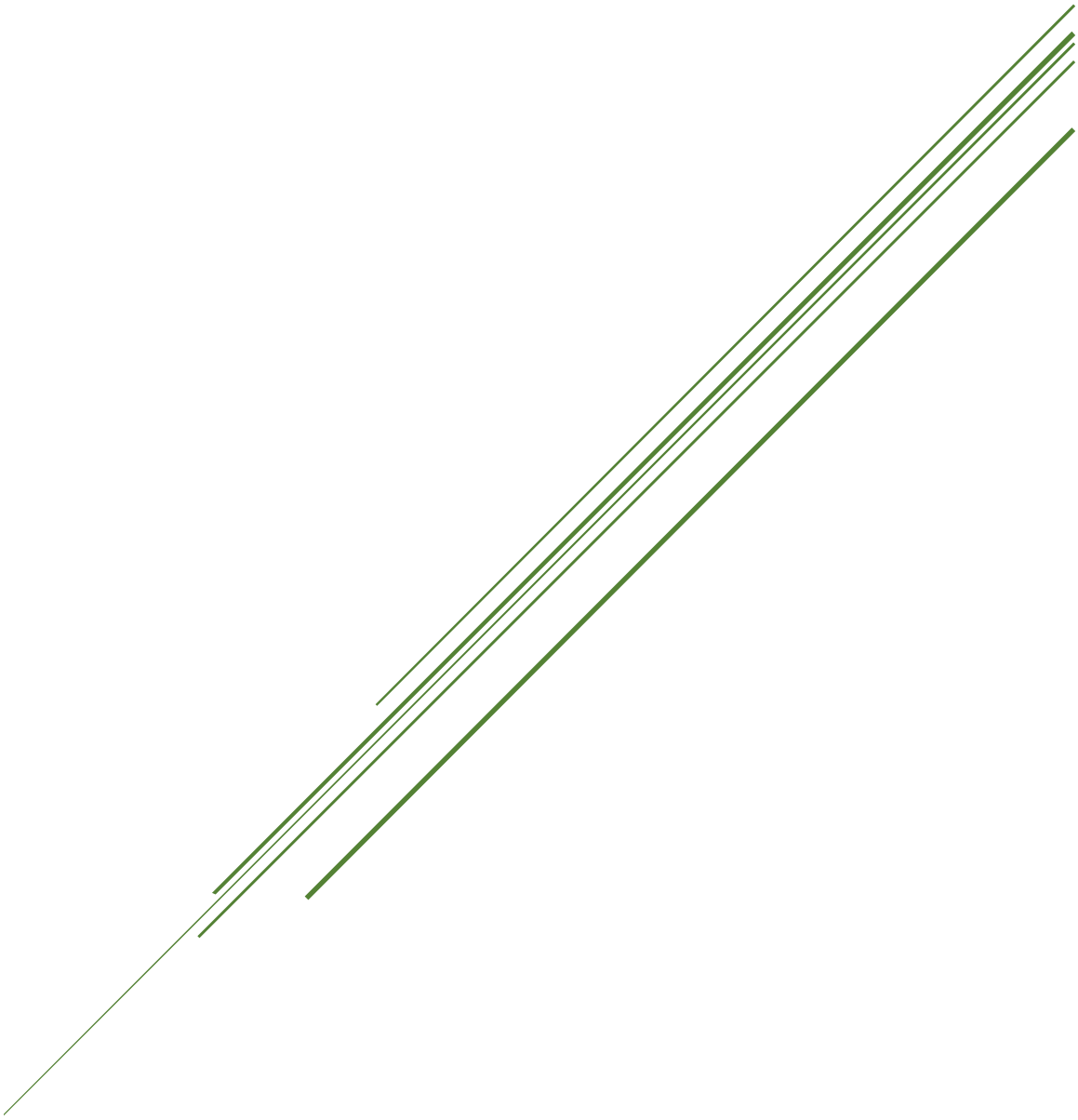
SUSTAINABLE & HEALTHY COMMUNITIES

Products Delivered in Fiscal Year 2019



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Summary

The Sustainable and Healthy Communities Research Program (SHC) emphasizes research and technology to support cleaning up contaminated sites and protecting associated communities, while also restoring ecosystems that provide benefits to those communities. It also emphasizes solutions-driven science to support decisions that will revitalize the nation's communities and make them more resilient to severe weather and other environmental incidents.

This Compendium contains a table of contents which list each individual research product delivered in Fiscal Year 2019. The listed products consist of work supported through SHC's prior Strategic Research Action Plan (2016-2019 StRAP) as well as collaborative, community-based research between ORD and Regional staff conducted through Regional Sustainability and Environmental Sciences (RESES) projects.

These FY19 deliverables are categorized within the compendium based on their relevance to one of SHC's three Topic areas emphasized in its latest StRAP (2019-2020). These are: Topic 1, Contaminated Sites (carried over from SHC Project 3.61 in the prior StRAP) and Chemicals of Immediate Concern (e.g., Pb; PFAS); Topic 2, Sustainable Uses of Wastes and Materials Management (from former Project 3.63); and Topic 3, Community Revitalization and Resilience to Natural Disasters and Extreme Events (includes the remainder of work carried over from the prior StRAP). Please note that for this FY 2019 report there is bioavailability and bioaccessibility research included in Topic 3; in future reports these will be consolidated in Topic 1. Oil spills research products (from former Project 3.62) are not included in this compendium as that research has moved to the Homeland Security Research Program.

The type of research product (e.g., peer-reviewed journal article; EPA external report) is indicated underneath each product title in the body of the compendium. Each product listing includes a brief summary of the product and its potential audiences, as well as URLs providing access to the documents and tools. At the end of the document, there is a comprehensive bibliography for all publications associated with the FY19 products.

Topic 1: Contaminated Sites

Improved Methods for Predicting the Mobilization of Arsenic in Reducing Environments

Product Type: Peer Reviewed Journal Article

Understanding metal speciation in aqueous systems is fundamental to developing fate and transport models, designing effective remedial systems, and for predicting human and ecological risk. Currently there is uncertainty about the chemical nature of arsenic species present in reducing groundwater systems. This uncertainty causes problems in predicting arsenic behavior and in quantifying the forms of arsenic present in natural waters. This research utilized new anion-exchange chromatography methods linked to inductively coupled plasma mass spectrometry (ICP-MS) which allowed sample/eluent pH matching and improved arsenic speciation analysis.

