Exposure Science in the 21st Century

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Drivers for a New Exposure Science

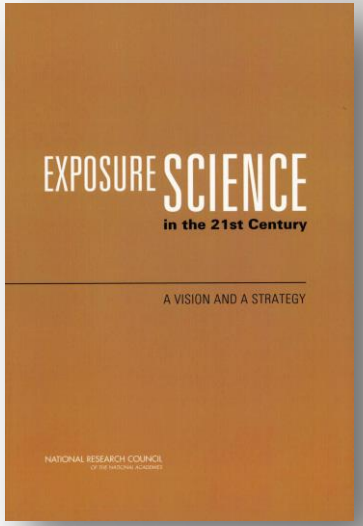
- **It is important**. Exposure science provides real world context for describing risk along with ways to reduce or prevent exposures and improve health

- New exposure science is needed to address complex societal problems and to develop sustainable solutions
  - Climate change
  - Security threats
  - Population pressure
  - Habitat loss
  - Increases in childhood illness

- Advances in measurements and computational techniques provide new tools

National Research Council Report — Exposure Science in the 21st Century

- Commissioned in 2010 by the EPA and NIEHS*
- Expands the way we think about exposure
  - Extends beyond the exposure event to the transport and transformation of agents from their source to internal dose
  - Embraces simultaneous consideration of multiple stressor
  - Promotes integration across scales of time, space, and biological organization
- Exposure science must deliver knowledge that is effective, timely, and relevant
- Provides a conceptual systems framework for exposure science
- Collaborations within and outside the Federal Government should be developed



* Environmental Protection Agency and National Institutes for Environmental Health Sciences

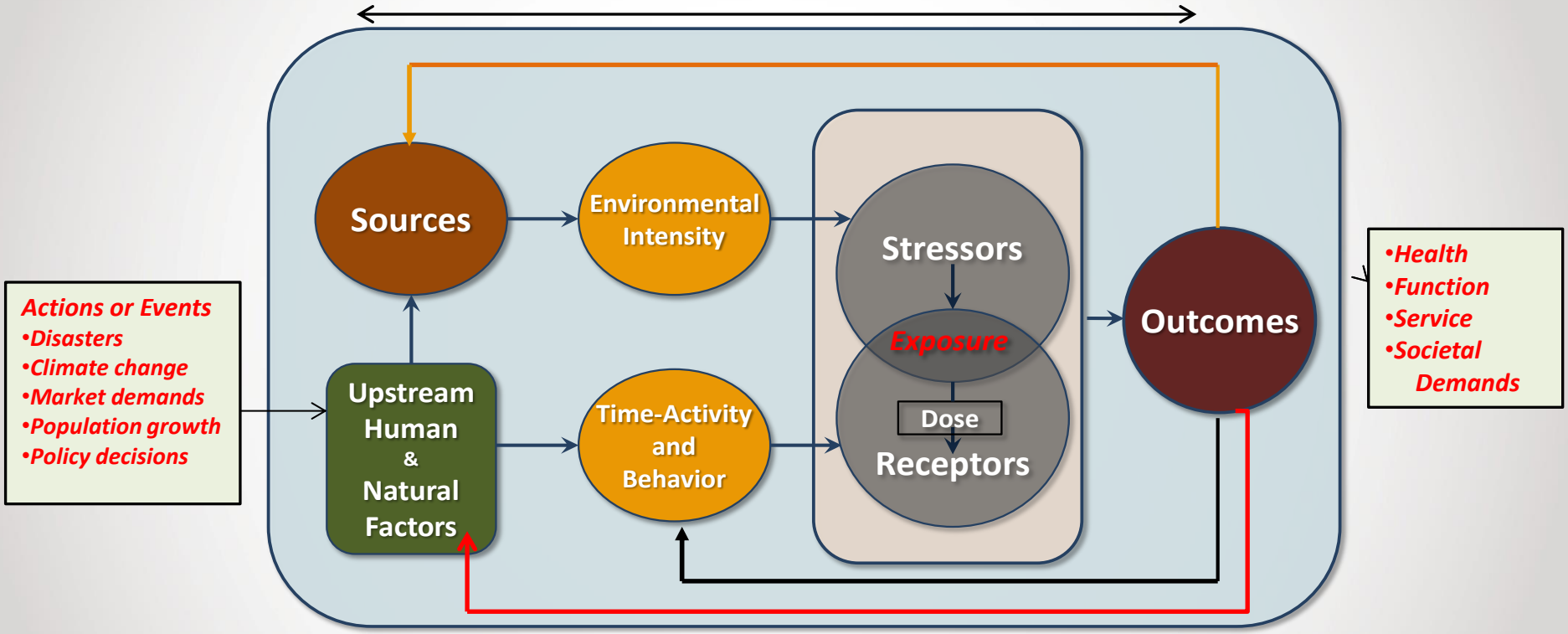
Working Group on Exposure Science for the 21st Century

