# INTERNAL DOSIMETRY MONITORING AT THE CHALK RIVER NUCLEAR LABORATORIES

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## INTRODUCTION

Employees at the Chalk River Nuclear Laboratories (CRNL) operate and maintain high flux reactors, zero power research reactors, radioisotope production facilities, accelerators, experimental fuel laboratories and waste management facilities. In addition much of the research and development carried out at CRNL involves work with unsealed radioactive materials. Internal contamination may occur during the course of this work, and monitoring for internal contamination (internal dosimetry monitoring) is a necessary complement to workplace monitoring to ensure employees are not contaminated, or if they are, to quantify the doses associated with these contaminations so that appropriate actions can be taken. Currently approximately one half of CRNL's 2400 employees are monitored by at least one method each year. This paper briefly reviews the process of selecting the employees to be monitored, the monitoring techniques used, and the reporting, recording and interpretation of monitoring results.

## SELECTION OF EMPLOYEES TO BE MONITORED

Employees are selected for internal dosimetry monitoring by their supervisory staff in consultation with staff from the Radiation and Industrial Safety (R&IS) Branch. The selection is made after reviewing such factors as the amount and form of activity handled. The results of this review are used to judge whether intakes by individuals in a year could exceed a significant fraction of the annual limit on intake (ALI), usually taken as 0.1 ALI. This judgement of what intakes could be is very subjective and hence conservative assumptions are used. It is therefore very unlikely that an activity exceeding 0.1 ALI would be taken in by an employee who has not been selected to take part in the internal dosimetry monitoring program.

The routine monitoring frequency depends on the likelihood of contamination, the derived investigation level (DIL - see below), and the sensitivity of the monitoring technique being used. Typical frequencies used are bi-weekly, monthly and bi-monthly for tritium and fission products in urine; semi-annually, annually and bi-annually for fission products in vivo; monthly and bi-monthly for uranium, thorium and plutonium in urine; and semi-annually and annually for uranium, thorium and plutonium in vivo. In addition to this routine monitoring, operational and special monitoring is performed as required.

The names and locations of each employee selected to take part in the monitoring program, along with the type of monitoring required, and its frequency are stored in a computer file (frequency file). A list of employees to be monitored in the following week is produced from this file each week, and once an employee's name appears on this list, it will continue to appear each week until the

requested monitoring has been performed, or the request is cancelled. Once a month, lists of employees' names with their current monitoring frequencies are sent to supervisors. This list is reviewed and any changes in monitoring requirements are used to update the frequency file.

## MONITORING TECHNIQUES

Urinalysis Tritium concentrations in urine are measured with a standard liquid scintillation counter at a sensitivity better than $10^4$ Bq $L^{-1}$. Calibration standards and quality control samples are analysed each day and the computer evaluated results are compared to the known activities. Once a month, or more often if changes in operation are made, a quench (calibration) curve is generated and compared to the previous quench curve. The urine tritium concentration results are automatically stored in the data base, from which they are available for subsequent dosimetry calculations.

The screening method (gross beta) that is used for beta emitting fission products in urine consists of an oxalate precipitation and counting in a standard planchet counter. This method will detect Sr, Pm, Ce and Ba (1) in urine at a level of about 60 mBq $L^{-1}$. The quality control on this method is performed by calibrating the counter each day, and by analysing a "blind" sample supplied by the Quality Control Manager (QCM) each week.

Gamma emitting fission products and other gamma emitting radionuclides are detected in urine in a Marinelli flask using a 5 x 5 cm NaI (Tl) detector inside a lead castle (1). The sensitivity of this method for a standard counting time of 800 seconds and 0.4 L of urine is better than 500 Bq (gamma) $L^{-1}$ over the range of gamma energies encountered. The efficiency and energy calibration of the detector is checked daily.

A gross alpha analysis is done on urine from persons working with Th, Pu, Am, Np or other actinides (excluding uranium) (1). The prepared sample is counted using a ZnS screen/photomultiplier tube detector and if any activity is detected, an alpha spectrum using a Si surface barrier detector is taken to aid in the identification of the radionuclide(s) present. The sensitivity of this method is about 0.5 mBq per sample. The quality control on this method is achieved by analysing blind samples supplied by the QCM each week.

Analysis for uranium in urine is done either fluorometrically for natural uranium (2) or radiochemically (3). The fluorometric analyses are calibrated by spiking aliquots of each sample. The radiochemical procedure is checked periodically with blind samples prepared by the QCM.

