TITLE:	Impacts of Train and Port Pollution and Air Toxics on Respiratory Symptoms and ED Visits within Vulnerable Communities in Southern California
CONTRACTOR:	University of California, Berkeley
SUBCONTRACTOR:	ResMed
PRINCIPAL INVESTIGATOR:	Jason Su, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$499,650
CONTRACT TERM:	24 Months

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I. SUMMARY

Regulations and technological upgrades have resulted in a steady decline in criteria air pollutants and air toxics in California. However, the distribution of goods from their entry ports to the rest of the United States involves diesel-powered vehicles, locomotives and equipment, creating significant exposures and health impacts in the vulnerable communities along the distribution routes. The vulnerable communities suffer from exposure not only to criteria pollutants like NO_X and PM2.5, but also to air toxics from those mobile sources as well as sources of air toxics from industry processing. In this proposed new contract, UCB and ResMed will study: 1) the respiratory health impacts of NO_X and PM2.5 emissions from locomotive and port craft operations; 2) the respiratory health effects of air toxics from point, area and mobile sources; and 3) the relative significance of individual pollutants when integrated in a single modeling framework, on daily rescue medication use within the vulnerable communities in Southern California (SoCal) for the years 2016-2019. The impacts of air pollution on annual Emergency Department (ED) visits within the vulnerable communities will also be investigated and compared with the impacts estimated on daily rescue medication use. Further, the sources contributing to the air pollution from NO_X and PM2.5 and air toxics emissions in

the vulnerable communities will be identified. The results of this new project will significantly compliment ongoing work funded by CARB. This study will help CARB quantify the dose-response functions of criteria pollutants and air toxics with health outcomes and identify sources of impact for the vulnerable communities. The study will also provide the information needed to include respiratory disease exacerbations as a new endpoint for CARB's health analysis in regulatory processes. The result will support CARB's regulations and policies to reduce emissions from rail and port operations from goods movement that particularly impact environmental justice (EJ) communities and will promote health equity in research.

II. TECHNICAL SUMMARY

Objective

The objectives of this research are to: 1) quantify the dose-response functions of exposure to air pollution from locomotive and port engine operations (including at-berth vessels and commercial harbor crafts) as well as air toxics from point, area and mobile sources; and 2) identify the marginal effects of individual pollutants including air toxics when modeled in a single framework, on sub-acute respiratory disease symptoms for the vulnerable communities in SoCal. Respiratory symptoms will be measured by the use of short-acting beta agonist (SABA) for the acute relief of respiratory disease symptoms which will serve as a proxy for the symptoms. It is hypothesized that participants living or spending more time in vulnerable communities near ports, the railway network and/or air toxics sources, would experience higher daily SABA use (i.e., total puffs). UCB and ResMed will work collaboratively to use the space-time resolved SABA use and activity space data collected by digital sensors for the 1,200 participants from January 2016 to December 2019 in SoCal to identify those dose-response functions and investigate sources of contributions to their exposures. The dose-response functions for annual ED visits at a community level (i.e., CT) from air pollution will also be modeled and compared with the dose-response functions for SABA.

Both environmental epidemiology models and advanced machine learning models (e.g., random forest models) will be used in the modeling process and compared with prediction powers.

Background

The distribution of goods from their entry ports to the rest of the United States involves diesel-powered vehicles and equipment, creating significant exposures and health impacts in the vulnerable communities along the distribution routes. The adjacent Los Angeles and Long Beach Port complex are the two busiest container ports in the United States moving more than $260 billion in goods a year. The vulnerable communities near the ports suffer from exposure not only to criteria pollutants like NO_X and PM2.5, but also to air toxics from those mobile and rail sources. Further, point and area sources of air toxics from industry processing create disproportionately higher exposures to the vulnerable communities. Previous studies investigating the effects of air pollution on respiratory disease have relied on aggregated and infrequently reported acute respiratory disease outcome measures, which lack temporal and spatial resolution due to annual aggregation and grouping to a zip code or county level. When the location of exposure was provided, previous studies often used an individual's residential address in defining the location of air pollution exposure. Air pollution exposure can occur in the community, at work, at home, at school, and elsewhere; therefore, a residential address does not capture the full signature of exposure for an individual. Additionally, the effect of air pollution on respiratory disease has largely been assessed using single pollutant modeling approaches despite the fact that people are exposed to multiple pollutants simultaneously, which may interactively influence respiratory disease symptoms.