- Chartered under the Toxics and Risk Subcommittee of the Committee on Environment, Natural Resources, and Sustainability; National Science and Technology Council

- Purpose: *Build on the NRC framework and promote Federal collaboration in the development of exposure science.*
  - *Focus: Biomonitoring; Modeling; Data Management; Sensor Technology; Community Engagement/Citizen Science*

- 25 Federal Agencies participating

Exposure as Dynamic System

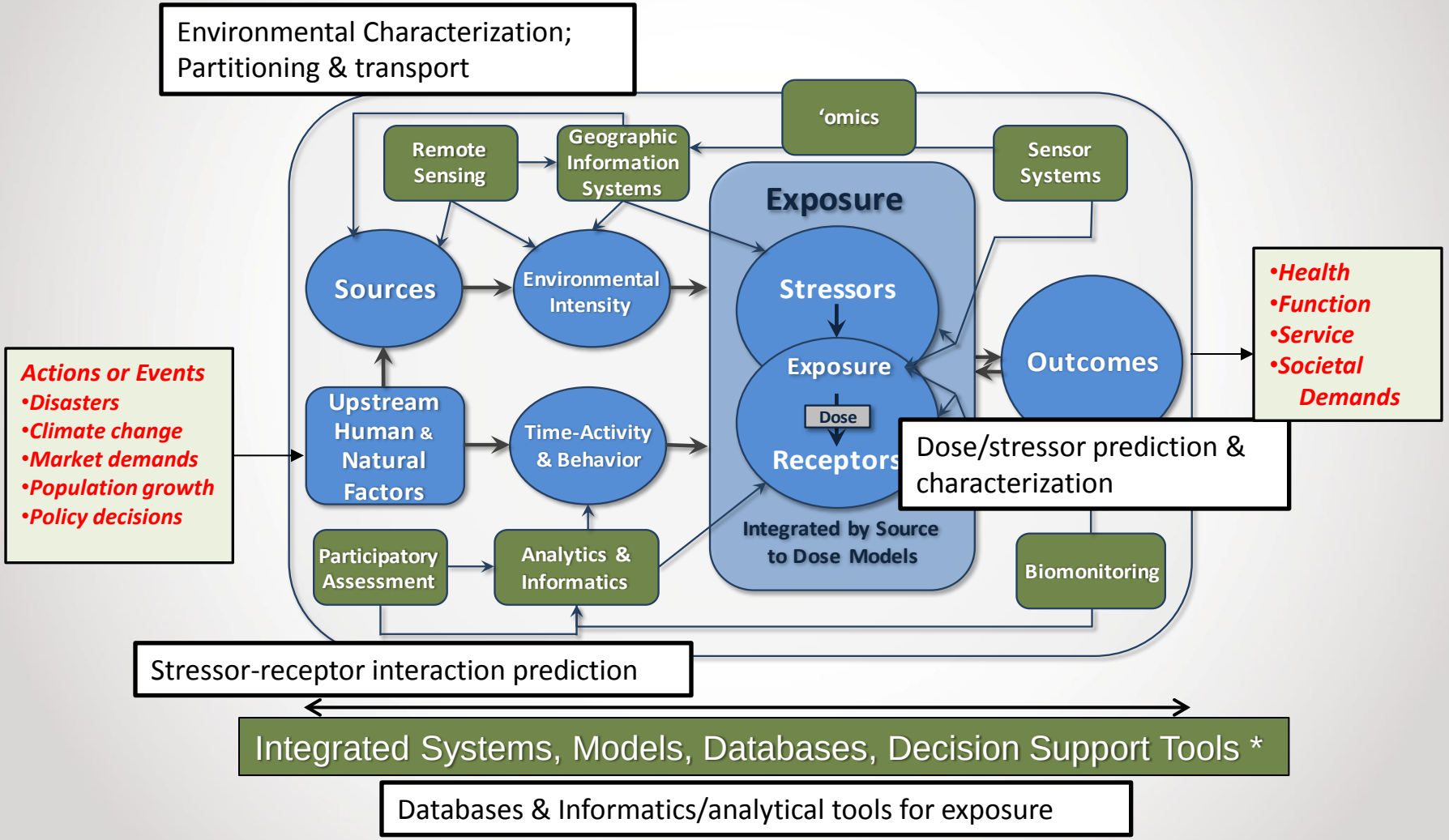


*Adaptation from NRC Report – in red

NRC Vision: Use Advanced Technologies to Move the Science Forward

- **Methods to Track Sources, Concentrations and Receptors at Multiple Scales**
  - Remote sensing
  - Ubiquitous and embedded sensing
  - Biomonitoring
- **Methods and Tools for Analysis**
  - Geographic Information Systems
  - Multi-scale exposure modeling
  - Statistical methods and tools for predictive modeling
  - Informatics
- **Information Management**
  - Publicly available systems for data sharing
- **Community Engagement and Promoting Public Trust**
  - Protecting research volunteers
  - Managing issues of privacy
  - Citizen Science

Using Advanced Technology to Move Exposure Science Forward

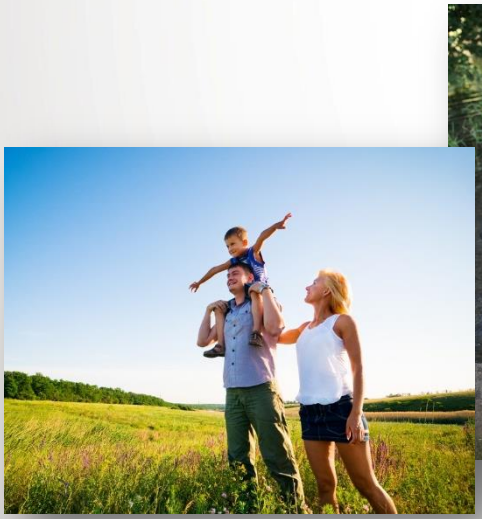


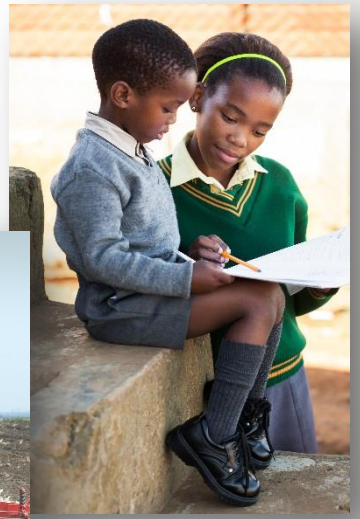
Evolution of Exposure Science

Areas of Decreasing Emphasis	Areas of Increasing Emphasis
Gathering Data	Novel Data Sources/Analytics/Informatics
Direct Field/Lab Measurements	'Omics/Remote Sensing/ Computational Predictive Measurements
Standalone Empirical Models	Integrated Systems & Predictive Models
Targeted Chemical Exposure Modeling	High Throughput Exposure Modeling

How EPA is Advancing New Exposure Science

Leading research on use of exposure science to protect the environment and public health





Computational Exposure: Integrating Disparate Data Streams and Models to Rapidly Predict Exposure to Chemicals

Advancing Computational Exposure Science to Enable Risk Assessment for the 21st Century

Peter P. Egeghy, Linda Sheldon, Kristin Isaacs, Haluk Ozkaynak, Michael-Rock Goldsmith, John Wambaugh, Richard Judson, Timothy Buckley

***computational exposure science**: the integration of advances in chemistry, computer sciences, mathematics, statistics, and social and behavioral sciences with new and efficient models and data collection methods to more effectively predict and estimate real-world exposures to natural and anthropogenic chemicals in the environment.*

Computational Exposure: Integrating Disparate Data Streams and Models to Rapidly Predict Exposure to Chemicals