- Thioarsenite Detection and Implications for Arsenic Transport in Groundwater (Wilkin et al., 2019)

Geophysical methods to characterize and monitor ground water-surface water interactions

Product Type: Peer Reviewed Journal Articles

Groundwater interactions with surface water bodies impact aquatic species and mobilize contaminants through the food chain impacting human health. These products support the scientific foundation to map, characterize, and understand groundwater inputs into surface water bodies. The purpose of this research effort was to use non-invasive, or minimally invasive measurements of the physical properties of the earth (i.e., geophysics) to map and monitor groundwater inputs into surface water bodies. Geophysical methods were used to characterize and monitor groundwater-surface water interactions. These are surface-of-the-earth based methods that do not rely on point measurements and can be deployed in long stretches of surface water bodies collecting three-dimensional distributions of physical property contrasts and four-dimensional distributions when measured over time. The results demonstrated the utility of temperature and electrical geophysical methods to locate groundwater upwelling zones, determine the location of the zone relative to fish habitat, and quantify the flux of groundwater entering a stream. These products will help protect our surface water bodies from contaminated groundwater plumes.

- Actively heated high-resolution fiber-optic-distributed temperature sensing to quantify streambed flow dynamics in zones of strong groundwater upwelling (Briggs et al., 2016)
- Hydrogeochemical controls on brook trout spawning habitats in a coastal stream (Briggs et al., 2018)
- The Dual-Domain Porosity Apparatus: Characterizing Dual Porosity at the Sediment/Water Interface (Scruggs et al., 2018)

Efficacy of passive sampler-based interstitial water measurements to improve predictions of contaminant concentrations in fish and shellfish

Product Type: Peer Reviewed Journal Article

This technical analysis investigates the effectiveness of passive samplers in combination with bioaccumulation modelling as tools to predict bioaccumulation of hydrophobic organic contaminants in fish and shellfish that may be consumed by humans. This product provides the Superfund program (OSWER/OSRTI), Regions, States, Tribes, and other users with an assessment of the merits of using passive samplers as tools, along with bioaccumulation models, for predicting bioaccumulation of hydrophobic organic contaminants at contaminated sites.

- Journal manuscript in review; draft available for now at Evaluating polymeric sampling as a tool for predicting the bioaccumulation of polychlorinated biphenyls by fish and shellfish (Schmidt and Burgess)

Analytical solutions for transport of volatile organic compound in vadose zone incorporating mass exchange through water table

Product Type: Peer Reviewed Journal Article

This report describes a group of innovative analytical solutions for equations describing the transport of volatile organic compounds in the vadose zone incorporating mass exchange through the water table.

The model investigates different transport mechanisms that appear in subsurface domains. Calculations of mass flux through the water table and ground surface can be used to assess the vapor intrusion risk. This research provides a modeling tool that facilitates the application of analytical models and helps to recognize the features of non-aqueous phase liquid (NAPL)-contaminated subsurface systems. The model solutions are specifically useful in assessing the vapor intrusion process in a contaminated site where a vadose zone is underlain by a water table aquifer 30 contaminated with volatile organic compounds.

- Journal manuscript in review; draft available for now at Analytical Model for Volatile Organic Compounds: Transport in the Coupled Vadose Zone-Groundwater System (Huang)

RESES: Understanding and Evaluating Ecosystem Services at Site Remediation Projects and Applying Benefits to Surrounding Communities

Product Type: Internal Report

In 2015, a collaborative Regional Sustainability and Environmental Sciences (RESES) project between EPA's Superfund Program, Regional Offices, and Office of Research and Development (ORD) was developed with the intent of providing project managers leading remediation activities at contaminated sites technical guidance on considering ecosystem services (ES), or the benefits to society provided by nature, at their sites. The primary goal of the project was to develop a framework for documenting ES provided on and around a remediation site and measuring any changes in ES, both positive and negative, resulting from remediation. The end goal is to utilize case study applications to determine whether the tools can generate information on ES impacts, both short- and long-term, that can be factored into the decision-making process by project managers as they consider various site cleanup management options. ORD supported the development of the ES evaluation framework by applying various decision-support tools and accounting systems for ES (e.g., EnviroAtlas, FEGS-CS), and the Superfund Program identified two active sites at which to pilot the tools.

A key finding is that the tools individually have a focused applicability across parts of the ES spectrum. There is no single tool to evaluate site information and provide complete results on ES for all sites; rather, each tool has its own advantages and disadvantages. Choosing which tool to use for a particular site depends on the site's landscape setting, the size of the site, the types of ecosystems present that could be impacted by the cleanup or restored for reuse, and the resources available to conduct the analysis. The primary target audiences for this report are Superfund and other contaminated site programs' technical team members.

- Ecosystem Services at Contaminated Sites (Harwell et al., 2019)

RESES: Deployment of DASEES to Support Superfund Remedial Action Decision Process and Enhance Community Involvement

Product Type: Internal Report

Superfund remedy decisions are often very complex and require consideration of input from a wide audience of stakeholders. The project managers on the site must understand and communicate the decision process with limited tools for transparently documenting how both technical and community values-based factors are considered in the prioritization of sites for remedial action. This RESES project

focused on using a structured decision-making process through the ORD tool DASEES (Decision Analysis for a Sustainable Environment, Economy, and Society) to formally include a comprehensive set of site evaluation factors when crafting a Superfund remedial action plan at the Bunker Hill Mining and Metallurgical Complex Superfund Site. The inherent complexity of this site was recognized by the National Research Council, which recommended an adaptive site management approach. A multi-agency working group including federal, state and tribal members used DASEES to quantitatively evaluate candidate cleanup sites using technical, regulatory, and community-based objectives. The project provides an example of how the DASEES analysis tool can be used by a Remedial Project Manager to inform prioritization of remediation sites and develop site specific remedy option design at other Superfund sites across the nation. This product was funded through SHC's Regional Sustainability and Environmental Science (RESES) program.

- Decision Support for Adaptive Site Management Planning and Remedy Implementation (Dyson et al., 2019a)

Topic 2: Waste and Sustainable Materials Management

Development of an application programming interface for an environmental material flow accountability model (USEEIO) to support multi-scale life cycle assessments

Product Type: Software and Model Documentation

States and others want to better understand material flows and impacts, so they can decrease and mitigate waste disposal. The US Environmentally-Extended Input-Output (USEEIO) model is a national model for calculating direct and indirect environmental and socioeconomic impacts of US goods and services. This product, the US Environmentally-Extended Input-Output Model Application Programming Interface, is a web service that provides pre-calculated USEEIO model results and model metadata for the USEEIO family of models, which will enable development of State-specific models and application for tools like the Sustainable Materials Management Tool Suite.

- https://github.com/USEPA/useeio_api/ (Srocka and Ingwersen, 2019)

Standardized Elementary Flow List for the Federal Life-Cycle Assessment Commons

Product Type: Published Report

EPA cooperates with other Federal Agencies to develop common tools and standards and a data portal for life-cycle assessment (LCA), referred to as the Federal LCA Commons. The Federal LCA Commons is intended to make LCA data more interoperable and accessible, increase the quality of Federal LCA data, and add value to existing data. This product consists of a standardized Federal LCA Commons elementary flow list with associated guidance, terminology dictionaries, and supporting programming code. Elementary flows are LCA data components for resources or emissions consisting of names, contexts, and units along with other metadata.

