J.Korean Asso. Radiat. Prot.
Vol.26 No.3 : 203-206(2001)

■Papers■

GAMMA-SPECTROMETRY IN ENVIRONMENTAL MONITORING OF NUCLEAR POWER

Tomas Cechak, Josef Gerndt, Jaroslav Kluson, Ladislav Musilek, Lenka Thinova
Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Brehova 7, 115 19 Praha 1, Czech Republic

Abstract - The mathematical processing (unfolding) of pulse height spectra from a scintillation detector helps to calculate the photon fluence rate energy distribution in a measured photon field. The data processing is based on the knowledge of detection system response function and directional dependence respectively. The experimental results of the photon fields measurements in the vicinity of the spent fuel temporary storage and inside the storage hall are presented. The containers Castor 440 are used for temporary storing of the burnt up fuel assemblies in the Czech nuclear power plant Dukovany. A set of periodical measurements was performed in order to get basic information on the time dependence of the photon fields spatial distributions and spectral characteristics in the temporary storage hall and its vicinity. The photon fields were measured by the scintillation system. The obtained photon fields spatial distributions and spectral characteristics present the information on the radiation hazard in the storage.

INTRODUCTION

The mathematical processing (unfolding) of pulse height spectra from a scintillation detector helps to calculate the photon fluence rate energy distribution in a measured photon field. The data processing is based on the knowledge of detection system response function [1] (usually approximated by response matrix) and directional dependence respectively. The other dosimetric quantities, such as exposure or air kerma rate, superficial/specific activities of radionuclides, dispersed in the soil surface layer (using a suitable source distribution and experimental arrangement models), etc., can be calculated from the photon fluence rate .

The main advantages of this approach are: 1) no experimental calibration and corrections of the energy dependence are necessary (both included in the mathematical model and resulting response matrix), 2) high sensitivity (depending on detector volume), 3) spectrometric information, 4) calculation of responses can be provided for any experimental arrangement, including special cases (e.g. accidental contamination of a large territory), when experimental calibration is impossible.

The aim of the photon field analysis in the vicinity of the spent fuel temporary storage and inside the storage hall was to assess the radiation risk inside the storage and the influence of the storage on the environment at its vicinity, as well as evaluate and estimate the time dependence of these factors, corresponding to the gradual storage filling. The storage was build on the Dukovany nuclear power plant territory and opened for trial operation at the end of 1995. The Castor 440 containers are used for storing burnt up-assemblies. The maximum capacity of the store is sixty containers and about one third of the capacity has been used till now. The set of the periodical measurements was performed in order to receive basic information on the time dependence of the photon field spatial distributions and spectral characteristic at the temporary storage hall and its vicinity.

METHOD AND APPLICATIONS

The basic principle of method designed is apparent in the flow diagram in Fig. 1. The full procedure of the detector response matrix calculations is described in the second flow diagram in Fig. 2.