Models

Models predicting chemical function from chemical properties or structures

Models describing fate and transport of chemicals within a residence

Probabilistic human exposure models

Dosimetry/pharmacokinetic models

Datasets

Chemical molecular structures and chemical function

Chemical end-use including presence in consumer products

Population patterns of consumer product purchasing

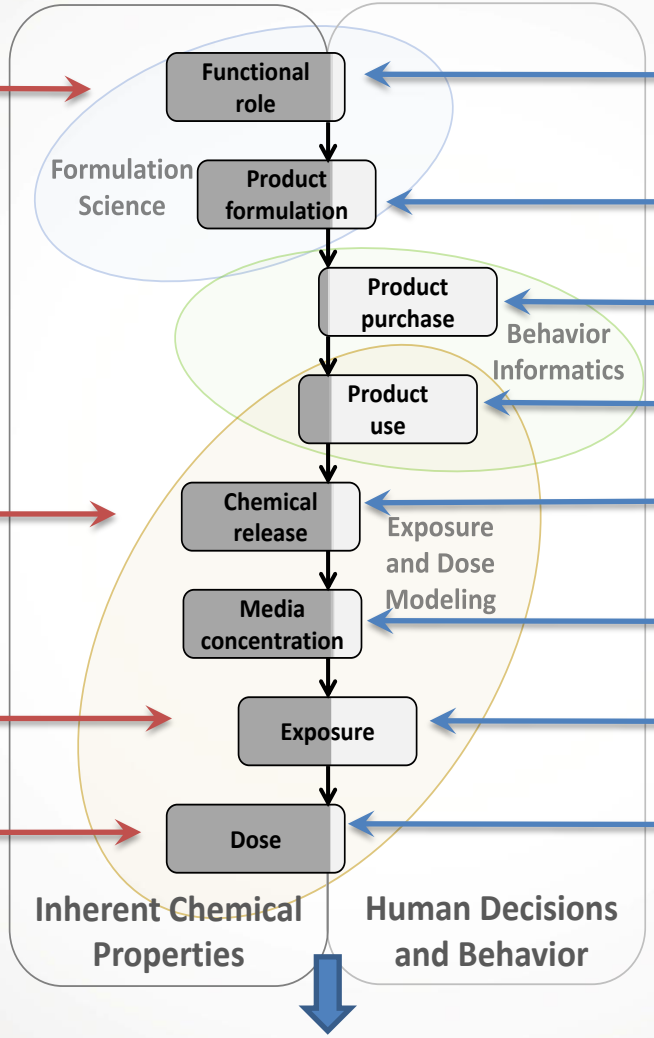
Patterns of consumer product use

Properties of homes and indoor environments

Chemicals measured in residential media

Human activity patterns and exposure factors

Human physiology and pharmacokinetic properties of chemicals



High-throughput Predictions of **Population-Level** Chemical Exposures and Internal Doses

Slides courtesy of K. Isaacs

Methods Development

Recreational Water Quality

National Epidemiologic and Environmental Assessment

Problem:

- Culture based methods to determine recreational water quality are limited
- Develop rapid methods to determine recreational water quality

Response:

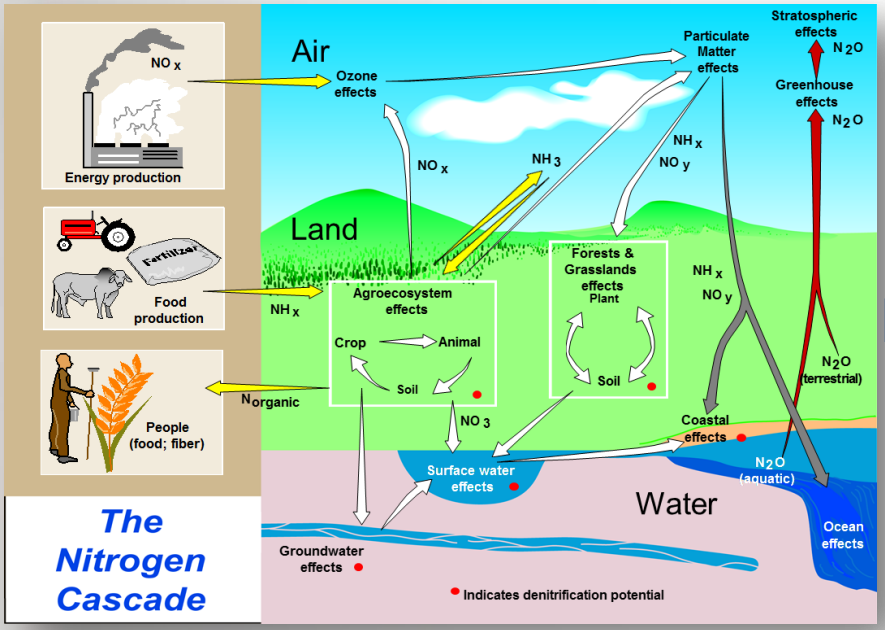
- Collaborative study between EPA (methods) and CDC
- Largest epidemiological study on recreational water exposures ever conducted; >30,000 beachgoers enrolled
- Developed an association between a rapid monitoring test (molecular method based on qPCR) for fecal contamination and swimming-associated gastroenteritis

