2003 EPA Science Forum
Partnering to Protect Human Health and the Environment

Toxicity-Based Chemical Agent Detection Systems

Homeland Security

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ABSTRACT

Environmental Issues:

This project will develop and characterize chemical agent detection systems that will provide broad toxicological screening information to first responders and building decontamination personnel. The primary goal for this technology is to detect the presence of airborne chemical agents that will damage metabolic or neurological function. The anticipated applications with respect to building decontamination will be to:

Provide a record of chemical toxins that have been present in the air over a specified time period; and

Provide a short term screening system to determine the current toxicological status of the local building environment.

One of the unique features of this technology is that the proposed techniques will be used to characterize a broad range of compounds and agent simulants that are toxic but not expected to be detected by currently available chemical sensor technologies. The proposed sampling technology will also provide a chemical exposure record for numerous locations throughout the building.

The ability to detect toxic chemicals on the basis of their potential biological / biochemical function is expected to provide the basis for a rapid response chemical hazard detection system.

Scientific Approach:

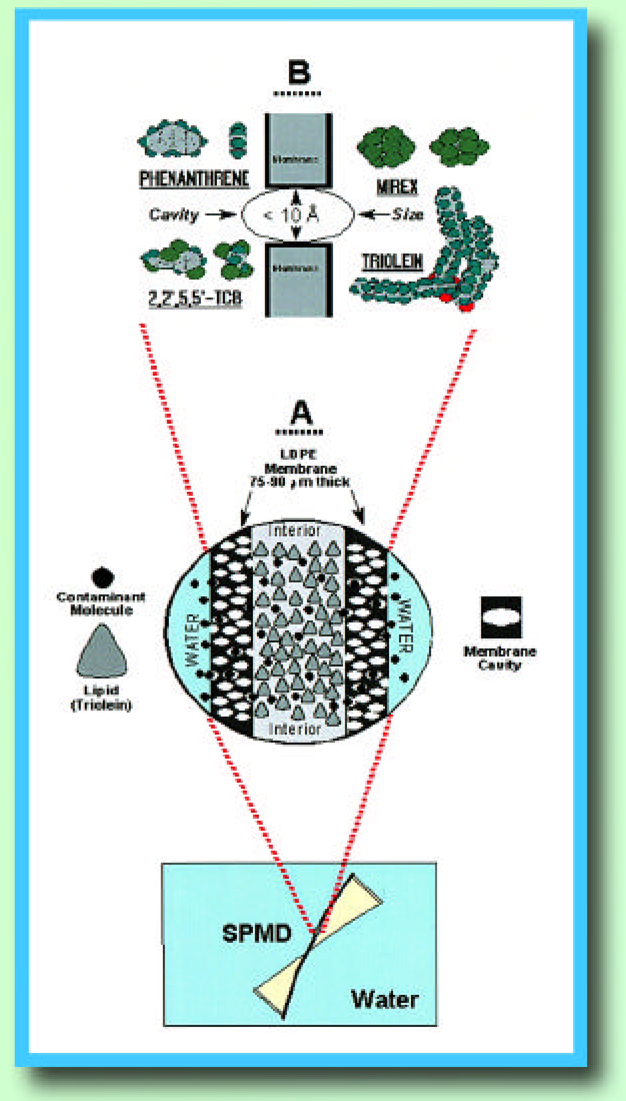
Continuous and time-integrated sampling of indoor air will be accomplished using Semi-Permeable Membrane Devices (SPMD) consisting of polyethylene tubing containing a thin film of high molecular weight oil. The accumulation of semivolatile organics through the pores and into the organic phase is similar to transport of organic vapors through biomembranes during respiration. SPMD sampling devices will be interfaced to two types of biochemical detection systems that include:

Enzyme systems for detection of organophosphate insecticides and the "nerve agent" class of chemical warfare agents;

Toxicity systems based on luminescent bacteria for the detection of metabolic inhibitors and membrane disrupting toxins.

