra, B., Papapostolou, V., Cheung, R., Polidori, A. One Year Spatial and Temporal Variability of PM in a Southern California Community using an Air Quality Sensors Network. 10th International Aerosol Conference, September 2018, St Louis, Missouri. (Podium presentation)

Feenstra, B., Papapostolou, V., Cheung, R., Polidori, A. Cloud-based Application to Manage Data from Distributed Air Quality Sensors Networks. 10th International Aerosol Conference, September 2018, St Louis, Missouri. (Podium presentation)

Papapostolou, V., and Feenstra, B. Low Cost Sensors: The "How" of Performance Evaluation, Network Design and Data Handling. 10th International Aerosol Conference, September 2018, St Louis, Missouri. (Presentation and Tutorial Session)

Hagler GSW, Williams R, Papapostolou V and Polidori A. Air quality sensors and data adjustment algorithms: When is it no longer a measurement? *Environmental Science and Technology*, DOI: 10.1021/acs.est.8b01826, **2018.**

Papapostolou V, Zhang H, Feenstra BJ and Polidori A. Development of an environmental chamber for evaluating the performance of low-cost air quality sensors under controlled conditions. *Atmospheric Environment*, 171: 82-90, **2017.**

Papapostolou V, Feenstra B, Zhang H, Polidori A. "Low-cost" Sensors for Measuring Gaseous and Particle Air Pollutants: Performance Results from Three Years of AQ-SPEC Field and Laboratory Testing and

Network Applications at the Fenceline and Community Level. Air and West Management Association – 2017 Air Quality Measurement Methods and Technology, November 2017, Long Beach, California. (Podium presentation).

Papapostolou V, Zhang H, Feenstra B, Polidori A. Development of an Environmental Chamber for the Laboratory Evaluation of "Low-Cost" Air Quality Sensors. 36th American Association for Aerosol Research, October 2017, Raleigh, North Carolina. (Podium presentation)

Polidori A, Feenstra B, Papapostolou V, Zhang H. Performance Evaluation of "Low-Cost" Sensors for Measuring Gaseous and Particle Air Pollutants: Results from Three Years of Field and Laboratory Testing. 36th American Association for Aerosol Research, October 2017, Raleigh, North Carolina. (Podium presentation)

Feenstra B, Papapostolou V, Pikelnaya O, Zhang H, Polidori A. Spatial and Temporal Variability of Particulate Matter Using a Network of Air Quality Sensors in a Southern California Community. 36th American Association for Aerosol Research, October 2017, Raleigh, North Carolina. (Poster presentation)

Upcoming Activities:

Aim 1. Continued revisions of the guidebook will occur in during the next reporting cycle. STI will work with South Coast AQMD to create a final draft version, which will then be shared with UCLA and other community organizations in order to inform final revisions relating to usability and ensuring the guidebook is appropriate for its intended audience. The complete analysis of all survey data and feedback will also inform these guidebook revisions. Other elements of the Toolkit will also be undergoing development and/or revision. For example, the AirSensor R-package will be completed and released to the public. This package will also be used to support the development of “shiny apps” for data visualization. Shiny is another open-source R package that can be used to build standalone applications that can be hosted on a website. By leveraging the AirSensor and Shiny R-packages, each STAR Grant community to access, view, and interact with their data. Additionally, one internal application will allow South Coast AQMD to view easily assess sensor performance and conduct analysis internally. **Aim 3.** We will complete the deployments in all participating communities as well as a final validation, analysis, and interpretation of the data for each community. A number of final reports will be available from partner organizations showcasing the analysis and interpretation of data from their respective STAR Grant networks. **Aim 4.** During the upcoming reporting period, the “post-deployment” workshops will be held in each community to share the results from the project (including lessons learned), distribute incentives, and gather final feedback. These meetings will also provide an opportunity to discuss new resources that are or will soon be available including the AirSensor package, the web-based data visualization applications (i.e., the AirSensor and Shiny package products), and the Toolkit as a whole. South Coast AQMD plans to share overviews of the STAR Grant and lessons learned at several upcoming scientific conferences. South Coast AQMD also plans to complete and submit several journal articles sharing both lessons learned and analysis of STAR Grant sensor network data with the research community.

Supplemental Keywords: community science, community engagement, community education, community empowerment, sensor testing, sensor selection, sensor deployment, particulate matter, PM2.5, PM10, ozone, data interpretation, public outreach. **Relevant website:** www.aqmd.gov/aq-spec