Proposal Summary

Digital sensors fitted onto inhalers can capture the date, time, and location of the use of SABA for the acute relief of respiratory disease symptoms; thereby, offering an objective signal of respiratory disease symptoms in real-time. The sensors also send out "heartbeats," which is a signal from the sensor that reports battery life and records the Global Positioning System (GPS) locations when paired with a smartphone. The heartbeat indicates that the sensor is functioning properly, and able to transmit data; but that the inhaler has not been used since the last data transmission. Evaluating the signals of all heartbeats and rescue inhaler uses for an individual over time can help characterize individual's exposure space over time. UCB and ResMed will use the heartbeat locations and locations of SABA use of a patient as his/her activity space for this project. The activity space helps to clarify the time an individual spent in the vulnerable communities

nearing port or locomotive operations, or near sources of air toxics. Residential information also enables the investigators to identify whether participants living in vulnerable communities bear a disproportionate burden of air pollution and whether that is associated with heightened SABA use.

The project will be comprised of following tasks.

Task 1: Exposure Assessment

Subtask 1.1: Data Sources for Air Pollution Modeling

UCB will develop data sources including: 1) air pollution emissions of NO_X and PM2.5 from locomotive and port operations (i.e., San Pedro Bay Los Angeles and Long Beach port complex, referred as San Pedro Bay port complex hereafter;) and 2) air toxics emissions from point, area and mobile sources.

Subtask 1.2 Daily Hybrid LUR Models and Air Pollution Surfaces

UCB will develop daily hybrid LUR models for SoCal and generate corresponding air pollution surfaces with 30 m spatial resolution for criteria pollutants NO_X and PM2.5 and air toxics. However, many predictors are not daily data. For instance, cargo data (entering or leaving port) is monthly or annual, toxic emission data are annual. The investigators will include in daily land use regression modeling the predictors of daily traffic, daily weather conditions, daily remote sensing pollution data, every two-week vegetation index, and monthly port cargo volumes. Daily remote sensing air pollution data is part of the predictors in their modeling process. They will also run dispersion model through Stochastic Time-Inverted Lagrangian Transport (STILT) and the results can also be used as input for the daily land use regression model development. The monthly cargo volumes will be adjusted to daily Twenty-Foot Equivalent Unit (TEU) statistics based on daily traffic entering and leaving the ports as measured by the California Department of Transportation (CalTrans).

Subtask 1.3 STILT Footprint Model to Identify Source Contributions of Air Pollution

In order to examine the impacts of sources on sensitive communities in this proposal, the investigators will develop daily dispersion models through the STILT modeling framework for the years 2016-2019. UCB will create gridded receptors of 50 m spatial resolution and identify daily NO_X and PM2.5 concentrations and the associated sources of pollution in the vulnerable communities in SoCal, with a focus on identifying the contributions of port operations and operations of locomotives on NO_X and PM2.5 concentrations. The investigators will also characterize the exposure levels and sources of air toxics in the vulnerable communities using the same gridded receptors at 50 m spatial resolution.

The researchers will use CARB air toxics emissions data when such data are available, and make adjustments on National Emissions Inventory (NEI) data for data not covered by CARB through comparing the CARB and NEI data when both datasets are available. Although exposure to ambient air pollution is the focus of this proposed project, the investigators still aim to adjust levels of exposure when the digital sensor identifies a participant's location of events in his/her home address. Using residential parcel data provided by CARB that identifies every property characteristic for SoCal such as building age, building square footage, number of bedrooms and bathrooms, heating type, number of fireplaces, land value and improved value, building specific infiltration coefficient will be estimated using building characteristics plus other related data such as weather and season. While it will not be possible to measure and take into consideration the contribution of indoor sources on exposure, paired indoor/outdoor purple air monitoring data will be used together with the property assessment data to derive infiltration coefficients for properties in SoCal.

