

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

Abdul R. Dulloo (dullooar@westinghouse.com; 412-256-2140)
Thomas V. Congedo (congedtv@westinghouse.com)
Frank H. Ruddy (ruddyfh@westinghouse.com)
John G. Seidel (seideljg@westinghouse.com)
Westinghouse Electric Company
1330 Beulah Road
Pittsburgh, PA 15235-5081

Alireza Haghighat (haghigha@gracie.nuce.psu.edu)
Bojan Petrovic (petrovic@gracie.nuce.psu.edu)
The Pennsylvania State University
University Park, PA 16802

Michael E. McIlwain (mem@inel.gov)
Robert J. Gehrke (rjg@inel.gov)
Idaho National Engineering and Environmental Laboratory
P.O. Box 1625, Idaho Falls, ID 83415-2114

Markku Koskelo (mkoskelo@canberra.com)
Canberra Industries
800 Research Parkway, Meriden, CT 06450

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, especially at waste incinerators. Excessive concentrations of mercury, cadmium and lead in the process feed may either result in offgas 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 at waste incinerators due to their volatility. It is believed that a successful development of this technology will allow mixed-waste treatment incinerators to significantly optimize their waste treatment process control.

In the first phase of the program, potential sources of interference from typical mixed-waste radioactive constituents on PGNAA detection sensitivity were evaluated. Modeling calculations completed in an earlier program had shown that ^{235}U , ^{238}U and ^{239}Pu at the expected concentration levels in mixed-waste sludge do not interfere with the PGNAA detection of Hg, Cd and Pb. Experimental tests performed with ^{235}U and ^{238}U verify the modeling results, providing confidence in the modeling methodology employed. Additional modeling calculations show that, for the vast majority of sludge-waste drums, interference from ^{241}Am , chlorine and waste density variation is either negligible or can be corrected for in the concentration measurement values reported for the RCRA metals studied. As expected, 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.

Hardware and software modifications intended to improve system performance have been identified and/or implemented. Better detection sensitivity as well as more reliable performance in the field are expected from these modifications. In addition, a computational model of a PGNAA system for the assay of 55-gallon drums was developed. Studies carried out with this model provided estimates of the lower limits of detection of the 55-gallon drum system which were at least as good as the detection limits demonstrated with the eight-gallon drum system. Furthermore, a favorable indication of the system's ability to assay drums containing a nonuniform axial distribution of RCRA contaminant was provided by the modeling results.

The results obtained in the first phase of the program confirm that PGNAA is a viable technology for the nondestructive assay of RCRA metals in mixed-waste sludge. In the next phase, we plan to assemble, test and demonstrate a 55-gallon drum PGNAA prototype designed for the assay of mixed-waste sludge. We also plan to evaluate the ability of PGNAA to assay debris-type waste.