Low Cost Air Quality Monitoring Tools

Gordon Pierce

Four Corners Air Quality Group

September 13, 2017

COLORADO
Air Pollution Control Division
Department of Public Health & Environment

Traditional monitoring approach

- Permanent fixed sites
- Meet all US EPA requirements
  - Number of sites
  - Siting criteria
- Generally neighborhood scale or greater
- Extensive QA/QC and reporting requirements
- Data used for:
  - NAAQS designations
  - Forecasting/public reporting
  - Health studies
  - Model input/validation

Problems with traditional approach

- Does not necessarily address specific community or local concerns
  - Dust
  - Odors
  - Smoke
  - Visible emissions
  - Traffic
  - Perceived risk
- Not source-specific
- Not mobile/portable
- Lot of knowledge and QA

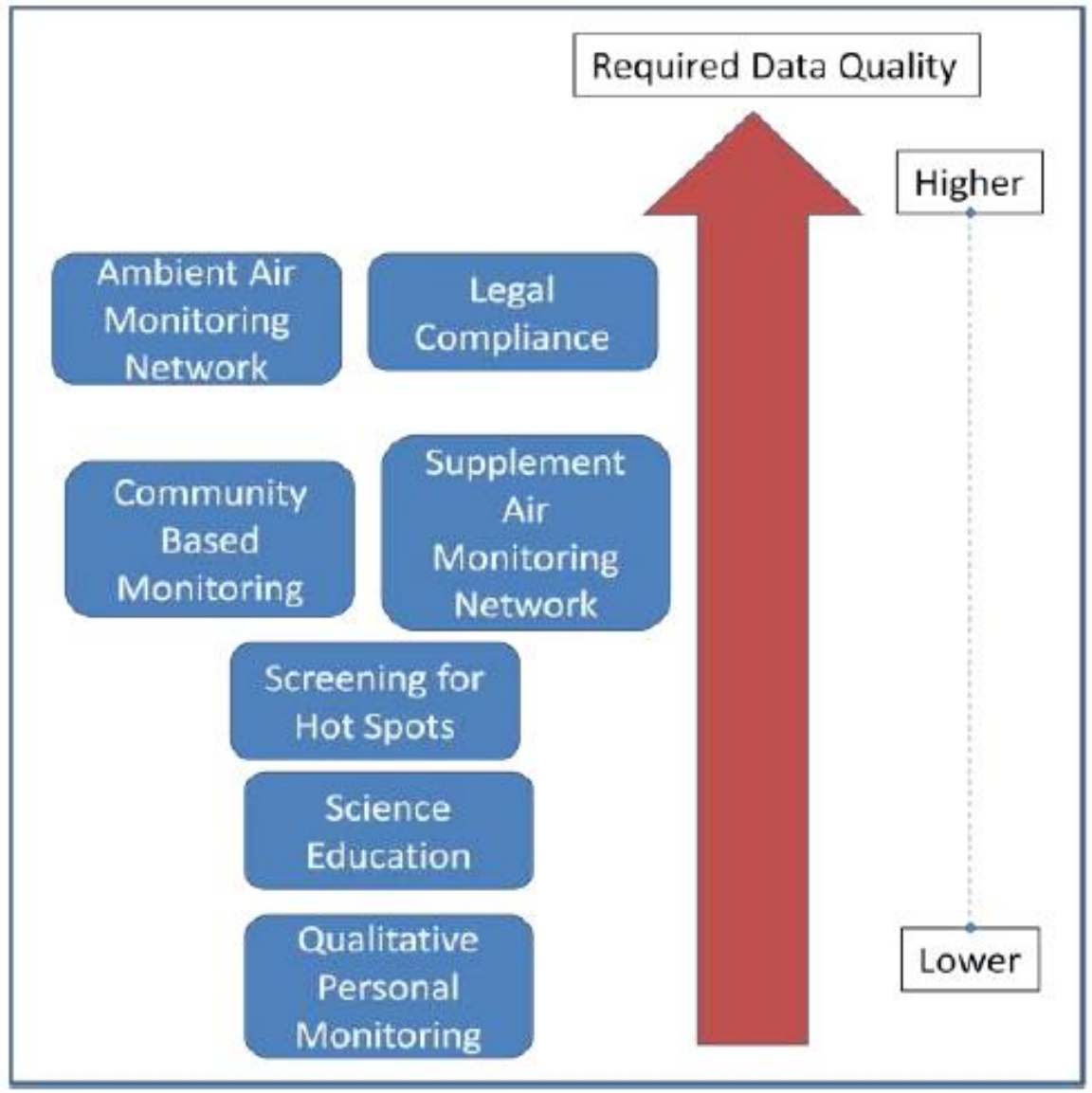
Desires for special studies and community monitoring

