

μChemLab™/CB Handheld Detector

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Objectives:

The objective of this project is to develop and demonstrate hand-portable, low-power devices that can detect a broad range of chemical and biological agents rapidly and sensitively with low false alarm rates. Two approaches are being pursued that target a wide chem-bio threat space. The “liquid-phase” device employs capillary electrophoresis/laser-induced fluorescence (CE/LIF) techniques to detect biotoxins and viruses. The “gas-phase” device detects chemical warfare agents (CWA) and toxic industrial chemicals (TICs) through a combination of preconcentration, gas chromatography and surface acoustic wave (SAW) array detection. μChemLab™/CB systems are envisioned as field units for first responders and/or for facilities monitoring.

Recent Progress: Liquid Phase

Work this year has focused on: (1) extending detection capability to viruses based on protein signature analysis, and (2) integrating and optimizing preconcentration for improved device sensitivity. Additionally, we are developing new methods for integrating fluorescent tagging with protein analysis.

Viral signature development. A key objective for this year is to develop microseparation methods for the analysis of viral proteins which produce a unique protein signature for that organism. We tested capillary gel electrophoresis (CGE) against a family of T-even bacteriophages and found that this method alone could differentiate between closely-related T2, T4 and T6 phages. Engineering improvements to the high voltage control board and optimization of the sample prep procedure enabled highly reproducible migration times ($\leq 0.5\%$ RSD) and molecular weight assignment to within ~2 kDa. A laboratory field trial designed to generate protein signatures for pathogenic viruses is planned for this spring/summer. The results of the field trial and other viral methods development will feed into the design of a combined biotoxin/virus research prototype scheduled for demonstration in FY04.

Integration of preconcentration capability. Last year we evaluated two preconcentrator technologies for possible inclusion in μChemLab: porous polymer monolith solid-phase extraction and a microfabricated filter design. Based primarily on the readiness of the technology for implementation in μChemLab, we chose to further develop the microfabricated filter design originally developed by ORNL. This design has been adapted for μChemLab and shown to give up to 100-fold preconcentration in one

minute; however, the chip-to-chip variability was high and preconcentration levels were somewhat unpredictable. Improvement in chip design to precisely tailor filter thickness has led to significant improvement in performance. Preconcentration has been demonstrated for both CGE and capillary zone electrophoresis (CZE) methods, although new CZE methods development was necessary.

Recent Progress: Gas Phase

There were two major thrusts this year: (1) completing and deploying a continuous CWA gas phase analyzer and (2) developing a _ChemLab analyzer with a toxic industrial chemical (TIC) detection channel.

Analyzer for the PROACT Test Bed. Tests were completed in the San Francisco International Airport terminal and the findings summarized in a final report. Over seventy thousand continuous tests were performed with no false alarms while remote self-test protocols worked as designed. A post-mortem of the analyzer revealed two areas for improvement in the hardware. Appropriate modifications were made to the prototype and the new hardware was continuously tested with over 2500 self-test runs before installation in the Boston test bed in April 2003. Improvements in the deposition chemistry of the GC stationary phase has enabled self-tests to now require significantly smaller sample aliquots and use a lower temperature separation, resulting in significant reduction in peak tailing and improved hardware reliability. A second analyzer is being built to acquire simultaneous data from two locations in the Boston Subway.

Analysis of Toxic Industrial Chemicals. This year, we are continuing methods development for TIC detection. For volatile toxic industrial chemicals (VTICs), we have tested SAW sensitivity and improved separation using different gas chromatographic phases. We determined the porous polymer adsorbent Hayesep A provides the highest capture efficiency and the cleanest desorption profile for GC injection of VTICs. We have also tested chromatographic separations and SAW sensitivity for several semivolatile toxic industrial chemicals (SVTICs). Using newly developed primer chemistries, we can employ new polar stationary phases that were not compatible with the previous deposition technique. The new deposition technique produces fewer active sites on the column and has enabled lower temperature separations of SVTICs.

Future Outlook:

Results from the viral signature method development and field testing will feed into the design and development of a combined biotoxin/virus research prototype to be demonstrated in FY04. Results of the on-chip labeling experiments will be used to demonstrate integrated fluorescent labeling, providing fully automated sample prep capability for biotoxins. Integration of viral solubilization will enable fully automated sample prep for viruses.

In order to complete design and build a gas-phase unit for detecting TICs, we will test the two channel prototype to establish effective detection limits and linear dynamic range. In FY04 we will develop hardware for a nitrogen phosphorous detector, designed to advance TIC detection using element selective detection. In addition, we will continue to support subway field emplacement of specialized continuously operated gas-phase prototypes by including hardware and software improvements, provide operational assistance and evaluate continuous monitoring data.

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