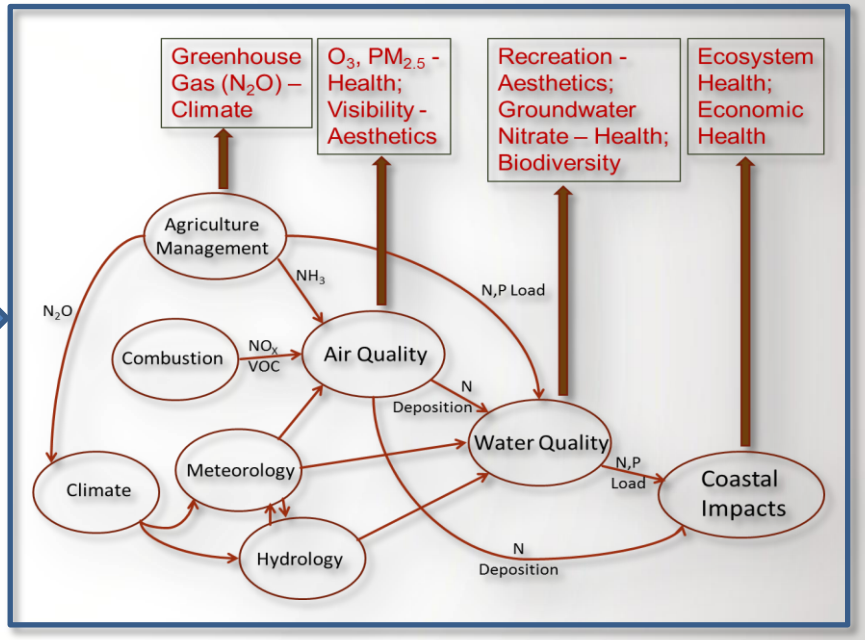
Impact:

- Showed a rapid, same day test could be used to predict health effects
- Showed children were at higher risk of gastroenteritis after exposures to fecal contamination in water
- Directly informed recent EPA revised water quality criteria for human health protection at beaches

Integrated Systems Modeling

A one-biosphere approach yields a holistic, process-based modeling structure for nitrogen and co-pollutants that facilitates the exploration of alternative pathways to environmental, societal and economic sustainability.





The introduction of stressors such as climate and land use changes can result in too little or too much nitrogen in this system, leading to unsustainable levels of economic growth, societal behaviors and environmental quality.

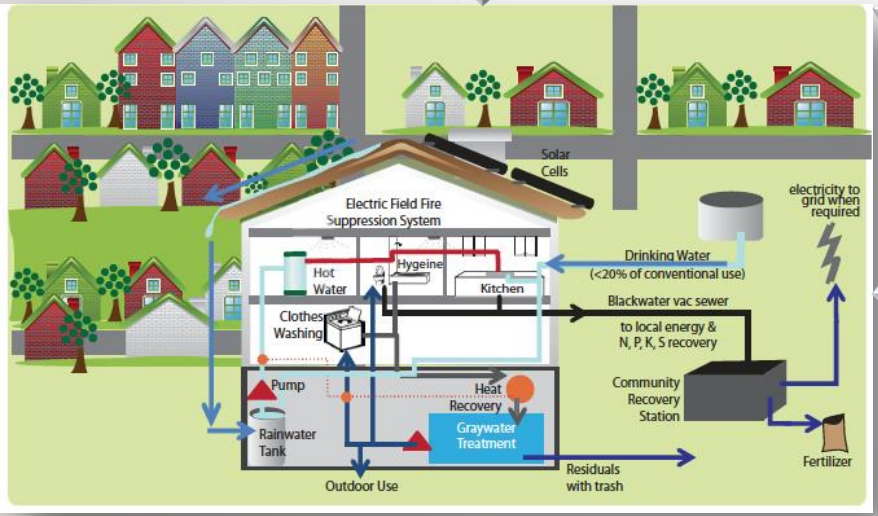
Innovations in Water Infrastructure Development and Assessment of Next Generation Water Systems