- Do not always need regulatory samplers
- Do not always need long-term permanent sites
- Need to focus on different objectives
- Need portable monitoring equipment
  - Cheaper
  - Smaller
  - Battery powered
- Easy for anyone to operate
- Easier data access
- Better communication with locals/citizens

Common goals between communities and regulators

- Identify sources
- Identify risks
- Engage the public
- Low cost monitoring equipment
- Accurate monitoring equipment
- Provide timely and relevant information
- Protect public health

Data Quality Requirements



U.S. EPA

"Next Generation" Sensors Overview

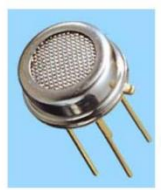
- Low cost = less than $2000, many less than $1000
- Small, easy to transport
- Easy to set up at a location
  - No line power needed
  - No phone line needed
- Unobtrusive
- Easy to use and obtain data
- Common applications:
  - Ozone
  - Carbon monoxide
  - Carbon dioxide
  - Nitrogen dioxide
  - Particulates
  - VOC

Particulate

- Most small sensors based on light scattering or particle counts
- Issues:
  - Airflow to sensor if no fan
  - Sensor sensitivity
  - Conversion from scattering or counts to concentration
- Examples of sensors/units:
  - Dylos
  - MicroAeth
  - PurpleAir
  - AirBeam
  - Shinyei
  - Thermo PDR

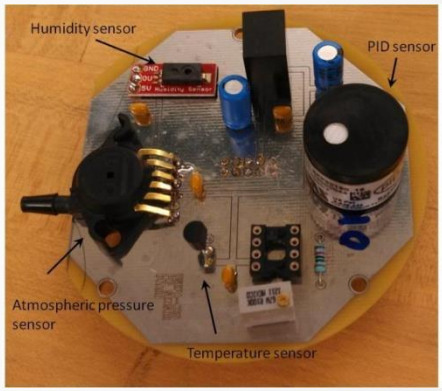
Gaseous

- Metal oxide or electrochemical sensors
- O_3, CO, NOx, SO_2
- Issues:
  - Short sensor lifespan (2-5 years)
  - Interferences of other gases
  - Temperature/humidity interferences
  - Linearity
- Examples of sensors/units
  - CairClip
  - Aeroqual
  - AQMesh
  - Air Quality Egg
  - PurpleAir
  - CitiSense
  - Aeroqual
  - M-Pod
  - Cairpol



VOC

- Photoionization or IR sensors
- Issues:
  - Baseline drift with some
  - Sensitivity
  - Sensor lifetime
  - Total VOC calibrated to one compound
- Examples of sensors/units:
  - S-Pod
  - MIPEX
- Laser spectrometry for methane near-ready



Problems/Concerns with Next-Generation Sensors

- Small, low-cost air monitors are becoming common and easy to obtain
- Anyone can monitor and post data to a website
- Unspecific monitoring objectives
  - Little or no interaction with air quality experts
  - Incorrect pollutants
  - Incorrect averaging times
- More focus on design, data display, networking, mobile/web apps, etc. and not on accuracy…though this is changing
- Quality of the data are unknown
  - Pollutants, detection limits, interferences, accuracy, QA, time scale
  - Sensor technology not fully ready
- Not always suitable for health risk assessments
- Data assimilation with traditional networks difficult
- Hard for agencies to address after data are out

