Enabling field spectroscopies

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ABSTRACT

Environmental measurements are significantly enhanced by a complement of field-worthy spectroscopic instrumentation. These improvements can result in rapid turn around time, more representative sampling of larger areas, and lower overall costs. The qualities that make instrumentation field-worthy include real-time analysis, ruggedness, size/portability, analyte selectivity or specificity, detectability and, of course, sufficient accuracy and precision. The Characterization, Monitoring & Sensor Technology Crosscutting Program (CMST-CP) within the U.S. Department of Energy Environmental Management (DOE-EM) supports a wide range of spectroscopic applications directly related to accelerating their cleanup efforts. Examples include tunable near infrared diode laser, laser-induced breakdown, imaging, beta, and mass spectroscopic technologies. Awareness of new technologies is crucial. An overview of these technologies will be presented.

Keywords: atomic spectroscopy, molecular spectroscopy, environmental analysis

1. FIELD SPECTROSCOPIES

Spectroscopies play an important role in environmental measurements. The Office of Environmental Management is responsible for the DOE environmental remediation efforts. The Office of Science and Technology (OST) has been tasked to advance new or improved technologies to accelerate the cleanup effort, particularly where technology gaps arise. The measurement needs encompass a wide range of analytes and matrices in various problem areas - groundwater and soil, high-level waste tanks, mixed waste, spent nuclear fuel, and deactivation and decommissioning. The sampling and analyses in these areas often present great challenges for expeditious remediation efforts under the DOE's Environmental Restoration, Waste Management, and Nuclear Material and Facility Stabilization Offices. The activities often require measurements to survey, characterize, monitor the remediation process, verify cleanup and/or provide post-closure monitoring. Spectroscopies that avoid matrix interferences and sample pretreatment requirements, provide rapid, real-time, multi-analyte, precise and accurate determinations, and are rugged and small enough to be used in the field are available for applications. The CMST-CP aids DOE-EM in bringing these new technologies to the field.

Summary statements for some of the new technologies included in the poster presentation are given here. More detailed information can be found in the CMST-CP Technology Summary available on the CMST-CP world wide web site (<http://www.cmst.org>).

- 1) *Laser-induced fluorescence remote sensing* complements existing passive techniques. Fluorescence from plants has been shown to be altered by stresses such as metal contamination. No comparable technologies exist for surveying large areas for minor to moderately severe subsurface contamination. The technology can provide earlier warning of contamination, reduce the required clean-up footprint, and provide measurements in hazardous or not easily accessible areas.
- 2) *Raman spectroscopic cone penetrometer probe* allows direct determination of Dense Nonaqueous Phase Liquids above and below the water table. Characterization measurements made *in situ* provide information for modeling and remediation efforts.
- 3) *Raman sensor for in-tank corrosion monitoring* allows the chemistry in many high-level waste tanks to be maintained to minimize corrosion. The technology provides intrinsically safe measurements in an extremely harsh environment!
- 4) *On-line nuclear magnetic resonance process monitor* of inlet and outlet streams provides a non-contact, non-destructive, quantitative measurement for ^{99}Tc for real-time monitoring of ion exchange or adsorption column breakthrough. The measurement system is immune to highly radioactive backgrounds and harsh operating conditions.

- 5) *Acousto-optic tuneable filter echelle-grating spectrometer* provides detection capability for high optical resolution measurements of isotopes of actinide elements (U, Pu) and RCRA metals (e.g., As in the presence of Cd) in real matrices. One application combines this small spectrometer (with resolution comparable to a 1 to 1.5 m spectrometer) with an air-inductively coupled plasma for continuous emissions monitoring (CEM) in stack gases for the six toxic EPA-regulated metals (As, Be, Cd, Cr, Hg, Pb).
- 6) *Laser-induced breakdown CEM* provides an in-situ measurement of the EPA-monitored RCRA metals in stack gas emissions. This technology can also give information on particle size and elemental associations in particles.
- 7) *Laser induced fluorescence imaging* is useful as a survey tool for uranium contamination in facilities for deactivation and decommissioning efforts. The real-time analysis permits timely decisions to be made at the survey sites.
- 8) *K-edge, x-ray spectroscopy* provides an *in situ* quantitative measurement of materials contained within pipes, ducts, and equipment. The technique detects heavy metals such as U, Pu, and Hg. It does not require correction for matrix effects. Little prior knowledge of sample composition or geometry is required.
- 9) *Infrared emission on-line process monitoring* optimizes waste processing technologies in addition to increasing the speed. The number of verification analyses required and the need to reprocess materials can be reduced. Spontaneous thermal emission has been developed for real-time concentration measurements of metal oxides in the molten glass stream associated with waste processing for vitrification in an americium-curium stabilization project. Transient infrared spectroscopy was used for optimizing the waste content for polyethylene microencapsulation.
- 10) *Tunable diode laser near infrared spectroscopy* provides the required high-resolution absorption measurements for monitoring ammonia concentrations in processing wastes for vitrification. These measurements are critical not only for process optimization, but also for safety!
- 11) A portable, real-time, *direct-sampling ion-trap mass spectrometer* detects hazardous organic compounds at extremely low concentrations. This device reduces sample-processing time.
- 12) *Beta Scintillation sensor* (BetaScint™) provides accurate measurements of radioactivity in soils contaminated with strontium-90 or uranium-238 in about 20 minutes. This greatly expedites environmental remediation decision-making.

The above technologies encompass a wide range of spectroscopies. All are needed in environmental cleanup efforts. The common threads in all the technologies is that they can be taken to the field and provide high quality measurements. Whether they incorporate novel approaches to sampling, analyte source, excitation, emission, and/or data analysis, they are all rugged, portable instruments that when applied to a specific application form a technology useful for environmental measurements. The important communication here is awareness. Like a good analytical chemistry laboratory manager, the environmental field manager must be aware of the availability and performance capabilities of these techniques.

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3. REFERENCES

1. "Characterization, Monitoring, and Sensor Technology Crosscutting Program: Technology Summary," Office of Science and Technology, Office of Environmental Management, U.S. Department of Energy (August 1998).

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