A Review of Emerging Sensor Technologies for Facilitating Long-Term Ground Water Monitoring of Volatile Organic Compounds

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Accelerating Site Closeout, Improving Performance, and Reducing Costs through Optimization
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This presentation is based on the following EPA report:


EPA 542-R-03-007

Prepared by GeoTrans for EPA OSRTI

Information gathered by:
- Interviewing environmental consultants
- Reviewing publicly available literature
- Interviewing research and/or commercial teams of each technology

*Downloaded the report from www.cluin.org*
Presentation Topics

- Current long-term ground water monitoring practices
- Requirements for an effective sensor-based instrument for long-term monitoring of ground water quality
- Emerging sensor-based technologies
  - In-situ sampling and analysis
  - Commercialized technologies for automated sampling with above-ground analysis
  - Hand-held or otherwise portable analytical units
- Considerations for implementing these technologies
- Conclusions
Current Practices

- **Field work**
  - Measure water elevation in the well
  - Sample
    - Three-well purge
    - Low-flow sampling
    - Passive diffusion bags
  - Prepare and ship samples (including QA samples)
  - Decontaminate equipment

- **Analytical work**
  - Independent laboratory
  - Standard methods (e.g., 8260b, 8021b, etc.) with backup
  - Standard turnaround times ranging from 2-3 weeks
  - Provide data in electronic format
Current Practices

- **Approximate sampling cost (assume 20 monitoring wells)**
  - Three-well purge or low-flow sampling
    - $3,000 to $8,000 per event
  - Passive diffusion bags
    - $2,000 to $3,000 per event

- **Approximate analytical cost (assume 20 monitoring wells)**
  - $2,500 per event (including analysis of QA samples)

- **Sensor technologies would attempt to**
  - Reduce labor and costs
  - Provide real-time data
  - Reduce errors associated with collecting and transporting samples
Requirements for an Effective Sensor-Based Instrument

- An effective sensor-based instrument would...
  - Have the necessary detection limit
  - Be accurate and precise
  - Revert to a common baseline for each sample
  - Provide results in a reasonable time frame
  - Withstand field conditions
  - Require little maintenance
  - Be easy to use and calibrate
  - Distinguish one VOC from another
  - Be cost-effective
  - Be acceptable to regulators and other stakeholders
Emerging Technologies

**In-situ sampling and analysis**
- Most sensors in this category are in the research and development phase with operational and testable prototypes
- Most are designed to analyze for one constituent or one family of constituents
- Some sensors conduct analysis in the vapor phase, rely on VOCs to partitioning according to Henry’s Law
  - Chemiresistors
  - Quartz crystal microbalance
  - High resolution ion mobility spectrometry (IMS)
- Other sensors make the measurement directly in the aqueous phase
  - Resonance Enhanced Multiphoton Ionization (REMPI)
  - Wave-guides
  - Mid-infrared fiberoptic sensors
Emerging Technologies

- Commercialized automated sampling with above-ground analysis
  - VOC Monitor (Waste Technologies of Australia)
    - Measures total VOCs
    - Detection range of 100 µg/L to 20,000 µg/L
    - Approximately $4,000 per well (assumes one system for 4 wells)
    - Improvements in detection range, selectivity, and cost reduction underway
    - [www.wastetechnologies.com](http://www.wastetechnologies.com)

  - Burge Environmental Sampling System and TCE Optrode
    - Measures TCE or chloroform (other constituents under development)
    - Detection range (1 µg/L for TCE)
    - Calibration, QA sampling, etc. is automated
    - Approximately $5,000 per well (assumes one system for 6 wells)
    - [www.burgenv.com](http://www.burgenv.com)
Emerging Technologies

- Hand-held analytical technologies
  - μChemlab™ – miniaturized GC and surface acoustic wave (SAW) sensor
    - Similar in size to a personal digital assistant (PDA)
    - Separate unit required for analyzing aqueous samples
    - Sample time is approximately 2 minutes
    - Detects multiple constituents in a single sample (DL is < 5 ug/L for TCE)
    - In prototype stage, has commercialization partner
    - Cost might be under $5,000

- Hand-held GC – miniaturized GC and a glow-discharge detector (GDD)
  - Similar in size to a brick
  - Accepts gas and liquid samples
  - Detects multiple constituents in a single sample (DL is < 5 ug/L for TCE)
  - Commercialized
  - Cost might be under $30,000
  - [www.handheldgc.com](http://www.handheldgc.com)
Emerging Technologies

- Field portable analytical equipment
  - Five technologies evaluated by the EPA ETV Program in 1997 for ability to detect chlorinated VOCs in ground water
    - Electronic Sensor Technology (ESTCAL) – EPA 600-R-98-141
    - Inficon, Inc. HAPSITE – EPA 600-R-98-142
    - Innova Air Tech Multi-Gas Monitor – EPA 600-R-98-143
    - Perkin-Elmer Voyager Photovac Monitoring Instrument – EPA 600-R-98-144
    - Sentex Systems Scentograph Plus II – EPA 600-R-98-145
  - Two instruments provided comparable results to an off-site laboratory. Instruments could be used for investigations and routine monitoring.
    - HAPSITE – cost of $76,000, requires a chemist with experience and 3 days of training
    - Scentograph Plus II – cost of $28,000, requires a technician with 1 day of training
Considerations

- **Demonstrating reliability**
  - Sensor reliability
  - Instrument reliability

- **Site-specific conditions**
  - Sensitivity
  - Addressing multiple contaminants
  - Other constituents of ground water (bacteria, turbidity, metals, pH, etc.)
  - Well construction and yield

- **Regulatory approval**
  - Sampling well water vs. sampling aquifer water
  - Precision and accuracy
  - QA/QC measures (calibration, blanks, etc.)
Considerations

- **Cost-effectiveness**
  - Consider the following scenario
    - Site with 20 monitoring wells with quarterly sampling
    - One type of sensor could replace traditional sampling
    - Sensor lasts for 5 years before needing replacement
    - Significant travel is not required
  
  - Consider the following sensor options
    - Option 1 – one sensor for each well
    - Option 2 – two technicians, each with a probe, sample wells at a rate of one well per hour
    - Option 3 – Automated sampling with above-ground analysis
    - Option 4 – Traditional sampling, but using hand-held or field portable instruments for analysis
## Considerations

### Summary of Cost-Effectiveness

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Sensor costs also include estimated cost for basic maintenance.
Conclusions

- Permanently installing a sensor-based instrument in each well
  - Might not be cost-effective
  - Would make calibration and maintenance difficult

- Other presented options
  - Might be cost-effective
  - Would make calibration and maintenance easier

- Cost-effectiveness increases with required sampling frequency.

- There are potential linkages between some of the automated sampling technologies and some of the hand-held analytical technologies.
Question and Answer Session
Emerging Technologies

- Chemiresistors
  - Clifford Ho (www.sandia.gov/sensor)
- Quartz crystal microbalance
  - Joel Roark (www.nomadics.com), Joseph Salvo (www.crd.ge.com)
- High resolution ion mobility spectrometry (IMS)
  - Joe Hartman (http://coen.boisestate.edu/sensor/sensorweb.html)
- Resonance Enhanced Multiphoton Ionization (REMPI)
  - University of South Carolina
- Wave-guides
  - Georgia Institute of Technology
  - New Jersey Institute of Technology
- Mid-infrared fiberoptic sensors
  - Boris Mizaikoff (http://asl.chemistry.gatech.edu)