Integrated Sustainability Assessments

Life Cycle Impacts
(global warming, eutrophication, water footprint)
Life Cycle Costs
Quantitative Health Risks
Resiliency

Technology Development

Anaerobic Membrane Bioreactor
wastewater to energy
Engineered nanomaterials
nutrient recovery & reuse



Alternative Systems Based on Resource Recovery (water, energy, nutrient)

Innovative Approaches To Exposure Monitoring
(Focused on Water Reuse Applications)

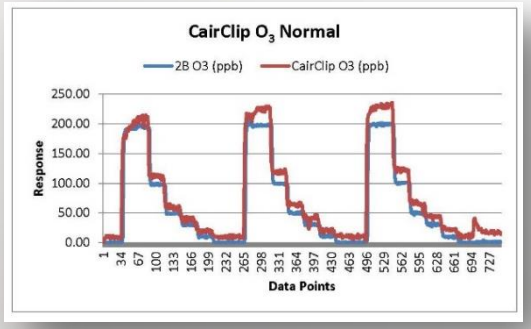
Computer Based On-Line Event Detection
CANARY Software
High throughput genomic sequencing
New indicators/targets for on-line sensors

Sensor Technology

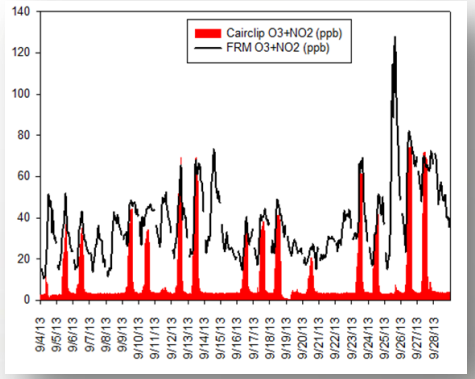
Catalyzing the Development and Use

- **Next generation Air Monitoring**
  - Many sensors being developed
  - Focus on data collection not reliability
  - Clear need for assessment and education
- **"Open house" for Air Sensor evaluations**
  - 15 sensors evaluated for ozone and NO2 monitoring
  - Range of quality – some nearly FRM quality
  - Brought sensor developers together with a wide variety of internal/external stakeholders
- **Sensor Evaluations**