- EPA Report: The Federal LCA Commons Elementary Flow List: Background, Approach, Description and Recommendations for Use (Edelen et al., 2019)

Separation Process Options for Solvent Recovery and Reuse

Product Type: Peer Reviewed Journal Article

Replacing virgin solvents with reclaimed materials requires the application of separation technologies to recover those solvents from their mixtures with the other processing materials, such as water, and to purify the solvents to meet process specifications. This report provides scientific support regarding efficient separation technology options to EPA researchers, to enable development of further information, analyses and tools for program and regional offices, states, tribes, and the regulated industries seeking to implement the re-manufacturing exclusion in the new definition of Solid Waste. The report focuses on the review and development of advanced separation technologies for energy-efficient solvent re-processing. This research will be used in US EPA Regions 2 and 3 to increase their recovery and reuse of solvents to reduce the environmental impact of solvent use.

- Review of pervaporation and vapor permeation process factors affecting the removal of water from industrial solvents (Vane, 2019)

ADEPT: Alternative for Disposition of Electronics Planning

Product Type: Spreadsheet-based Model

The Alternatives for Disposition of Electronics Planning Tool (ADEPT) is built in an Excel workbook, with several supporting worksheets used in the calculation of waste generation at various stages in reuse, recycling, and end of life (EOL). It employs a combination of top-down data sources and bottom-up assumptions to track the generation of used electronics by state and estimate the material flows from generation to collection as well as processing and three disposition pathways (reuse, recycling, and disposal). ADEPT produces national- and state-level results for the quantity of electronic products entering EOL management annually (during the years 1980 through 2040) as well as the subsequent volume of waste being landfilled at each stage of the EOL management process. Understanding the pathways of used electronics from the consumer to their final disposition will help scientists produce additional information, analyses and tools that provide insight to decision makers about their impacts and support efforts to encourage improvements in policy, technology, and beneficial use.

- ADEPT Model
- ADEPT User Guide (Northeim et al., 2019)

Geophysical forward modeling tools: the scenario evaluator of electrical resistivity SEER and MoisturEC, applicable for landfill investigations

Product Type: Software

Contaminant fate and transport, landfill degradation models, site conceptual model development, and subsurface hydrodynamics require an understanding of the moisture distribution in the subsurface. This product includes two software models; MoisturEC, which converts geophysical electrical conductivity data to 3-D subsurface moisture models and the Scenario Evaluator for Electrical Resistivity (SEER), which enables pre-survey, or forward, modeling of the resistivity response to user configured subsurface geologic, hydrogeologic, or contaminant distribution. The SEER tool is intended for users who desire to determine the value of using an electrical resistivity survey to meet project objectives. It is designed for broad application in industry, teaching and research. MoisturEC is intended for users needing a

subsurface moisture map derived from field data. These applications can impact the use and improved application of surface geophysics, guide degradation models, and understand site hydrodynamics.

- MoisturEC: A New R Program for Moisture Content Estimation from Electrical Conductivity Data (Terry et al., 2018)
- Scenario Evaluator for Electrical Resistivity Survey Pre-modeling Tool (Terry et al., 2017)

Recovery of Critical Elements and the Conversion from Electronic Waste

Product Type: Peer Reviewed Journal Article

Electronic waste (e-waste) is currently the fastest growing hazardous waste stream that continues to be a challenging concern for the global environment and public health. The average useful life of electronic products has continued to decline, and obsolete products are being stored or discarded with increasing frequency. In this study, pyrolysis was investigated as a possible approach to recovering material and energy from e-waste reducing the content that ends up in landfills. The report identifies the various techniques used for the recovery of critical elements from used electronics including those that can be removed magnetically and with eddy current, and results of experimental studies for the proper recycling of cathode ray tube glass, and other elements that are regulated under the Resource Conservation and Recovery Act (RCRA). The findings are important to e-waste researchers, OLEM, and possibly recycling industry staff because material and energy recovery processes have to be conducted in safe and well-controlled conditions to reduce the risk to human health and the environment.

- Journal manuscript pending publication, draft available at Resource Recovery from Electronics Waste using Thermal Processes: Environmental Emission and Risk Assessment (Sahle-Demessie et al.)

White Paper - Steps in Conducting an Organics Diversion Plan

Product Type: Published Report

The Agency has set a goal of a 50% reduction of food waste by 2030. In order to accomplish this the Agency is synthesizing what is known, informing the public and private sector, and identifying knowledge gaps. This research focused on military kitchens and used a food waste tracking system. Tracking technology was installed in two kitchens, staff were trained, and food waste was measured before, during, and after a test period. This interim product will be used to develop a guidance document for installations and communities looking to explore organics diversion strategies and co-digestion opportunities. This guidance document will include broadly applicable steps and methodologies for conducting a practical food waste diversion plan.

- EPA Report: Food Waste Reduction in Military Kitchens A Tracking Technology Demonstration at Fort Jackson (Rock and Lan, 2019)

Topic 3: Healthy and Resilient Communities

Urban Footprint and SWMM integration

Product Type: EPA Public Website

Stormwater management is a significant urban problem, especially as it effects flooding or Combined Sewer Overflows. This plug-in module for the Urban Footprint model will compute differences in storm water volume and pollutant runoff for scenarios of changes to the built environment. The EPA model SWMM will be used within Urban Footprint to calculate storm water runoff. As a result, communities will be able to better predict which changes in land use could exacerbate or mitigate stormwater flows.

- https://swcweb.epa.gov/ (US EPA, 2019a)
- Storm Water Plug-in User's Manual

Next generation decision support tools that capitalize on existing reusable software and advances in information technology to ensure interoperability while filling gaps in tools currently available to inform community decisions that promote sustainability

Product Type: Internal Report

SHC Project 1.61 was focused on providing tools for environmental problems such as stormwater management and the cleanup and reuse of land. The compiled information from this output can inform the utility, functionality, and affordability for the next generation of tools, and the means and methods to develop and deliver tools that will better support the decision-making needs of communities. Methods included the 1) re-configuration/re-use of interoperable software components, 2) identifying tool gaps, and 3) finding and applying appropriate tools. Results included methods for software component reuse, interoperation, and development supporting EPA research and program needs. The examples and demonstrations of emerging methods for effective software development support simulation and prediction of processes or outcomes for informing better decisions.

