A FIELD DEPLOYABLE HIGH-RESOLUTION URINE GAMMA ANALYZER

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Abstract—**The Human Monitoring Laboratory has extended the use of its portable whole body counters to portable gamma spectrometers for urinalysis. The protocol tested measured a 120-mL sample in a polypropylene sample container for 5 min. Minimum detectable activities were estimated for ^{241}Am, ^{57}Co, ^{137}Cs, and ^{60}Co. The former is 113 Bq per sample, and the latter three are between 27–29 Bq per sample. Assuming an intake 5 d before the measurement, and all other parameters as default, the committed effective doses are 517 Sv, 76 μSv, 402 μSv, and 1.5 mSv, respectively. Clearly, this instrument can be used as a field deployable gamma spectrometer for urinalysis for activation and fission products, but actinides (and other low energy photon emitters) remain problematic.**
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INTRODUCTION

PREVIOUSLY, THE Human Monitoring Laboratory (HML), which operates the Canadian National Calibration Reference Centre for Bioassay and In Vivo Monitoring (Kramer and Limson Zamora 1994), described the use of the Detective (Ametek, Ortec Division, 801 South Illinois Avenue, Oak Ridge, TN 37831-0895) as a high-resolution field deployable whole body counter that could be used following a terrorist attack or other incident releasing radioactive material (Kramer et al. 2005). Experience in the field, during an exercise in which the counting protocols were tested, showed that there was a need for a rapid urinalysis. The thinking at that time was that it might be simpler to collect urine samples at a reception center during the collection of demographic data post-incident as people are familiar with providing urine samples during routine visits to their physician. The aim was to keep panic levels low. The HML has, therefore, investigated the use of the field deployable whole body counter as a gamma spectrometer in the field. This paper describes the results of those findings.

The intent of the field deployable gamma urine counter is to a) identify radionuclide mixtures being excreted and b) estimate internal dose quickly to assess persons at immediate risk, which this instrument clearly does in most cases.

METHODS AND MATERIALS

The field deployable whole body counter

The instrument used as a field deployable whole body counter (Detective) was acquired from Ametek's Ortec division. It contains a 50-mm × 30-mm Ge crystal and is shown in Fig. 1. The instrument's nuclide identifier (based on gamma-ray emissions only) provides the following functions: search (scanning mode for location of radioactive sources, with audio alert using an external earpiece); identify (proprietary scheme for identification and classification of radionuclides); and dose rate (gamma dose rate is monitored by an internal compensated Geiger-Mueller tube).

Typical identifications are as follows:

- Industrial—including, but not limited to ^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs, ^{192}Ir, ^{241}Am, ^{75}Se;
- Medical—including, but not limited to ^{67}Ga, ^{99m}Tc, ^{111}In, ^{123}I, ^{131}I, ^{133}Xe, ^{201}Tl;
- Naturally occurring radioactive material (NORM)—including, but not limited to ^{40}K, ^{226}Ra, ^{232}Th, ^{238}U; and
- Nuclear—including, but not limited to ^{233}U, ^{235}U, ^{237}Np, ^{239}Pu, ^{252}Cf.

These classifications are based on an internal, fixed library that cannot be changed by the user. However, when the instrument is connected to a laptop computer running Ortec's Renaissance software it becomes a fully functional spectroscopy system that could be used as a high-resolution gamma spectrometer. The HML now has three such instruments available for use.

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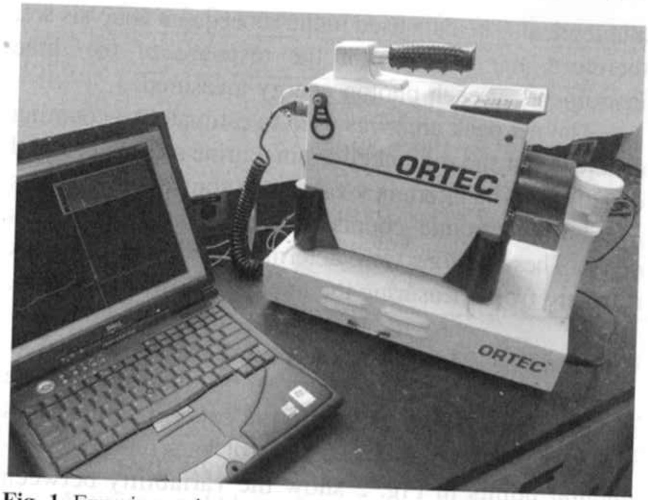

Fig. 1. Experimental set-up for the calibration of the HML's field deployable whole body counter.