In the Lab

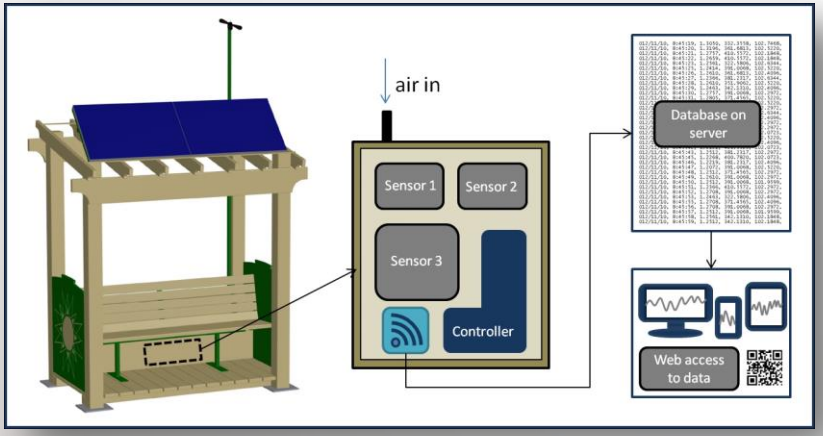


and in the Field



Sensor Technology Village Green Project

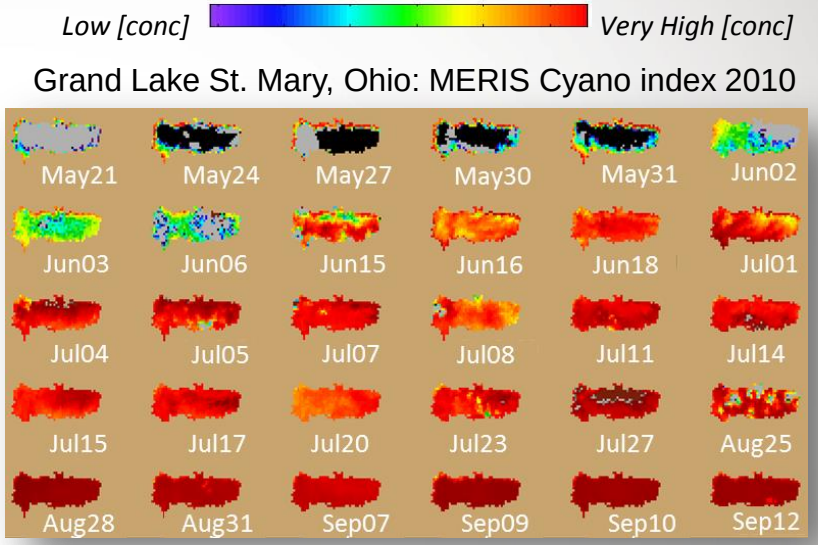
- EPA researchers are developing next-generation air pollution sensor systems to engage communities and the public on environmental issues and provide real-time data
- The system includes:
  - Self-powered air and meteorological samplers
  - Lower cost, real-time instruments - proven capability at ambient levels (wind, black carbon, $PM_{2.5}$, ozone)
  - Wireless data communication to publically-accessible website
- Designed to add value to and be secure in public environments

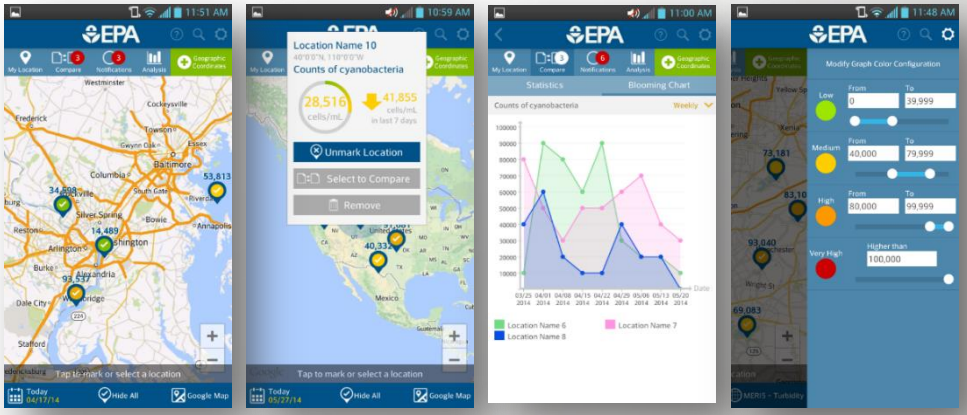


http://villagegreen.epa.gov

Mobile Applications
Cyanobacteria Assessment Network (CyAN)

- **Problem:** With all of our resources combined, we still cannot monitor every water body at all times.
- **Action:** Development of satellite remote sensing mobile application to monitor cyanobacteria.
- **Result:** The **Android Mobile Application** allows users to set thresholds and mark specific locations.
- **Impact:** Support monitoring under CWA & SDWA with sophisticated tool to decrease costs and reduce exposures.





Decision Support Tools
EnviroAtlas

EnviroAtlas is a web tool giving users ability to view, analyze, and download information to help inform decisions concerning the places in which we live, work, derive resources, and play

It includes:

- Geospatial indicators and indices of the supply, demand, and benefits
- Drivers of change
- Reference data (e.g., boundaries, land cover, soils, hydrography, impaired water bodies, wetlands, demographics, community design)
- Analytic, mapping, and interpretive tools

The EnviroAtlas is designed to provide information useful to decision making in the community

http://enviroatlas.epa.gov

Community Engagement

EPA Health Impact Assessment (HIA) of Green Infrastructure Project in Atlanta, GA

Impacts on:	Such as changes in:
Environment	Exposure to water-borne disease Exposure to air pollutants Exposure to vector-borne disease
Society	Opportunity for educational outreach Access to goods / services Safety and security
Economy	Property value Employment opportunity Costs of living

Summary

- Exposure Science provides context to inform many of the environmental decisions
- The New Exposure Science will provide tools to do this in a timely and cost effective way
- EPA is developing many internal and external partnerships to conduct this work
- I have only presented a small snapshot of the exciting new research at EPA that will make a difference