- Next Generation Decision Support Tools (Dyson and Brookes, 2019)

EnviroAtlas

Product Type: EPA Public Website

The EnviroAtlas team continues to develop new data, tools, use cases and other resources to help their user community explore eco-health relationships and inform decision-making that affects local environmental assets and the value they provide to communities. The team has developed several new national geospatial indicators and indices, including estimating 100-year flood plain for the entire conterminous US (gridded, 30-m resolution based on FEMA flood-plain data) as well as land cover and land use metrics within the flood plain. Additional new national metrics include regulated facilities and toxic exposures, water pollutant discharges, aquatic invasive species, and farmers markets. At a finer scale1-meter resolution, the EnviroAtlas team completed land cover classifications and 100s of data layers for six additional metropolitan areas, which include nearly 600 new cities and towns -- Philadelphia, PA; Salt Lake City, UT; Sonoma County, CA; Washington, DC; Saint Louis, MO; and LA County, CA. To demonstrate how to use EnviroAtlas and potential applications of this wealth of data, the EnviroAtlas team developed 1) a tutorial story map demonstrating the features and functions of the EnviroAtlas interactive map, 2) "quick use" featured collections related to non-point source pollution, carbon storage, and urban heat islands; and 3) an educational curriculum of six mini lessons introducing the concept of ecosystem services.

- https://www.epa.gov/enviroatlas (US EPA, 2019b)

Application of a data fusion method in Kansas using dispersion modeling and observations from KC-TRAQS

Product Type: Peer Reviewed Journal Article

Currently, there is a lack of accessible tools that can be easily applied to study near-source pollution, identify contributing sources, and develop strategies for reducing emissions and exposure. SHC researchers developed an approach to combine dispersion modeling with stationary, mobile, and portable sensor measurements to create accurate, fine-scale air quality characterization. This data fusion method allowed researchers to create spatially-resolved maps of pollutant concentrations, identify hot spots in the study area, and improve emissions inputs for dispersion modeling applications to better identify contributions from local and regional air pollution sources. This approach may be of interest to researchers, air quality managers, and communities potentially impacted by emissions from local sources.

- Combining Dispersion Modeling and Monitoring Data for Community-Scale Air Quality Characterization (Isakov et al., 2019)

Community-based application of bioavailability tools for co-occurring metals applied to specific communities

Product Type: Peer Reviewed Journal Articles

Soil ingestion can be a major route of exposure for contaminants, such as lead and arsenic. Bioavailability research is needed to accurately determine human health risk from soil ingestion. To address this problem, SHC researchers have developed a better understanding of 1) the influence of soil amendments for reducing lead bioavailability, 2) the influence of arsenic speciation on contaminated soils, 3) arsenic and lead bioaccessibility, and 4) potential exposures to contaminated soils in urban community gardens. This research can inform risk assessment as well as public health interventions to reduce dietary arsenic exposure.

- Opportunities and Challenges for Dietary Arsenic Intervention. (Nachman et al., 2018)
- Total and Bioaccessible Soil Arsenic and Lead Levels and Plant Uptake in Three Urban Community Gardens in Puerto Rico (Misenheimer et al., 2018)
- Arsenic Speciation of Contaminated Soils/Solid Wastes and Relative Oral Bioavailability in Swine and Mice (Stevens et al., 2018)
- State of the science review: Potential for beneficial use of waste by-products for in situ remediation of metal-contaminated soil and sediment (Karna et al., 2017)

Key factors and novel interventions to reduce asthma disparities

Product Type: Peer Reviewed Journal Articles

The prevalence of asthma in disadvantaged communities is often much higher than in more affluent communities. There are many indoor and outdoor exposures, including mold contamination in homes, that may explain this difference. This research 1) evaluated the relationships between indoor particulate matter (including mold) and lung function in children living near roadways; 2) mold contamination and asthma prevalence in adults and children in low-income, Hispanic immigrant communities in the Eastern Coachella Valley, CA; and 3) indoor air quality before and after installation of

air-purifying units in bedrooms and respiratory health in children with asthma in low-income families. The research suggests high levels of mold contamination may be one reason for the high prevalence of asthma/respiratory illness in the Eastern Coachella Valley, CA; and for children with poorly controlled asthma, air purifiers improved their respiratory health. This research can inform actions at the local and individual levels. For example, development and enforcement of housing codes can affect people's exposure to indoor air pollution and mold. At an individual level, purchasing home air purifiers could help. The overall goal of this research is to provide tools and information that will lead to a lower prevalence of asthma in the US.

- Indoor particulate matter and lung function in children living near roadways. (Isiugo et al., 2019)
- Mold Contamination in Housing in Eastern Coachella Valley California and Asthma. (Sinclair et al., 2018)
- Effectiveness of a portable air cleaner in removing aerosol particles in homes close to highways. (Cox et al., 2018)

Community-based associations of morbidity and mortality with environmental stressors

Product Type: Peer Reviewed Journal Articles

The goal of this research is to identify social and demographic determinants of health to address the uncertainty in the heterogeneity of health effects from environmental stressors across multiple US cities. This research links health data to measured or modeled environmental data to estimate the associations between environmental stressors and health outcomes across multiple metropolitan areas, counties, or zip codes with specific attention to spatial heterogeneity across locations. Findings demonstrate the impact of the built environment on health outcome, especially cardiovascular health events and mortality. Socially deprived populations show stronger associations than more affluent populations, but this effect modification by race and socioeconomic status may be declining over time.

- Associations Between Residential Proximity to Traffic and Vascular Disease in a Cardiac Catheterization Cohort (Ward-Caviness et al., 2018)
- A novel approach for measuring residential socioeconomic factors associated with cardiovascular and metabolic health (Mirowsky et al., 2017a)
- Neighborhood sociodemiographic effects on the associations between long-term PM2.5 exposure and cardiovascular outcomes and diabetes (Weaver et al., 2019)
- Fine Particulate Matter and Cardiovascular Disease: Comparison of Assessment Methods for Long-term Exposure (McGuinn et al., 2017)
- Association of Long-term PM2.5 Exposure with Traditional and Novel Lipid Biomarkers Related to Cardiovascular Disease Risk (McGuinn et al., 2019)
- Fine particulate matters: The impact of air quality standards on cardiovascular mortality (Corrigan et al., 2018)
- Divergent trends in life expectancy across the rural-urban gradient and association with specific racial proportions in the contiguous USA 2000-2005 (Jian et al., 2019)
- Human exposure factors as potential determinants of the heterogeneity in city-specific associations between PM2.5 and mortality (Baxter et al., 2019)

- Early life exposure to air pollution and autism spectrum disorder: Findings from a multisite case-control study (McGuinn et al., 2020)
- Air Pollution, Neighborhood Deprivation, and Autism Spectrum Disorder in the Study to Explore Early Development (McGuinn et al., 2019)
- The contribution of improved air quality to reduced cardiovascular mortality: Declines in socioeconomic differences over time (Wyatt et al., 2020)

Ingestion of soils and house dusts by children: the role of chemical and non-chemical stressors in determining the bioaccessibility of sorbed organics

Product Type: Peer Reviewed Journal Articles

Soils and dusts are important exposure metrics for understanding children's exposure to various chemical and non-chemical stressors because they are sorbents for several regulated compounds. This research examined the behavior of sorbed organic chemicals -- specifically a phenylpyrazol insecticide, fipronil, and various PCBs -- following ingestion, considering physicochemical properties of the soil and dust, physicochemical properties of the sorbed organics, and chemistry of the digestive tract. It also evaluated the role of food preparation in determining bioaccessibility. The research results indicate that different bioaccessibility models are required for soils and dusts but that post-ingestion bioaccessibility could be estimated using the total organic carbon content of soil or dust and the log kow (sigmoidal) of the chemical of interest. Further, sugar and protein consumption don't affect bioaccessibility, but presence of fat slightly increased bioaccessibility. These models will be included in ExpoBox and linked to SHEDS and other human exposure models, as appropriate, so they can reduce the uncertainty in dose calculations for the soil and dust ingestion pathway.