Sensor concerns

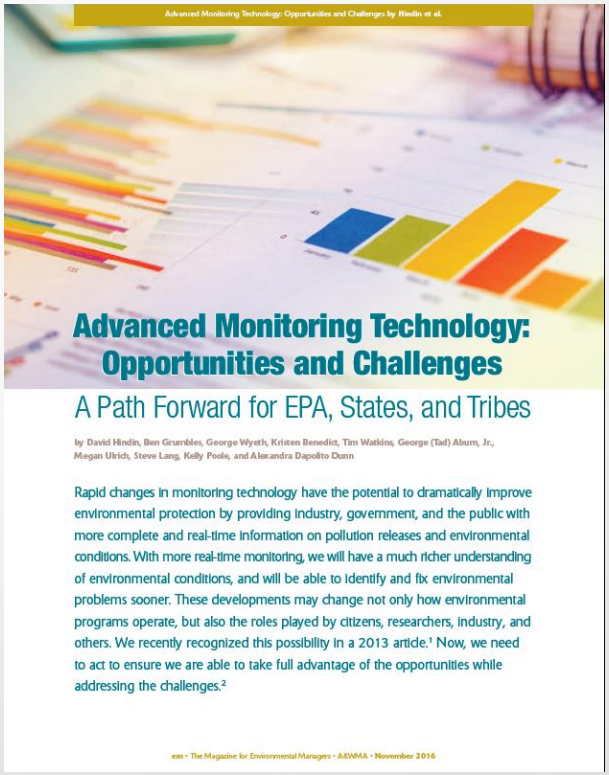
- Often no real evaluation of sensors
  - No field or chamber testing
  - No calibration
- False positives
  - Instrument error, interferences
  - Indoor or personal-scale source
  - Result: May result in unwarranted concerns and significant resources wasted to evaluate
- False negatives
  - Measuring the wrong pollutant
  - Poor sensitivity
  - Result: May result in a false sense of safety
- Spatial and temporal representativeness

Future

- Next-generation samplers are here
- They have great potential and a lot of uses
- Will likely become a key component of health care
- EPA/State/Locals/Communities need to work together
  - Better communication with manufacturers and communities
  - Outreach and education
  - Guidance for sensor developers/manufacturers
  - Testing/evaluation protocols
  - Manufacturer calibration
  - Clear guidance for communities/users
  - Better health-risk data are needed

Current work

- EPA guidance and sensor testing
- SCAQMD sensor testing lab
- E-Enterprise "Advanced Monitoring Strategy and Implementation"
- ARPA-E for methane leak detection