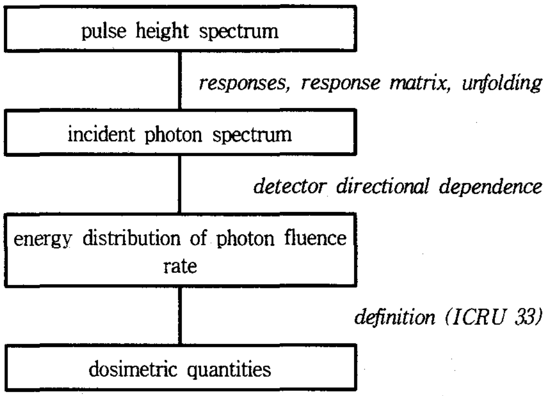

Fig. 1. : Flow diagram of the method for the full data processing and analysis

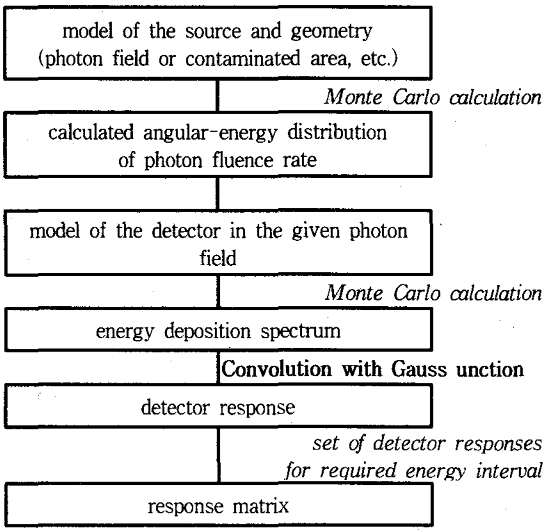

Fig. 2. : Calculation of the detector response and response matrix - flow diagram

The individual experimental arrangement models and the Monte Carlo particle transport simulation are used for detector response calculations. Examples of the sets of calculated 3"×3" NaI(Tl) detector response functions for broad parallel beam (incident perpendicularly to the detector end-face) and energy intervals up to 10 MeV are in Fig. 3. The response matrixes with energy bins 15, 30, 60, 90 keV and different energy intervals (according to the application) were prepared from calculated responses. The iterative (Scofield-Gold) method [7] (to solve corresponding matrix equation) is usually used for unfolding experimental spectra. The use of neural networks for data processing and analysis was also tested.

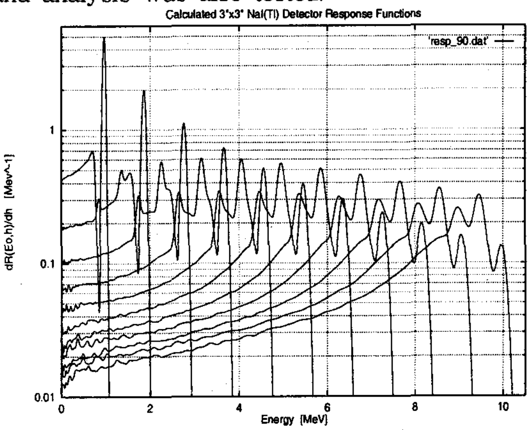

Fig. 3. : Calculated 3"x3" NaI(Tl) Detector Response Function

The method developed for processing and interpreting experimental spectrometric data was used to a wide scope of applications. An example of in-situ gamma ray spectrometry result in the usual reference point of 1 meter above ground in the Spent Fuel Temporary Storage Hall is shown in Fig. 4.

The method was applied for monitoring the gamma fields in the spent fuel temporary storage and for studying its influence on the radiation fields in the storage close neighbourhood. The first measurement was done for empty storage, while the second one followed after storing the first 6 containers (Castor type). The comparison of those results shows the first evidence of the negligible impact of the storage on radiation in the neighbourhood.

The results of measurements inside the storage hall are presented on Fig. 5. To follow the development of the photon field characteristics with the gradual filling of the storage, the set of measurements was repeated periodically. The spatial distribution of the air kerma rate in the storage hall was calculated from values measured in the individual points.

The spectral analysis of the gamma field shows a contribution of about 10% of the high energy part (up to 3 MeV). In order to interpret the high energy response, an additional study of neutron fields using the Bonner spectrometer was done. Relatively high neutron fluences were confirmed. It was concluded that the high energy response consists of two parts:

- response of prompt gamma radiation
- response to neutrons due to sensitivity of NaI(Tl) detector to neutrons

The spectrum in Fig. 4 measured in the reference point 5 represents a typical spectrum in the storage hall.