- Using paired soil and house dust samples in an in vitro assay to assess the post ingestion bioaccessibility of sorbed fipronil. (Starr et al., 2016)
- The bioaccessibility of polychlorinated biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/furans (PCDD/Fs) in cooked plant and animal origin foods. (Shen et al., 2016)
- The role of soil and house dust physicochemical properties in determining the post ingestion bioaccessibility of sorbed polychlorinated biphenyls. (Shen et al., 2019)
- Is food type important for in vitro post ingestion bioaccessibility models of polychlorinated biphenyls sorbed to soil? (Starr et al., 2020)

Interactions of chemical and non-chemical environmental stressors that impact children's healthy development and well-being

Product Type: Peer Reviewed Journal Articles

Adverse health effects of air and water pollutants have been well characterized, however, the potential modifiable factors for these effects by non-chemical stressors have not been evaluated. These studies specifically examine obesity, which has reached an epidemic level in our population, and psychosocial stress, which are associated with environmentally deprived communities. This research examines interactions between maternal obesity and ozone exposure as well as the interactions between psychosocial stress and manganese exposure from drinking water during pregnancy and in offspring. Maternal obesity exacerbated the adverse health effects of ozone exposure, postnatal growth and

development of offspring. These effects can be mitigated by physical activities of the pregnant animals, but dietary supplementation with essential fatty acids during pregnancy is less effective. Researchers have developed an animal model to simulate psychosocial stress in humans, but work is ongoing to examine the interactions between stress and manganese exposure. This information is useful for public health officials and community decision-makers to optimize environments and develop strategies for children's healthy development and mitigating health disparities.

- Internal Summary Report (Lau et al., 2019)
- Agerelated differences in pulmonary effects of acuteand subchronic episodic ozone exposures in Brown Norway rats. (Snow et al., 2016)
- Uterine Artery Flow and Offspring Growth in Long-Evans Rats following Maternal Exposure to Ozone during Implantation. (Miller et al., 2017)
- Ozone Exposure During Implantation Increases Serum Bioactivity in HTR-8/SVneo Trophoblasts. (Miller et al., 2019)
- Aspirin pre-treatment modulates ozone-induced fetal growth restriction and alterations in uterine blood flow in rats. (Miller et al., 2019)
- Effect of high-fructose and high-fat diets on pulmonary sensitivity, motor activity, and body composition of Brown Norway rats exposed to ozone. (Gordon et al., 2016)
- Interaction of diet and ozone exposure on oxidative stress parameters within specific brain regions of male Brown Norway rats. (Valdez et al., 2019)
- The influence of maternal and perinatal high-fat diet on ozone-induced pulmonary responses in offspring. (Snow et al., 2019)
- Journal manuscript pending publication, draft available at Maternal High Fat Diet Modify Offspring Susceptibility to Inhaled Ozone-Induced Systemic Metabolic Alterations. (Snow et al.)
- Ozone-induced vascular contractility and pulmonary injury are differentially impacted by diets enriched with coconut oil, fish oil, and olive oil. (Snow et al., 2018)
- Mitochondrial bioenergetics in brain following ozone exposure in rats maintained on coconut, fish, and olive oil-rich diets. (Valdez et al., 2019)
- Active vs. sedentary lifestyle from weaning to adulthood and susceptibility to ozone in rats. (Gordon et al., 2017)
- Journal manuscript pending publication, draft available at The effects of ozone exposure and sedentary lifestyle of neuronal microglia and mitochondrial bioenergetics of female Long-Evans rats. (Valdez et al., 2019)
- Impacts of maternal diet and exercise on offspring behavior and body weights. (Moser et al., 2017)
- Effects of maternal high-fat diet and sedentary lifestyle on susceptibility of adult offspring to ozone exposure in rats. (Gordon et al., 2017)
- Developmental origins of cancer. In Waters, M.D. and Hughes, C.L. (eds.), Translational Toxicology and Therapeutics: Windows of Developmental Susceptibility in Reproduction and Cancer. (Vulimiri and Rogers, 2018)
- Epigenetics and the Developmental Origins of Health and Disease. (Rogers, Lau, Ellis-Hutchings, 2018)

- Smoking and pregnancy: Epigenetics and the developmental origins of the Metabolic Syndrome. (Rogers, 2019)

Proper functioning condition of ecosystems which provides ecological assessments centered on Tribal culture and values to help manage ecosystem and human health issues

Product Type: Published Reports, Internal Reports, and Peer Reviewed Journal Articles

Environmental quality is necessary to maintain and improve Tribal sustainability and resilience in the face of climate change and other stressors. One way to address these concerns is through ecological proper functioning condition (PFC). PFC is relevant to human and environmental well-being, and it provides ecological assessments centered on Tribal culture and values to help manage ecosystems and human health issues. The objective of managing for PFC is to identify ecological modifications to prevent degradation and restore the ecosystem to its potential natural condition. This research demonstrates several applications of this approach throughout North America. Restorations are underway and adaptive management is being used at multiple locations based on the results of this research.

- Using Ecosystem Function in the Clean Water Act (Aron et al., 2017)
- Ecological risk-based assessment used to restore riparian physical functions to a fresh water Creek. (Hall et al., 2018)
- Linking Changes in Management and Riparian Physical Functionality to Water Quality and Aquatic Habitat: A Case Study of Maggie Creek, NV (Kozlowski et al., 2013)
- An Ecological Function Approach to Managing Harmful Cyanobacteria in Three Oregon Lakes: Beyond Water Quality Advisories and Total Maximum Daily Loads (TMDLs) (Hall et al., 2019a)
- Assessing Dungeness River Functionality and Effectiveness of Best Management Practices (BMPs) Using an Ecological Functional Approach (Hall et al., 2019b)
- Investigating the Geomorphic Stability of Pond and Plug Projects in the Sierra Nevada Range: A Report prepared for the Environmental Protection Agency Office of Research and Development (Wagner et al., 2019; EPA/600/X-17/248)
- Commission for Environmental Cooperation (CEC) Project 15: Proper Functioning Condition (PFC) Assessment Report (Hall et al. 2015; EPA/600/X-17/078)
- Using Ecosystem Function and Traditional Ecological Knowledge Together to Build Resilience and Adapt to Climate Change in North America: An Ecological Condition Assessment near El Mingo, Tabasco, Mexico, March 29-31, 2016 (Lin et al. 2016; EPA/600/X-17/084)
- Commission for Environmental Cooperation (CEC) Project 15 Georgina Island Report (Hall et al., 2017; EPA/600/X-17/105)
- Coyote Valley Rancheria (CVR) Proper Functioning Condition (PFC) Assessment Report (Hall et al., 2019c; EPA/600/X-19/125)