In addition to the above analyses that are performed routinely, analytical techniques have been developed for Ni-63 (4); radium (5); S-35 and P-32 (6); Cl-36 (7); Tc-99 (8); and Ce-144/Pm-144, Sr-90 and Y-90 (9), for use as required.

In Vivo Monitoring Whole body monitoring is performed in a specially constructed low background building (10) with a shadow

shield monitor. This monitor has been calibrated using standard bottle phantoms filled with various radionuclides (10). The sensitivity of this system is about 40 Bq for Cs-137. The efficiency, energy calibration and background spectrum of the monitor are checked daily. All spectra are routed to the main CRNL computer for analysis and storage of spectra and results.

Routine thorax (lung) monitoring is carried out with phoswich detectors in the low background building (11). These detectors have been calibrated using a thorax phantom based on the well known Livermore phantom (12). These monitors will detect about 3 mg of U-Nat, 1 mg of Th-Nat and a variable amount of plutonium, depending on body build and plutonium burnup and time since separation (11).

Routine thyroid monitoring for I-125 (other radioiodines are measured with the whole body monitor) is performed with a 2.5 x 0.1 cm NaI (Tl) detector. In addition various other detectors (including a 20 cm diameter phoswich detector optimized to detect U-Nat and Th-Nat) are available for non-routine monitoring as required.

Thoron-in-Breath Monitoring A thoron-in-breath monitor has been recently developed (13) for monitoring employees working with thoria powders. Calibration of this monitoring technique is difficult and work is continuing on this problem, but its sensitivity is much superior to in vivo monitoring or urinalysis.

## RECORDING AND REPORTING OF RESULTS

A computerized data base system has been constructed in order to efficiently record and report the approximately 12,000 monitoring results on approximately 1200 employees obtained each year and to allow easy retrieval of these results at a later date if required. The data base is constructed using the indexed sequential filing system available in the main CRNL computer. Employee identification and status (i.e. retirement, etc.) is kept up-to-date by access to the main personnel files. The programs used to access (input, retrieve, correct, etc.) records are interactive and contain various checks to help ensure that the monitoring results that go into the data base are correctly assigned to the right employee. A report of the monitoring results obtained each week is produced from the data base and sent to supervisory and R&IS staff. This report contains the results of each test, and whether any internal contamination measured by the test was judged to be at a negligible, minor, caution or removal level (see below). In addition, supervisory and R&IS staff are immediately informed if any result exceeds the caution or removal level. Each month, a summary report is produced that lists all minor, caution or removal levels for use by the Site Safety Committee during their monthly review. The only internal contamination that is routinely present at non-negligible levels is tritium. Doses associated with tritium contaminations are routinely calculated (14, 15) and are reported bi-weekly, quarterly and annually.

## INTERPRETATION OF RESULTS

Except for tritium, very few monitoring results exceed the detection limit of the monitoring procedure. Those that do are compared to pre-derived levels so that further actions can be taken if necessary. The highest of these levels is the removal level and

when a result exceeds this level the employee is removed from sources of further significant contamination for evaluation. Nominally, the removal level (16) is based on an intake of 1/20 of the ALI for the radionuclide in question, calculated via GENMOD (17) with the assumption that the contamination occurred immediately after the previous measurement. This level is called the derived investigation level (DIL), and differs somewhat from that recommended by ICRP (18, 19). Actual removal levels for some radionuclides are considerably below the DIL if past results indicate that this level can be easily maintained without disrupting the efficient operation of the laboratory in question (ALARA). In other instances, the DIL is below the detection limits of the available monitoring techniques (notably for the actinides) and the removal level is set at any activity that significantly (at approximately the 95% confidence level) exceeds the detection limit. In most instances when a removal level is exceeded, subsequent monitoring reveals that the dose resulting from the contamination is negligible. If effective or organ dose equivalent exceed 2.5 mSv, they are reported and recorded.

Caution levels are normally set at one half the removal level, and if this level is exceeded, the employee is subjected to further monitoring to evaluate the significance of the contamination. Minor levels are set at somewhere between 1/2 and 1/100 of the caution level, the purpose of the minor level is to bring them to the attention of the responsible persons so that any appropriate action may be taken.

## SUMMARY

The internal dosimetry monitoring program at CRNL has been reviewed. This program has evolved from a very simple one in the late 1940's to the comprehensive one described above. Results obtained with this program indicate that measures taken to control internal contamination at CRNL are effective.

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