Previous studies have demonstrated the efficacy of SPMDs for sampling organic vapors in residential settings. In addition, enzyme and microbial systems have been used for detection of toxic compounds associated with waste water operations. The feasibility of interfacing these systems together to measure toxic vapors has not been previously established and will be the primary goal for this project. Studies will also be conducted to compare the proposed toxicity screening system to an Ion Mobility Spectroscopy (IMS)-based technology.

Time-Integrated Detection of Toxic Vapors in Indoor Air Using Semi-Permeable Membrane Devices (SPMD)



Diagrammatic representation of semi-permeable membrane device illustrating the diffusion and trapping of toxic organic vapors into the interior of the sampling device.

Toxic chemical agents are accumulated into one of several substances which will include:

- High molecular weight oil (current SPMD)
- Activated carbon (for toxic vapors)
- Immobilized enzyme
  (cholinesterase for detection of nerve agents)

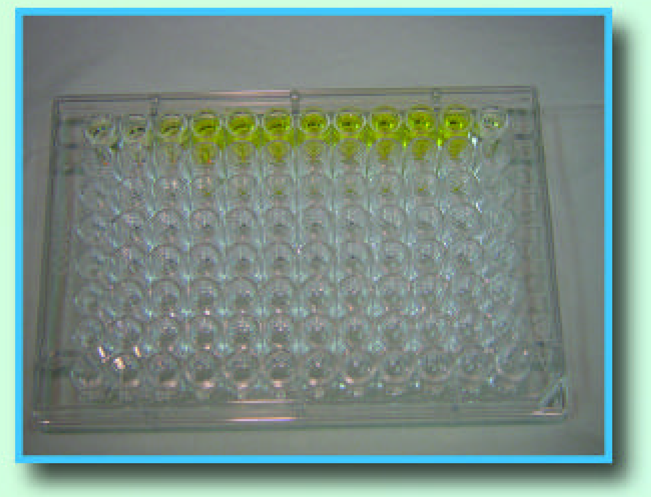
The SPMDs are calibrated using an environmental exposure chamber. Vapors of various compounds are generated for specific durations at specific concentrations.

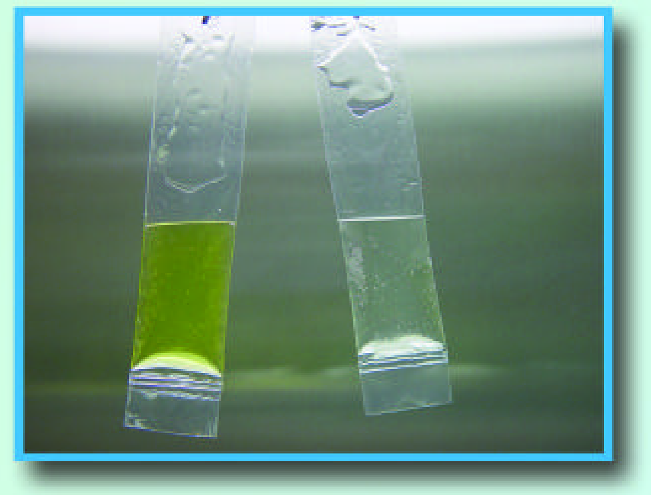
Two types of biochemical detection systems (Enzyme and Bacterial Toxicity) will be interfaced with SPMDs.

Cholinesterase enzyme activity will be used to detect the "nerve agent" classes of Toxic Industrial Chemicals (TICs) such as Organophosphate Insecticides and surrogates of Chemical Warfare Agents (CWAs).

The enzyme Acetylcholinesterase is highly sensitive to chemical neurotoxins. For this assay, the absence of chemical agent results in the enzyme catalyzed formation of a colored product. However, in the presence of neurotoxin, the enzyme is inhibited resulting in no color formation.