Report detailing neighborhood and community level factors that can disproportionally impact disadvantaged communities

Product Type: Peer Reviewed Journal Article

Individual-level characteristics, including socioeconomic status, have been associated with poor metabolic and cardiovascular health; however, residential area-level characteristics may also independently contribute to health status and are not as clearly understood. This study used a novel application of hierarchical clustering to aggregate US Census block groups in Durham, Orange, and Wake Counties, NC into six homogeneous clusters of similar characteristics based on 12 demographic factors. Researchers examined clinical conditions (diabetes and congestive heart failure) and physiological measures (obesity and hypertension) ascertained at clinical examination. After controlling for individual age, sex, smoking status, and race, there were elevated odds of patients being obese, having diabetes, congestive heart failure, and hypertension in a cluster that was urban, impoverished, and unemployed compared to an urban cluster with a low percentage of people impoverished or unemployed. This study demonstrated the feasibility of applying hierarchical clustering to an assessment of area-level characteristics. It indicates that neighborhood characteristics -- living in impoverished, urban residential clusters -- may have an adverse impact on health.

- Ozone exposure is associated with acute changes in inflammation, fibrinolysis, and endothelial cell function in coronary artery disease patients (Mirowsky et al., 2017b)

Development of a novel method to estimate children's dust ingestion

Product Type: Peer Reviewed Journal Article

Children's dust ingestion is an important route of exposure for many chemicals. Current methods for estimating dust ingestion rates are inadequate and limited. Researchers developed a framework for evaluating chemicals as tracers and implemented the system to identify 5 chemicals with high potential to be prominent tracers. This research is a first step in identifying and prioritizing chemical tracers found in dust samples that could improve the estimates of dust ingestion that are critical for exposure and risk assessments.

- Journal manuscript in review; draft available for now: Using Non-Targeted Analysis, Multimedia Modeling, and Literature Review to Identify Organic Chemical Tracers for Estimating Children's Dust Ingestion (Panagopoulos et al.)

Quantitative and Qualitative Linkages Between FEGS and Human Health

Product Type: Internal Fact Sheet and Peer Reviewed Journal Articles

Nature provides benefits for people, but these benefits are not easy to consider in decision-making because they are difficult to quantify let alone monetize so they could be included in cost-benefit analyses. Over the last several years, ORD has invested in advancing ecosystem services science, particularly as it relates to community-scale decision-making. This product summarizes SHC's research demonstrating the importance of articulating the decision contexts, the utility of decision support tools, the types of metrics and models examined, and estimated benefits to humans. The purpose is to stimulate conversations with Program and Regional partners around areas of mutual interest and potential application in various programmatic contexts to help communities develop best practices for their environments, economies, and the well-being of their citizens.

- Internal fact sheet

- Final Ecosystem Goods and Services Classification System (FEGS-CS): https://www.epa.gov/eco-research/final-ecosystem-goods-and-services-classification-system-fegs-cs
- Kingsbury Bay-Grassy Point Habitat Restoration: A Health Impact Assessment. Presentation at the Minnesota DNR Public Meeting. (Williams and Hoffman, 2019)
- Health Impact Assessment (HIA) of Proposed Code Changes Regarding Onsite Sewage Disposal Systems in Suffolk County, NY. Presentation to the American Public Health Association Meeting. (Shattuck, 2017)
- Linking Ecosystem Services to Human Health to Inform Estuary Management in Puerto Rico. Presentation to ACES Conference. (Yee et al., 2018)
- Valuing Community Benefits of Final Ecosystem Goods and Services: Human Health and Ethnographic Approaches as Complements to Economic Valuation. EPA Report. (Johnston et al., 2017)
- Ecosystem Goods and Services Case Studies and Models Support Community Decision Making using the EnviroAtlas and Eco-Health Relationship Browser. EPA Report. (Bolgrien et al., 2018)
- Linking Wetland Ecosystem Services to Vector-borne Disease: Dengue Fever in San Juan Bay Estuary, Puerto Rico. (de Jesús Crespo et al., 2019a)
- Linking Water Quality to Aedes aegypti and Zika in Flood-Prone Neighborhoods. (Yee et al., 2019)
- Flood Protection Ecosystem Services in the Coast of Puerto Rico: Associations Between Extreme Weather, Flood Hazard Mitigation and Gastrointestinal Illness. (de Jesús Crespo et al., 2019b)
- Eco-Health Linkages: Assessing the Role of Ecosystem Goods and Services on Human Health Using Causal Criteria Analysis. (de Jesús Crespo et al., 2018)
- Spatiotemporal Modeling of Ecological and Sociological Predictors of West Nile Virus in Suffolk County, NY, Mosquitoes. (Myer et al., 2017)
- Spatiotemporal Bayesian Modeling of West Nile Virus: Identifying Risk of Infection in Mosquitoes with Local-scale Predictors. (Myer & Johnston, 2018)
- Mapping Aedes aegypti (Diptera: Culicidae) and Aedes albopictus Vector Mosquito Distribution in Brownsville, TX. (Myer et al., 2019)

Exploring quantitative measures and qualitative aspects of resilience

Product Type: Peer Reviewed Journal Article

A growing number of States, localities and Tribes are developing resilience plans, and many recognize the value of ecosystem services in their resilience. This product provides a synthesis of efforts to explore quantitative measures and qualitative aspects of resilience for ecological and human systems. It involves: (1) surveying measures for assessing resilience in human and natural systems. It includes cross walking pertinent indicators from previous or existing ORD activities and reviewing literature pertinent to community and ecological resilience, (2) examining qualitative aspects of resilience by presenting strategies for incorporating law and policy (to include governance and adaptive management) into resilience science, (3) employing various measures to assess case study systems. The goal is to identify key characteristics of system dynamics, early warning indicators and possible drivers of change useful for planning and management.

- Enhancing quantitative approaches for assessing community resilience (Spanbauer et al., 2018)

Population-based Survey Dissemination/Implementation

Product Type: Peer Reviewed Journal Articles, Internal Report, and Survey Questions

Although the health-promoting influence of nature has been generally recognized for many years, a more complete accounting informs cost—benefit analyses strengthening environmental regulation and State/local/Tribal actions. Leveraging existing studies could provide affordable data, but an important data limitation remained about how one perceives the natural environment and access to it. To address this limitation, researchers comprised a short survey module that was then included within the 2017 NSF General Social Survey. With this survey's results, data about the benefits of nature to health and wellbeing is more complete, which can allow federal, state, local and tribal governments to better make policy that effectively considers the environment's benefits as well as adverse influences.

