6.3 Pulsed Gamma Neutron Activation Analysis (PGNAA) System for the Assay of RCRA Metals in Mixed Waste

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Abstract

The presence of certain metals defined as hazardous by the Resource Conservation and Recovery Act (RCRA) in mixed-waste drums can seriously limit the operation of waste treatment processes. Excessive concentrations of mercury, cadmium and lead in the process feed may either result in off-gas emission concentrations which exceed regulatory limits and/or interfere with the treatment process control. There is currently no adequate nondestructive assay (NDA) technique to monitor the RCRA metal content of mixed-waste drums.

Pulsed gamma neutron activation analysis (PGNAA) shows great promise as a technique for the NDA of RCRA metals in sealed containers. The ability of a laboratory PGNAA system to noninvasively detect and quantify low levels of mercury, cadmium and lead in eight-gallon drums of surrogate waste has already been demonstrated. For a ten-minute assay, the detection limits are 15 ppm for Cd, 170 ppm for Hg and 8600 ppm for lead. This system employs an approach whereby the energy spectra of gamma rays produced from neutron-induced reactions in the sample are acquired by a germanium detector in four successive time domains ("groups") following each pulse of a 14-MeV neutron generator. This timing scheme results in the separation of fast neutron-induced

reactions, which occur concurrently with the neutron pulse (group 1), from thermal neutron-induced reactions, which occur on a time scale governed by the mean thermal neutron capture lifetime (groups 2 and 3), and from the decay events of neutron activation products with half lives ranging from milliseconds to minutes (group 4). With this approach, prompt gamma rays originating from fast and thermal neutron capture reactions as well as decay gamma rays emitted by short-lived activation products can be detected with superior signal-to-background ratios.

Based on the encouraging results obtained with PGNAA, a program was undertaken to design, build and demonstrate a field-deployable PGNAA prototype capable of characterizing the RCRA metal content of 55-gallon drums containing mixed-waste sludge. The focus was on mercury, cadmium and lead since these elements are of primary concern in mixed waste. It is believed that a successful development of this technology will allow mixed-waste treatment operators to significantly optimize their waste treatment process control.

During the first program phase, which has been completed, potential sources of interference from typical mixed-waste constituents and physical properties on PGNAA detection sensitivity were evaluated with a combination of modeling calculations and experimental testing. The results showed that, for the vast majority of sludge-waste drums, interference effects from transuranic constituents, chlorine and waste density variation are either negligible or correctable. However, the detection sensitivity of PGNAA, like other neutron-based assay techniques, is perturbed by the presence of boron-10. The occurrence of this perturbation can be monitored by analysis of the PGNAA data routinely acquired during an assay. In addition, studies were carried out with a computational model of a 55-gallon drum PGNAA system. The modeling results indicated that the lower limits of detection of this system would be at least as good as the detection limits demonstrated with the laboratory eight-gallon drum PGNAA system. Furthermore, the modeling results provided a favorable indication of the system's ability to assay drums containing a nonuniform axial distribution of RCRA contaminant.

In the current program phase, we plan to assemble, test and demonstrate the 55-gallon drum PGNAA prototype. Data obtained in the first phase were used to prepare an optimized system design. The engineering specifications for the prototype's mechanical platform have been issued, and fabrication is in progress. Testing and calibration of the entire system will be performed at the BNFL Instruments and Westinghouse Science & Technology sites, followed by a demonstration of the prototype at the Idaho National Engineering and Environmental Laboratory.