Calibration

The field deployable whole body counter was calibrated for urinalysis using a urine sample bottle containing 120 mL of water (as a simulant for urine) spiked with ^{57}Co (8.0 kBq), ^{137}Cs (4.0 kBq), and ^{60}Co (4.0 kBq). The water solution was made up to be the same composition as the standard solution (i.e., to have the same chemical composition) from which the radioactive solution was taken to avoid wall deposition, which can occur if the solution either is not acidic enough or does not contain sufficient inert tracer or both. The container was placed on the energy calibration mount on the charging station (with the calibration source removed) and counted on contact (Fig. 1). All three of the HML's field deployable whole body counters were calibrated in this manner.

Simulations—urine counting

The Monte Carlo code used for the simulations was MCNP5 (Monte Carlo N-Particle), which is described elsewhere (X-5 Monte Carlo Team 2003) and was obtained from the Radiation Safety Information Computational Center (Post Office Box 2008, 1 Bethel Valley Road, Oak Ridge, TN 37831-6171). MCNP5 is a general purpose program that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport, although this work uses the photon transport capabilities. It has been used for many applications, such as radiation protection and dosimetry, radiation shielding, radiography, medical physics, nuclear criticality safety, detector design and analysis, nuclear oil well logging, etc.

The source was defined as the liquid in a 132-mL polypropylene sample cup, and was homogeneous in the liquid. The virtual sample cup was constructed by measuring the actual cup used for the calibrations described above. The wall thickness was 1 mm, the base outer diameter was 4.9 cm, the top outside diameter was 6.0 cm, and the cup had a height of 7.2 cm. The cap was modeled by a macro-body using the same material and had an outside diameter of 6.4. Indentations in the cap and base of the sample cup were not modeled. The sample cup material was polypropylene (0.95 g cm^{-3}), and the cap was polyethylene (1.0 g cm^{-3}) and was 2-mm thick.

The following energies were simulated individually: 40, 60, 122, 280, 364, 662, 834, 1,173, 1,332, 1,460, 1,836, and 2,754 keV. Many of these energies will be recognized for being close to the primary energy of common radionuclides (e.g., 662 keV ^{137}Cs), other energies were used to fill in the calibration curve.

The authors of MCNP consider that a relative error on a predicted value calculated by the code of 0.1–0.2 suggests that the tally result is questionable (X-5 Monte Carlo Team 2003). Tally results for which the relative error is above 0.2 are not likely to be meaningful; however, results are generally reliable for a relative error less than 0.1. Ten million photons were generated and those that reached the detector and deposited full energy therein were tallied (tally type f8). Relative errors for all tally results were less than 0.015 for all simulations.

Minimum detectable activity (MDA)

An unshielded background was used. The count time was 3,600 s. The counts for the photopeaks of interest (^{241}Am, ^{57}Co, ^{137}Cs, and ^{60}Co) were taken from the same regions of interest used in the calibrations described above. The background was also repeated in a shielded environment (one of the HML's counting chambers) in an attempt to improve the MDA for ^{241}Am.

The following formula for MDA, which is only valid if the counting time for sample and background are the same, is based on the work of Currie (1968), with Brodsky's (1986) modification, although in practice, and in this work, the second term is often neglected as it adds little to the size of the result when N is large:

$$MDA = \frac{4.65\sqrt{N}}{ET} + \frac{3}{ET}, \qquad (1)$$

where N = background counts in the region of interest (ROI), E = counting efficiency (cps Bq^{-1}), and T = counting time (s).

Dosimetric implications

Calculations of intakes and dose were performed using Integrated Modules for Bioassay Analysis (IMBA) Professional Plus (version 4.0.36) provided by ACJ & Associates, Inc (129 Patton Street, Richland, WA 99352-1618). Calculations were performed using the default assumptions loaded by IMBA (i.e., solubility, particle

CONCLUSION

The field HML's deployable whole body counter can be effectively used as a high-resolution urine gamma counter for fission and activation products. The overall sensitivity of the portable unit is sufficient for emergency response as it can detect intakes of nuclides that emit gamma photons above 100 keV that will result in a dose that is at a background level or less, depending on the energy of the emitted photons, solubility type, effective half life, etc. Nuclides that emit lower energy photons (e.g., ^{241}Am) remain problematic and cannot be detected with sufficient sensitivity.

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