- Advancing Environmental Epidemiology to Assess the Beneficial Influence of the Natural Environment on Human Health and Well-Being. (Silva et al., 2018)
- How do natural features in the residential environment influence women's self-reported general health? Results from cross-sectional analyses of a U.S. national cohort. (Tsai et al., 2020)
- General Social Survey module and writeup (Son and Smith, 2019)

Shared scenarios of nitrogen use in the future: Projected intersection of food, energy, transportation and air and water policy

Product Type: Peer Reviewed Journal Article

Developing a systems approach for Nitrogen (N) management and policy, which addresses the multiple sources, benefits and impacts, would lead to more effective solutions. This study introduced a suite of new nitrogen-focused scenarios based on the widely-used Shared Socioeconomic Pathways framework that includes all the major nitrogen-polluting sectors (agriculture, industry, transport and wastewater) and integrates the influence of climate and other environmental pollution control policies, while also incorporating explicit nitrogen-control measures. These shared scenarios can be used as core inputs to models evaluating different N management and use alternatives, so we may better address environmental impacts while simultaneously meeting key development goals.

- A World of Co benefits: Solving the Global Nitrogen Challenge (Houlton et al., 2019)
    - Earth's Future Feature story on Houlton et al. article
    - ScienceDaily interview/article with Houlton

A Review of Nonpoint Source Pollution Models for Managers Making Landscape and Watershed Decisions in Communities

Product Type: Peer Reviewed Journal Article

Providing insight to managers, modelers and decision makers on how to select and evaluate the proper tools for Nitrogen management of watersheds and water quality is a critical concern. This work comprised an integrated evaluation of such tools, their strengths and limitations, to assist watershed practitioners and decision makers when model selection is occurring. The result is a clear and organized summary of water quality models available and evaluation of the scale, scope, decision context, source,

data availability, complexity and ease of use of those models so that practitioners, state, and local professionals can make more informed holistic nitrogen and other water quality management decisions.

- Journal manuscript in review, available at A Review of Nonpoint Source Pollution Models for Managers Making Landscape and Watershed Decisions in Communities (Yuan et al.)

Valuing Coastal Recreation in an Estuary

Product Type: Peer Reviewed Journal Articles

Americans take over 900 million trips to coastal areas each year, spending at least $44 billion per year on those trips. However, there isn't good information on how these activities and economic values are affected by poor coastal water quality. This product addresses methods to provide important factors for that, in terms of the number of visitors and the value per visit. This research will help researchers provide better information, analysis and tools, so communities can better evaluate recreational uses of their coastal access points, including the number of visitors and values per day, as well as the value of improving coastal water quality.

- Valuing Coastal Beaches and Closures Using Benefit Transfer: An Application to Barnstable, Massachusetts (Lyon et al., 2018)
- Quantifying Recreational Use of an Estuary: A Case Study of Three Bays, Cape Cod, USA (Mulvaney et al., 2020)

An approach for evaluating the ecological and social resilience of coastal water systems

Product Type: Peer Reviewed Journal Article

The Commonwealth of Massachusetts and the Cape Cod Commission were charged with updating the 208 Water Quality Management Plan to address nutrient standards violations. This product comprises a resilience framework that integrates ecosystem service concepts with components of social-ecological systems to guide targeted science and better inform long-term community planning and management decisions regarding nutrient pollution. The resulting approach, an interim product, allowed case studies to better clarify the effectiveness and acceptance of water quality improvement efforts and their effect on the delivery of ecosystem services. The framework is intended to be transferable to other geographical settings, as well as more generally applied to systems exposed to chronic disturbances, in order to coordinate interdisciplinary research planning and inform environmental management.

- A Resilience Framework for Chronic Exposures: Water Quality and Ecosystem Services in Coastal Social-Ecological Systems (Merrill et al., 2018)

RESES: Using Ecosystem Services Assessment and Health Impact Assessments as Part of a Stakeholder-driven Approach to Storm Recovery

Product Type: Peer Reviewed Journal Article

This project, a RESES collaboration with Region 1, supported ecosystem services assessment being conducted to inform Long Island recovery from Hurricane Sandy. The project developed a methodology for incorporating local stakeholder values and input into the economic valuation of targeted ecosystems. The team examined two Long Island communities to identify stakeholder priorities most important to the valuation of ecosystems. They then identified models to predict the response of Long Island ecosystems, for certain scenarios of land use, climate and population change. The researchers

assisted the community in identifying which EGS were relevant to the key planning decisions and worked with the stakeholders to prioritize their limited resources. The project resulted in a prioritized inventory of EGS for each pilot community, data sets that indicate a baseline for evaluating each community's storm recovery, and an initial methodology to link health impact assessments with ecosystem services assessments. By providing Long Island-specific data sets, tools, and a methodology, and a suite of potential recovery indicators, policy makers and planners at the Federal, state, and local level are better prepared to make recovery decisions that support community health and well-being, healthy ecosystem functioning and long-term resilience.

- Spatiotemporal modeling of ecological and sociological predictors of West Nile virus in Suffolk County, NY, mosquitoes (Myer et al., 2017)

RESES: Community Resilience Planning and Decision-Making Framework for Coastal Communities

Product Type: Published Report

Climate resiliency action planning must reflect the values of multiple stakeholders to be effectively embraced and advanced by all individuals affected by these issues. The objective of this project is to therefore demonstrate a decision process that facilitates the development of a shared vision leading to refinement of resilient community design options and provides a path to begin implementation planning in coastal communities. Reviews of existing community resilience planning documents, meetings with stakeholders to present structured decision-making (SDM) with ORD tools and community training sessions in ORD tools were completed to increase community understanding and involvement. End products include an SDM-driven site-specific re-design options analysis and guidance for implementation, a compilation of community resilience influence diagrams developed to help identify science data gap and potential system response hypotheses, and a coastal community SDM template for resilience planning adaptable to communities across regions with guidance on integrating relevant ORD science tools as a "toolkit." Having a framework and access to ORD tools broadly applicable to coastal communities throughout the U.S. is useful for sorting through complicated environmental, economic, and community issues through the lens of climate resiliency and sustainability.

- Community Resilience Planning: A Decision-Making Framework for Coastal Communities (Dyson et al., 2019b)

RESES: Community Participatory Port Resilience Assessment

Product Type: Internal Report

In today's changing climate, port communities are at increased risk and vulnerability to extreme weather events. Several major port and distribution locations with significant low income, minority populations have already experienced the impacts of climate change. One example is North Charleston, which is environmentally overburdened due to both legacy pollution and continuing heavy industrial activity. EPA and the Lowcountry Alliance for Model Communities (LAMC) organized a community resilience workshop in North Charleston to introduce the EPA Inland Port Community Resilience Roadmap, develop a shared understanding of community resilience goals and objectives, articulate community resilience challenges and opportunities, support existing resilience activities in the community, and identify feasible resilience strategies. Residents participated in a ranking exercise using

the Cumulative Stressors and Resilience Index (CSRI) version 2.0, a community-informed screening tool developed to assess the cumulative burden of environmental stressors while accounting for resilience or health-promoting factors.