Task 2: Health Dataset and Analysis of Health Effects

Subtask 2.1 Health Dataset

Rescue Medication Use Data

ResMed will lead the development of a health cohort using data from the respiratory disease management platform, which includes ~1,200 participants from a number of different health programs. The participants have asthma or COPD, live or work in SoCal, were recruited between January 2016 to December 2019, and have recorded space-time locations of SABA use and heartbeats collected by digital medication sensors. Both SABA use and heartbeats events record space-time locations of the digital sensor and thus the

space-time locations of the patient who carries the sensor. The number of heartbeat events occurred in a day might not be a good indicator of an individual's activity space; however, when the data are collected through more than three months, the activity space of that individual can be clearly identified and can be used to characterize time-activity pattern of an individual, but it is not the focus of this study. The scope of the study includes counties of Los Angeles, Ventura, San Bernardino, Orange, Riverside, San Diego and Imperial. Based on the initial analysis on the 1,206 participants identified in SoCal up to March 15, 2019 (this study will use subjects data up to December 2019), the participants have a median age of 33 with the minimum and maximum, respectively, being 4 and 80 years old. Among those 1,206 participants, 315 (26 percent) of them live in the vulnerable communities defined by the Senate Bill (SB) 535 through CalEnviroScreen.

Acquire and Process Healthcare Utilization Data

UCB acquired healthcare utilization for asthma-related ED visits (primary discharge diagnosis codes ICD10-CM (J45)) from the California Department of Public Health (CDPH) at zip code level for years 2016-2018. They will also derive annual ED visits for years 2016-2018 for those zip codes with a total ED count < 12, using the California Health Interview Survey (CHIS) data.

Subtask 2.2 Statistical Analysis of Health Effects of Vulnerable Communities

UCB will perform health outcome analysis by identifying the dose-response relationships between air pollution and respiratory disease symptoms for: 1) individual pollutants including criteria pollutants and air toxics; 2) pollutant mixtures of criteria pollutants NO_X and PM2.5; 3) pollutant mixtures of air toxics; and 4) pollutant mixtures of criteria pollutants and air toxics. The modeling approach will include advanced linear mixed modeling techniques and advanced machine learning techniques.

Task 3: Educational Outreach

UCB will present their study design, research efforts and findings to the local communities and receive feedback. They will collaborate with a statewide asthma coalition the Community Action to Fight Asthma (CAFA) network, and a local asthma community called the Long Beach Alliance for Children with Asthma (LBACA) to help vulnerable community members get connected to their research and participate in outreach efforts.

Two outreach activities will be implemented: The first outreach will be conducted in the initial stage of the new research project to gather community input. The second outreach will be conducted by the 2nd quarter of the project in the second year to pass research findings to communities. The outreach will include the study design, exposure assessment, digital inhaler sensor description, statistical analysis, asthma self-management practices, local asthma risk hotspots, issues related to their daily air pollution exposure and health concerns, perceived benefits of the research and recommendations for future changes. The outreach platform will be available in Spanish and English, and all communications will accommodate a wide range of community literacy skills. They will also use the educational outreach to identify potential changes to improve the proposal within the goals of the proposed study.

Task 4: Project Management

A kick-off meeting will be held at the start of the contract to introduce the study, discuss reporting requirements, and provide an overview of the modeling techniques. Quarterly progress meetings will be conducted via Zoom to update staff and management on the progress of the contract. Six months prior to the end of the contract, UCB will submit a draft final report, which will be subject to formal review by the RSC. Once accepted by the RSC, UCB will revise the modified draft final report addressing the RSC comments and will submit the revised final report to CARB. All non-confidential datasets and exposure data layers, including the information needed to understand and use the datasets and exposure data layers, will be included as deliverables and will be provided to CARB before the end of the contract. UCB will also present project findings at the Chair's seminar, in Sacramento, at the end of the contract.

III. STAFF COMMENTS

The PI, Jason Su's (Associate Researcher and Principal Investigator of Public Health, UCB) research focus is on the applications of Geographic Information Sciences (GIS), remote sensing, statistic and machine learning modeling skills for air pollution exposure assessment, green space characterization, and environmental epidemiology, which are all important skills to successfully carry out this project. He has conducted a number of similar research projects in the past and has the expertise, leadership and training necessary to successfully carry out the proposed research project. An ongoing CARB

funded study led by Dr. Su will investigate the relationship between vehicle pollution (PM2.5, NO_2 and O_3) including non-exhaust pollutants (chromium, lead, manganese, nickel, selenium and zinc) and sub-acute respiratory disease symptoms using digital inhalers in 2,870 patients, statewide in California. This new proposed study will add ED visits, impacts of air toxics in addition to the criteria pollutant and non-exhaust pollutants, separating the sources of impacts and focusing on exposure from rail and port operation in disadvantaged communities in SoCal.