This assay can be formatted for 96 well plates for high throughput instrumental screening or for use with SPMDs for visual determination.

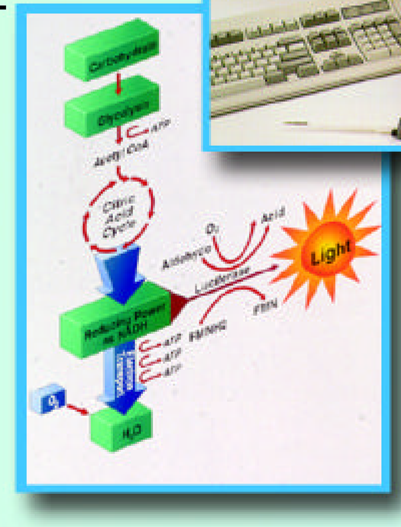




Luminescent bacteria will be used to detect metabolic inhibitors and membrane disrupting toxins.

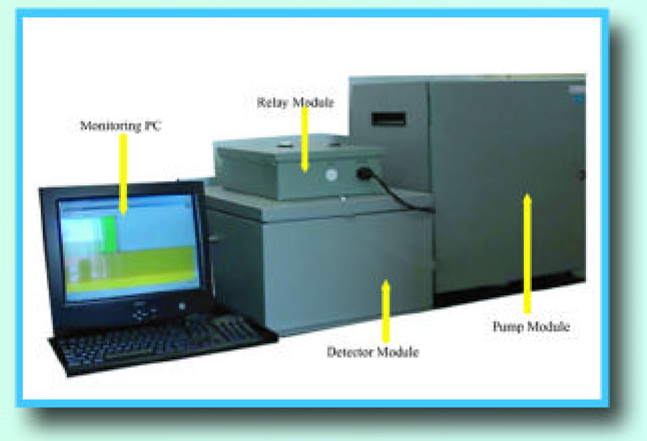
Although this technology has been widely used for waste water applications, it has not been well characterized for toxic vapors of CWAs and TICs.

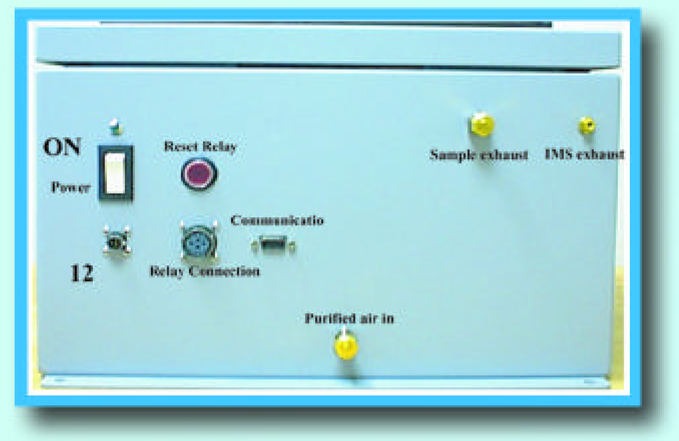
SPMDs will be interfaced to the Microtox® System. Bacterial bioluminescence is expected to be a sensitive indicator of toxic vapors.



Comparative studies will also be conducted using commercially available Ion Mobility Spectroscopy (IMS) instrumentation.

The Centurion® IMS unit draws air samples through the Pump Module and into the Detector Module. The instrument is calibrated to detect 12 CWAs and 12 specific TICs.





Expected Impact:

This project will demonstrate the use of toxicity-based technologies for monitoring of a wide range of toxic agents in indoor air. In addition, currently available IMS technology will be characterized for detection of specific TICs. This project is expected to provide toxicity-based air monitoring technology for potential building cleanup applications.

This work is being conducted under the EPA Safe Buildings Program.

Acknowledgments

The following individual is acknowledged for his participation in this project.

Dr. Jim Petty
U.S. Geological Survey
Columbia Environmental Research Center
Columbia, MO

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