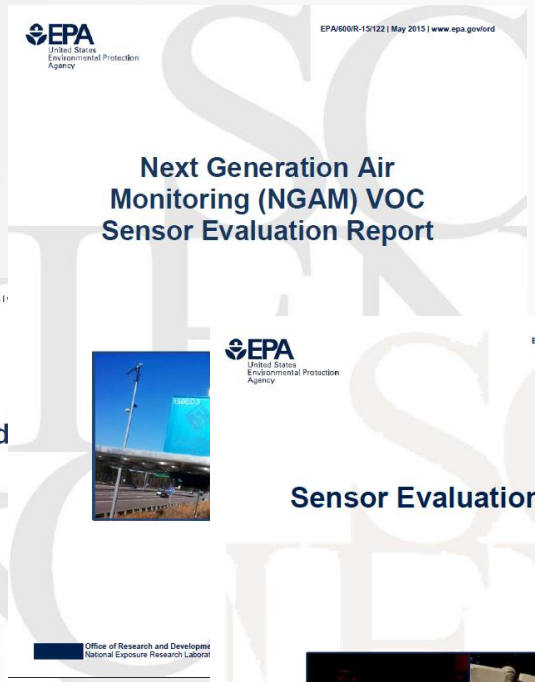


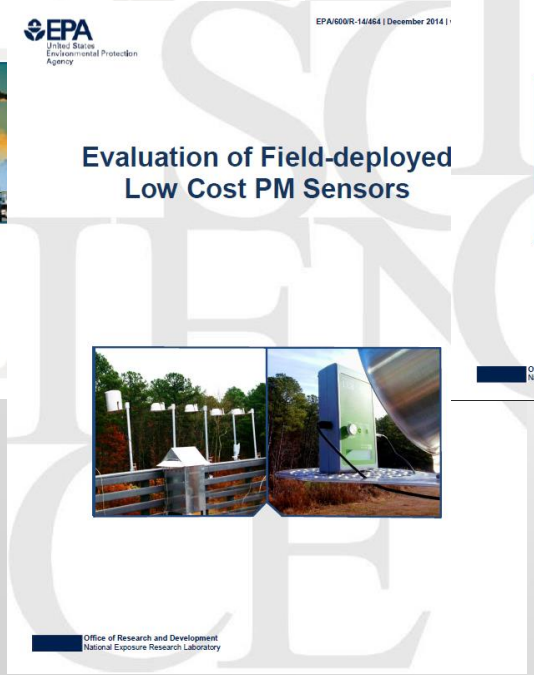
EPA Air Sensor Toolbox

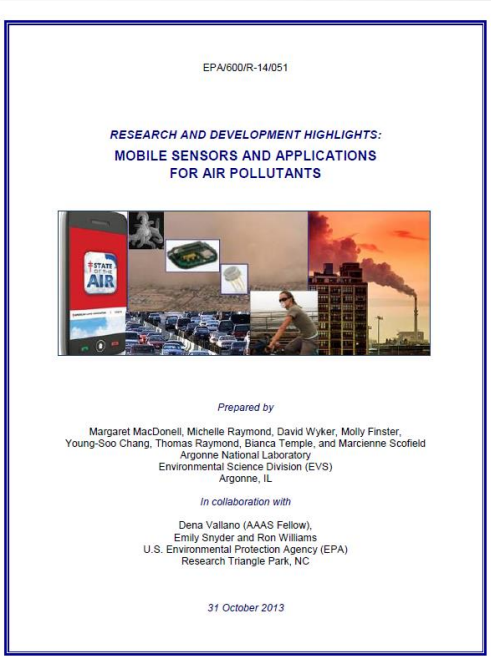
- Provides information for citizen scientists and others on how to select and use low-cost, portable air sensor technology and understand results from monitoring activities
- https://www.epa.gov/air-sensor-toolbox

EPA Guidance and Reports

- Available on Air Sensor Toolbox website

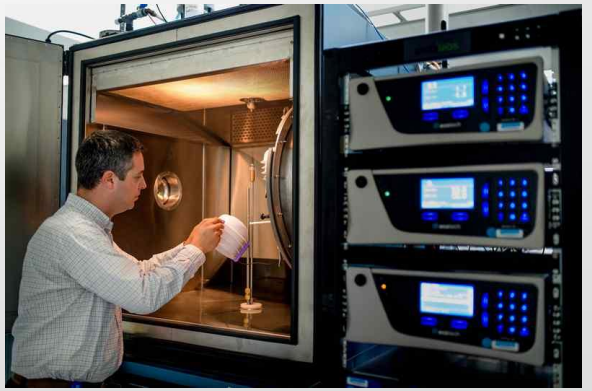






South Coast Air Quality Management District

- Air Quality Sensor Performance Evaluation Center (AQ-SPEC) program.
  - Evaluate the performance of commercially available "low-cost" air quality sensors in both field and laboratory settings
  - Provide guidance and clarity for ever-evolving sensor technology and data interpretation
  - Catalyze the successful evolution, development, and use of sensor technology
- Evaluation reports available at: http://www.aqmd.gov/aq-spec



E-Enterprise

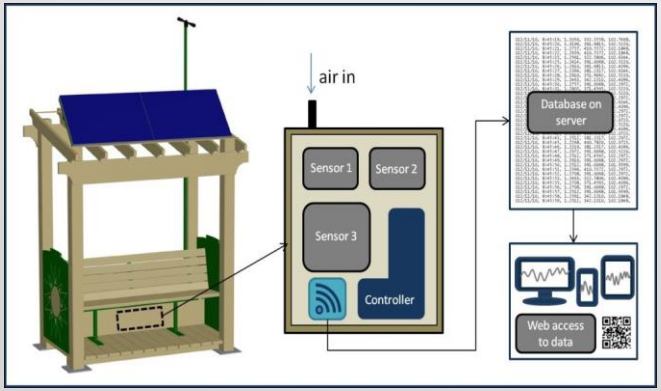
- Environmental Council of the States (ECOS)
  - Joint with EPA and States
- "Plan for Integrating Advanced Monitoring into our Environmental Programs"
- 5 projects recommended for continuation
  - Perform a detailed options and feasibility analysis on the creation of an independent third-party evaluation/certification program
  - Develop and start executing technology scanning and screening procedures
  - Develop messaging and tools to support the interpretation of monitoring results
  - Develop data use types (tiers) and data standards
  - Lean the current technology approval process
- https://www.epa.gov/e-enterprise

