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Title: NOBLE GAS ATMOSPHERIC MONITORING FOR INTERNATIONAL SAFEGUARDS AT REPROCESSING PLANTS

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NOBLE GAS ATMOSPHERIC MONITORING FOR INTERNATIONAL SAFEGUARDS AT REPROCESSING FACILITIES

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Abstract

The use of environmental sampling is a major component of the improvements of International Atomic Energy Agency safeguards being carried out under Programme 93+2. Nonradioactive noble gas isotopic measurements in the effluent stream of large reprocessing facilities may provide useful confirmatory information on the burnup and reactor type of the spent fuel undergoing reprocessing. We have taken and analyzed stack samples at an operating facility. The data show clear fission signals. We are currently applying a maximum-likelihood estimation procedure to determine the fuel burnup from these data. We anticipate that the general features involved in the stable noble gas problem—selection of appropriate signals, measurement of those signals under realistic conditions, and inverse calculation of parameters of interest from the environmental data—will be present in all environmental sampling problems. Our methods should therefore be widely applicable.

Introduction

As is well known, the International Atomic Energy Agency (IAEA) has been carrying out an across-the-board effort to improve the effectiveness and efficiency of its safeguards procedures under Programme 93+2.[1] The use of environmental sampling and analysis procedures at and around nuclear facilities has come to play a prominent role in this effort. Most of the research effort to date, however, has emphasized the development of new and improved experimental techniques to measure signals of interest in different matrices.[2] This emphasis is certainly merited; nevertheless, exploiting the full potential of environmental sampling for safeguards and transparency purposes will require the use of theoretical and statistical techniques to allow the IAEA to make quantitative statements based on environmental data regarding questions of safeguards interest.

The sections that follow explore this point of view in more detail, using the example of nonradioactive noble gas measurements and analysis at reprocessing facilities. The discussion will necessarily be brief, but many details have been outlined elsewhere.[3]

Stable Noble Gas Signals

Elemental krypton and xenon are readily produced and contained within nuclear fuel during irradiation. Examination of the thermal fission yields of the krypton and xenon nuclides that are produced in the normal course of fission reveals that the relative abundances of fission krypton and xenon are markedly different from the natural krypton and xenon isotopic abundances found in the atmosphere. The isotopic ratios are closely related to the fuel burnup and other details of the reactor and its operating history. Furthermore, the chemical inertness of these elements implies that they are released as off-gases early on in reprocessing—mostly during the initial dissolution of the spent fuel—and that the relative isotopic abundances are undisturbed by reprocessing. Finally, nonradioactive isotopes are preferred because their inventories in spent fuel are independent of the cooling or storage time of the fuel. In most commercial operations, this time is on the order of months or years.

In our particular example, two requirements must be met. The first requirement is a model relating the fission xenon inventories to burnup, i.e., irradiation history. This model should take into account details of the reactor geometry, coolant, moderator, spatial neutron transport, and time dependent nuclide inventories. We have constructed such a coupled transport/decay reactor model; it is in the process of validation.

The second theoretical requirement needed is a means of quantitatively relating the model to the experimental data. We have chosen a maximum-likelihood method, which has the virtue of simultaneously providing interval estimates for the burnup and a measure of the goodness-of-fit of the theory to the data (the chi-square test).

We have run many simulations using this general approach, which has been discussed in the literature.[4] Unfortunately, our calculations on the above data are not yet ready for release. But we do expect to have them completed and checked soon.

Conclusion

Environmental measurements have the potential, if properly interpreted, to yield useful information on the activities of nuclear facilities. The IAEA, along with many Member States, have taken the lead in researching and developing such measurements. Although experimental methods have been correctly emphasized, theoretical techniques are also required to render the data as useful as possible for safeguards purposes. Monitoring of stable noble gas isotopics at reprocessing facilities provides an interesting example of environmental sampling methods in action and may prove to be useful in safeguards and transparency methods at these facilities.

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[1] See Richard Hooper, "Strengthening IAEA Safeguards in an Era of Nuclear Cooperation," *Arms Control Today,* 14–18 (November 1995); David A. V. Fischer, "New Directions and Tools for Strengthening IAEA Safeguards," in *The Nonproliferation Review*, 69–76 (Winter 1996); and *Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System,* IAEA document GC(40)/17 (23 August 1996).

[2] For a good overview of current technologies see the Proceedings of the International Workshop on the Status of Measurement Techniques for the Identification of Nuclear Signatures, held at the Institute for Reference Materials and Measurements, Geel, Belgium, 25–27 February 1997.

[3] C. W. Nakhleh et al., "Noble Gas Atmospheric Monitoring for International Safeguards at Reprocessing Facilities," *Science & Global Security* **6**, 357–379 (1997).

[4] Ibid.

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