Applications and Research Opportunities for a Neutron Activation Analysis (INAA/PGAA/DNAA) of Radioactive Wastes

G.M. Sun, D.K. Cho, J.H. Moon, S.Y. Baek, S.H. Kim, Y.S. Chung and H.R. Kim
Korea Atomic Energy Research Institute, Deokjin-dong, Yuseong-gu, Daejeon 305-353, Korea
gmsun@kaeri.re.kr

1. Introduction

Management of the various wastes from nuclear power plants, medicine, industrial activities, research and development, is a knotty problem unless they are properly managed. Waste component analysis is an important key for a proper waste management. By determining the amount of harmful elements in the wastes, and by determining the radioactive characteristics, we can make decisions on how to manage these wastes. Waste quantitative analysis has been carried out by utilizing various chemical analytical methods like ICP-OES, ICP-MS and ion chromatography etc. But these methods can not always be carried out because of a high cost and the sample pre-treatment and preparation problems. Most chemical analytical methods require a total dissolution of the sample and so it is difficult to avoid a contamination of the apparatus, whereas nuclear analytical methods like an instrumental neutron activation analysis (INAA) and a prompt gamma-ray neutron activation analysis (PGAA) are free from these problems and cost-effective. In Korea, the INAA system has been operated at a research reactor since 1962, and the HANARO reactor, a research reactor of the Korea Atomic Energy Research Institute (KAERI), has been utilized since 1995 [1-3]. Also, a PGAA system was installed at HANARO by the joint efforts of Seoul National University and KAERI in 2002 [4]. These systems have been applied to various fields like industrial materials, agricultural and marine products, archaeology and forensic samples, biological samples, environmental samples and geological samples but not yet actively applied to a radioactive waste analysis. Recently, a new delayed neutron activation analysis (DNAA) system is under development with funding from the Korea Institute of Nuclear Nonproliferation and Control (NNCA).

2. Neutron activation analysis

Once a stable nucleus has been excited by a neutron capture, the resultant unstable nucleus will emit radiations for its stabilization. Characterization of the elements can be performed both by the prompt gamma-rays that are emitted from the resultant unstable nucleus (PGAA) or by the delayed gamma-rays that come from the decay of a radioactive nuclide (INAA). This characteristic is very useful to investigate the relative concentration of a stable and unstable nucleus. Because the sample preparation is simple, there is little or no risk of a sample loss or contamination. The materials with low-Z elements like H, B, N, Si, P and S can be analyzed by PGAA. Furthermore, PGAA is highly sensitive to toxic elements such as Cd, Hg, Sm and Gd [5]. INAA is well-known and useful for the determination of trace and minor elements in many fields. Due to its simplicity and good accuracy it has been accepted as a recommended method for certifying the reference materials and applied to multidisciplinary studies, from extraterrestrial matters to deep-sea sediments, from large archeological relics to very fine atmospheric particles, etc. Waste analysis has been one of the main issues in the INAA studies. When INAA is jointly used with PGAA, almost elements in the chemical periodic table can be analyzed [6]. If U and Th in a spent fuel and other radioactive wastes will are the main concern, then these elements can be rapidly analyzed both by a delayed fission neutron counting by using the DNAA system.

3. Applications

3.1. Combustible wastes

As we try to take responsibility for all the generated radioactive wastes and their effects on our future life, a management of the combustible wastes from nuclear power plants, medicine, industrial activities, research and development has been a thorny issue due to their large amounts. In the USA, the combustible wastes have been burned in an incinerator facility and sent to an intermediate storage site. For a volume reduction of the waste, this process must also be installed in Korea. If this incineration process is carried out, the resultant ashes must be analyzed by using various analytical methods because they still include not only radioactive nuclides but also natural elements including toxic and trace elements. PGAA and INAA will be the best choice for these wastes.

3.2. Coal and coal wastes

Coal and coal waste products including fly ash, bottom ash, boiler slag, and flue gas desulphurization contain many heavy metals, including As, Pb, Hg, Ni, V, Be, Cd, Ba, Cr, Cu, Mo, Zn, Se and Ra, which are dangerous if released into the environment. Coal ash also contains low levels of U, Th, and other naturally-occurring radioactive isotopes whose release into the environment may lead to a radioactive contamination. Even though, the radioactivity of fly ash is still very low, and it is of a concern because a small amount of the fly ash can end up in the atmosphere where it can be inhaled. These harmful elements can be analyzed by PGAA and INAA [7, 8].

3.3. Environmental pollutions

Capabilities of the nuclear analytical methods for an elemental analysis of water and sediment pollutions have been tested extensively. Following the Gulf War, oil (from spills), sediment and corals were analyzed by PGAA and INAA and other chemical methods [9, 10]. $^{32}S/^{34}S$ isotopic ratios in the oil were measured by PGAA, which presented a possible method of tracing oil spills to their sources. Hence, compositions for various elements can indicate the distribution and migration of these elements. Some natural and man-made radionuclides like ^{232}Th and ^{238}U from soils and sediments can be determined instrumentally both by INAA and DNAA. Activation of these nuclides produces samples which are endogenously labeled with ^{233}Pa and ^{239}Np [11].

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