ARPA-E

- DOE Advanced Research Projects Agency – Energy
- "MONITOR"
  - Methane Observation Networks with Innovative Technology to Obtain Reductions
- developing innovative technologies to cost-effectively and accurately locate and measure methane emissions/ leaks associated with natural gas production
- Fixed or mobile applications
- Goal: <$3000/site/year and detect methane at <6 SCFH
- https://arpa-e.energy.gov

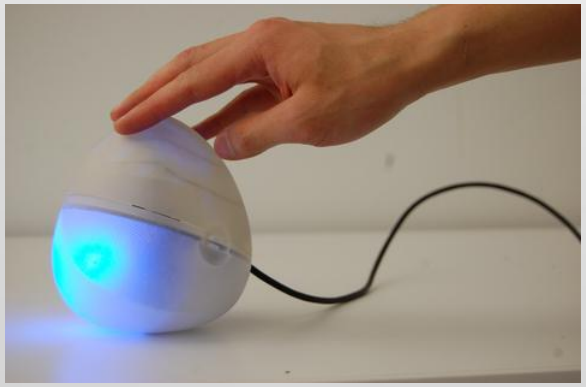
Example: EPA Village Green Project

- Solar-powered air-monitoring system designed and incorporated into a park bench
- EPA began testing the system in the summer of 2013
- 8 sites now active
- Measures O3, NOx, particulates, meteorology
- Air pollution and weather data are automatically sent to the Village Green Project website
- http://villagegreen.epa.gov



Example: Air Quality Egg

- Egg-shaped base station receives the wirelessly transmitted data from the sensor box outside
- Relays that data to the Internet via a wired Ethernet connection
- On-line map
- CO, NO2, O3, SO2 and PM sensors
- Purchase 2nd generation for $185
- www.airqualityegg.com



Example: M-Pod

- Developed by University of Colorado
- O3, NO2, CO, CO2, VOC, temperature, RH
- Data uploaded to mobile device and web
- Costs $300

Example: Dylos

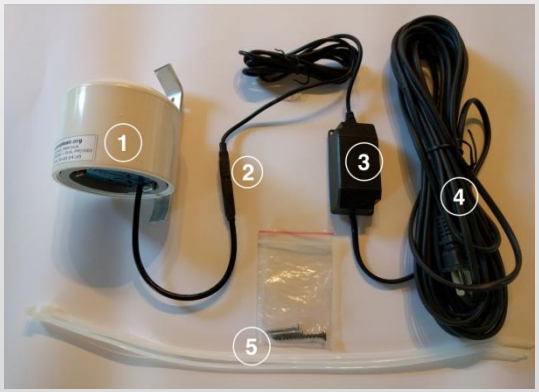
- Laser Particle Counter with 2 size ranges
- Store up to 30 days of air quality history
- Costs $260 – $425 (depending on model)
- www.dylosproducts.com

Example: CitiSense

- Data wirelessly transmitted to the user's smartphone
- Displayed on the smartphone via a custom app
- Display also utilizes the EPA's color code scale
- O_3, CO, NO_2

Example: PurpleAir

- Built in WiFi for logging to "the cloud"
- Real-time map display and historical data
- Dual laser counters for better particulate readings
  - PM1, PM2.5, PM10
- BME280 temperature, humidity and pressure sensor
- Costs $230
- www.purpleair.com



Four Corners small sensor projects

- Town of Mancos
  - Dylos DC-1700 particulate monitor
  - Monitoring of emissions from Western Excelsior wood products facility
  - Co-location sampler from EPA
- Navajo Nation
  - "Heating and Indoor Air Quality on the Navajo Nation"
  - U-Pod samplers from University of Colorado
  - Improve low-cost and quiet gas measurement techniques for indoor air quality monitoring applications
  - Inform air quality in homes using different fuels for home heating on the Navajo Nation

Questions?