EPA and LAMC also held a working session and community resource fair to develop an actionable implementation plan and share key resources with the community to help them address resilience challenges and solutions. EPA and other Federal and state agencies shared resources related to the community's environment, health, housing, transportation, economic opportunities as well as community enhancing tools such as EPA's A Healthy Environmental Actions Database (AHEAD). The North Charleston Community Participatory Resilience Project resulted in numerous successful outcomes and accomplishments including the development of the resource compendium specifically for North Charleston and the Collaborative Community Vulnerability Assessment for North Charleston which reflects the roadmap process and next steps for the LAMC community to increase their resilience and the community's science capacity through training, translation and the expansion of community partnerships.

- Collaborative Community Vulnerability Assessment for North Charleston, SC (ICF, 2019)

RESES: Local Information for Empowering Environmental Education (LIFE^3)

Product Type: Database with Supporting Documents

A collaboration between ORD and Region 5 addressed the many communities in the region facing local-scale environmental health concerns driven by pollution, as well as the need for the capacity to assess environmental health risks, identify research gaps, and prioritize regulatory and non-regulatory mitigation approaches. The project's approach was to use SHC tools to map issues in Saginaw and characterize health and environmental quality impacts using measures of community and ecosystem health, while also identifying and addressing research gaps related to environmental health and assessment techniques. The results of the project include the development of a searchable database of environmental health impacts and possible solutions, and the EPA and community partners also collaborated in applying SHC tools to provide and document integrated analysis that supports comprehensive planning to improve community well-being. The impact of these results is that they will improve the way in which the Region characterizes conditions, ranks environmental health concerns, prioritizes solutions, implements mitigation actions, and evaluates their effectiveness.

- AHEAD Database (MS Access file)
- AHEAD User Manual
- AHEAD Readme file

RESES: Temporal-Spatial Analysis of Mosquito Breeding Habitat, Arbovirus Health Risk, and Vector Mitigation in Brownsville, Texas

Product Type: Peer Reviewed Journal Articles

Vector- borne diseases are increasing across the United States and Puerto Rico. Diseases such as the Zika virus were declared a public health emergency by the World Health Organization in February of 2016. A major chunk of these diseases are spread by mosquitos. Mosquito control infrastructure are beneficial in mitigating the risk, but their programs are oriented toward a different species rather than the ones

spreading the arboviruses. Researchers from Region 6 will work with the Brownsville, Texas community on gathering relevant data and share early lessons with Region 2. The project will identify temporal patterns of the aegypti and albopictus mosquitos through web-based tools, GIS platforms, and citizen science systems. ORD tools such as EnviroAtlas will be used to help predict mosquito habitat. The data collected will be used to help the local community better predict and plan for potential breeding sites and promote vector mitigation when there is an increased risk in human disease. The community will have a better understanding of the factors related to the mosquitos and vector-borne diseases. Success of this project will help other communities plan for risk mitigation related to vector-borne diseases.

- Systematic Review: Land Cover, Meteorological, and Socioeconomic Determinants of Aedes Mosquito Habitat for Risk Mapping. (Sallam et al., 2017)
- Mapping Aedes aegypti (Diptera: Culicidae) and Aedes albopictus Vector Mosquito Distribution in Brownsville, TX. (Myer et al., 2020)

RESES: Environmental Siting Assessment for Solar Power Infrastructure - A Partnership with City of Brownsville on Economic Opportunities

Product Type: Peer Reviewed Journal Article

Localized assessment of solar energy economic feasibility will benefit the structuring of residential solar energy deployment globally. In the U.S. growing interest in rooftop residential solar among city managers has spurred the development of photovoltaic (PV) feasibility maps of the technical and economic solar potential within cities. The City of Brownsville, Texas was interested in evaluating solar feasibility for their city but lacked information to make informed policy decisions on PV development. This paper presents novel and systems approaches for determining the technical and economic feasibility of solar development for homes in the Brownsville using LiDAR and local information. Residential technical and economic potential was assessed by optimizing the internal rate of return (IRR) and an average residential building demand profile to determine ideal size and placement of solar arrays. Results showed that residential structures in Brownsville have the technical potential to generate approximately 11% of the total energy provided by the local utility; however, average IRR was only 2.9% with a payback period of over 15 years. Five neighborhoods in the City of Brownsville were identified with spatially clustered homes that had relatively higher IRRs compared with other areas in the city. Despite the high technical potential, modeled results indicate that perspective homeowners interested in solar development may require additional incentives to improve the economic feasibility of PV in Brownsville. This study provides a demonstration of an interdisciplinary systems approach and methodology that can be adopted internationally to evaluate the feasibility of solar development in other areas.

- Economic and technical assessment of rooftop solar photovoltaic potential in Brownsville, Texas, U.S.A (Mangiante et al., 2020)

RESES: Kansas City Transportation and Local Scale Air Quality Study (KC-TRAQS): Comparing Citizen Science and PM Data

Product Type: Peer Reviewed Journal Article

Citizens in the Kansas City, KS community were concerned about their local air quality because of particulate matter and black carbon resulting from a large rail yard operation next to the neighborhood. Accordingly, the goal of this project was to quantify the impact of various types of air pollution impacting the community using a combined modeling and measurement approach, while also engaging the community through citizen science. This research showcased the effectiveness of the AirMapper instrument, used to support real-time mapping of particulate matter by citizens, and the value of citizen science in the process. The objectives were achieved by using low-cost, portable air pollution sensors and the ORD research screening tools C-PORT and C-LINE. The accomplishment of the project provided environmental data for the Argentine community and empowered them to participate in the research, allowing them to have a greater understanding of the health impacts. This study demonstrates a new model of engagement with communities.

- The Kansas City Transportation and Local-Scale Air Quality Study (KC-TRAQS): Integration of Low-Cost Sensors and Reference Grade Monitoring in a Complex Metropolitan Area. Part 1: Overview of the Project (Kimbrough et al., 2019)

Report on the Environment

Product Type: EPA Public Website and Internal Report

The Report on the Environment (ROE) develops measures that provide a nationwide view of progress in EPA's efforts to protect human health and the environment. EPA's performance-based protection system relies on tracking and anticipating environmental and health issues of concern, managing and planning strategic goals, and making sound environmental decisions and policies. The ROE is EPA's resource for high level, efficient communication of the nation's environmental and related human health conditions, providing an objective basis for Agency decision making, planning, and tracking.

- https://www.epa.gov/report-environment (US EPA, 2019)
- EPA Internal Report: An ROE Update: Overview of Status and Trends, Analytics, and Communication (Gamble et al., 2019)

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