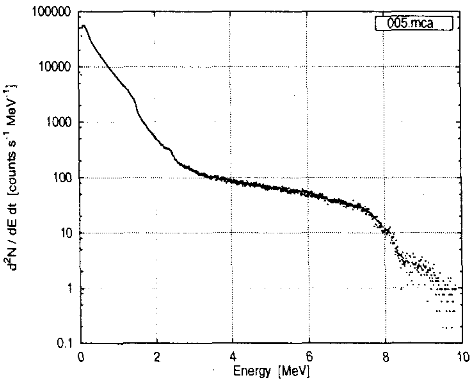

Fig. 4. : Typical spectrum in the storage hall

SUMMARY AND CONCLUSION

The method described was successfully used for environmental gamma ray fields study, monitoring and analysis, natural background components and variations studies [2, 3, 6], study of the environmental impact of uranium ore mining and processing, assessment of doses in dwellings, monitoring workplaces (including the mentioned nuclear power plant and spent fuel temporary storage), processing of the environmental spectral data from the Chernobyl region, works within the project of Semipalatinsk nuclear weapon test site radiological assessment [5], etc.

Calibration factors for determining the superficial/ specific activities from scintillation or semiconductor detectors spectrometry data were calculated (for defined experimental arrangements). Calculations were done for natural radionuclides (^{40}K and U, Th - series) as well as for ^{137}Cs and a set of other expected significant man-made contaminants.

The work carried out indicated that the scintillation spectrometer and deconvolution technique based on the knowledge of the detection system response matrix and Scofield-Gold iterative method are suitable for the calculation of the spectral distributions of the required dosimetric quantities.

The photon fields analysis performed in the temporary spent fuel storage vicinity and inside the storage hall respectively, gives a basic view

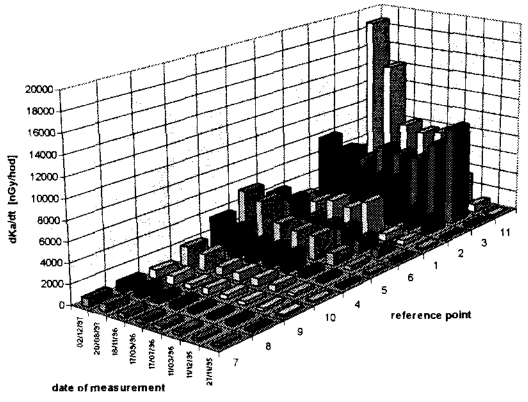

Fig. 5. Air Kerma Rates in the Spent Fuel Temporary Storage.

and assessment of the radiation hazards and trends of development of these hazards. It was confirmed that there has been no substantial influence of the storage on the photon fields and the environment in the storage vicinity up to now.

REFERENCES

1. Rogers, D.W.O.: More Realistic Monte Carlo Calculations of Photon Detector Response Functions. Nucl. Instrum. Meth. 199,(1982).
2. Klusoň, J., Malusek, A., Čechak, T., Jurza, P.: Airborne Gamma-Ray Spectrometry in Environmental and Accidental Monitoring. In: Proceedings of IRPA9 International Congress on Radiation Protection, April 14-19 1996, Vienna, Austria.
3. Pernička, F., Klusoň, J.: Variations of Natural Radiation Background and their Effect on Detector Response. Environ. Internat. 22, Suppl. 1, (1996).
4. Clements, P.J.: A Discussion of Variations on the Scofield-Gold Iterative Deconvolution Technique. AERE - R 7222(1972).
5. Hill, P., Hille, R., Bouisset, P., Calmet, D., Kluson, J., Smogulov, S., Seysebaev, A.: Radiological Assessment of Long Term Effects at the Semipalatinsk Testsite. NATO-Semipalatinsk Project 1995/1996, Berichte des Forschungszentrums J(lich, J(L - 3325 December(1996).
6. Klusoň, J.: Calculation of the Field Spectrometer Response and Calibration for the Operational and Accidental Monitoring of Nuclear Power Plant Neighbourhood. Progress in Nucl. Energy 24,(1990).
7. Scofield, N.E.: Iterative Unfolding. NAS - NS - 3107 (1963).