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# nuclear science and technology

# Optimisation of Monitoring for Internal Exposure

# (OMINEX)

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**Final report**
(summary)

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## Introduction

The primary aims of internal dose monitoring in the workplace are: (a) to verify and document that workers are protected adequately against risks from radionuclide intakes; and (b) to verify and document that the protection complies with legal requirements. The first aim is achieved by utilising monitoring programmes that allow the assessment of internal doses with sufficient *accuracy* so that an acceptable estimate of risk can be made. This requires a consideration of the uncertainties in assessed intakes and doses that arise from different monitoring programme designs. The second aim is achieved by ensuring that doses can be assessed with adequate *sensitivity*, so that workers who have received doses above a particular level are reliably identified. An example of such a requirement is the need to demonstrate that annual doses are not in excess of 6 mSv for Category B workers, in order to confirm that they have been categorised correctly as required by Article 25 of EC Directive 96/29/Euratom. This requires a consideration of the minimum detectable doses associated with the monitoring programme.

OMINEX aims to provide advice and recommendations on designing and implementing internal dose monitoring programmes in the workplace. The underlying approach to optimisation was to consider costs versus "benefits", the latter being quantified primarily by assessing either the *sensitivity* or *accuracy* with which intakes and doses are determined from the results of monitoring. The results of the project should be of use to dosimetry service managers, regulators and senior medical staff in the nuclear industry.

## Objectives

Work was organised into five distinct but inter-related work packages. The main objective of Work Package 1 was to collect information on, and provide a critical evaluation of, arrangements for internal dose monitoring in nuclear and non-nuclear industries in European Union (EU) countries. There has previously been little sharing of such information between different countries across the EU, and so it was considered necessary to have a reasonably comprehensive description of current internal dose monitoring practice in the EU before presenting new advice on best practice. Work Package 2 was closely related to Work Package 1. Its main objective was to collect information on the associated costs of monitoring programmes.

Work Package 3 had two main objectives. The first was to collect information on bioassay and *in vivo* monitoring procedures used in EU laboratories, together with information on measurement parameters affecting uncertainties in these measurements. The second objective was to define optimum measurement parameters in order to reduce uncertainties in measurements, using information collected in the laboratory survey.

Work Package 4 had three main objectives. The first was to quantify the major sources of uncertainty in internal doses assessed from the results of particular monitoring methods and measurement techniques. The second objective was to develop a methodology to assess total uncertainty in assessed intakes and doses taking into account uncertainties in intake patterns, measurements, and respiratory tract and systemic model parameters. The third objective was to investigate the use

of information on uncertainties in assessed intakes and doses to develop advice on monitoring.

The central objective of OMINEX was to develop and present advice on monitoring for selected radionuclides/compounds. This work was carried out in Work Package 5, making use of the results of the other work packages, particularly in respect of the assessment and optimisation of uncertainties in measured bioassay/*in vivo* quantities, and the assessment and optimisation of uncertainties in assessed doses. In addition, previously developed methods for the assessment of minimum detectable doses resulting from the use of different monitoring methods, monitoring intervals, etc. were utilised. These approaches are particularly important when considering monitoring for actinide exposures, where achieving adequate sensitivity is a significant issue.

Another important objective of Work Package 5 was to disseminate results effectively. In addition to the reports and publications that were issued during the course of the project, a two-day training course was held towards the end of 2003 to present the results of the project.

**Results**

In the first two work packages, surveys were carried of current internal dose monitoring practice in EU countries and of their associated costs. The most important finding was that, in many instances, there is little consensus across the EU on the optimum design of an internal dose monitoring programme.

In Work Package 3, surveys were carried out of bioassay and *in vivo* monitoring procedures in EU laboratories and of measurement parameters affecting uncertainties in these measurements. This information was then used as an input to investigations into ways of exploiting available methods and techniques to reduce uncertainties in measurements. For $\alpha$-spectrometric analysis of actinides in urine, a relative uncertainty of 25 % for a 1 mBq/24h sample and a minimum detectable amount (MDA) of 0.1 mBq/24h sample were set as the targets that should be achieved. For analysis of actinides in faeces, a relative uncertainty of 10 % for a 100 mBq/24h sample and an MDA of 1 mBq/24h sample were set as the targets. Less than half of the laboratories reach these targets. Recommendations on values for sample volume, tracer activity, counting efficiency, sample and backgrounds counting times, background count rate and chemical yield necessary to achieve these targets have been presented.

A novel aspect of the project was the development of a methodology to assess total uncertainty in intakes and doses assessed from monitoring measurements that takes into account uncertainties in intake patterns, measurements, and respiratory tract and systemic model parameters. This work was carried out in Work Package 4. The method was implemented for tritium monitoring and $^{60}$Co monitoring using programs written specifically for this task using MS Visual Basic™ 6.0. For routine tritium-in-urine monitoring, uncertainties in assessed dose were found to decrease as the monitoring interval was increased from 3 days, reaching a minimum at about 14 days, and then increased for longer monitoring intervals. For routine $^{60}$Co whole body monitoring, uncertainties in assessed dose were found to decrease slightly with

increasing monitoring interval. Uncertainties in doses assessed from routine $^{60}$Co urine monitoring were found to be much greater.

Development of advice on individual monitoring programmes was carried out in Work Package 5. Advice has been developed on routine and special monitoring following exposure to a range of radionuclides that represent some of the most difficult problems in internal dose assessment and are of the most radiological interest, ie tritium, cobalt-60, radioiodine, caesium-137, uranium, plutonium and thorium. Emphasis has been placed on compounds of these radionuclides that are encountered in the nuclear industries. Where achieving adequate *accuracy* was judged to be the more important requirement (tritium, cobalt, radioiodine), recommendations on optimised monitoring were developed from considerations of uncertainties in assessed doses, quantified using the methods developed in Work Package 4. Where achieving adequate *sensitivity* was judged to be the more important requirement (primarily, this applies to the actinides), considerations of minimum detectable dose were employed. Advice is provided on choice of monitoring method(s), (eg excretion monitoring vs *in vivo* monitoring), choice of measurement technique (eg alpha spectrometry vs mass spectrometry), monitoring intervals, measurement frequency, required measurement sensitivity and accuracy, measurement parameters needed to achieve this performance, the resulting uncertainty in assessed intakes and doses, and minimum detectable doses.

For *routine tritium-in-urine monitoring*, a monitoring interval of 28 days is recommended where doses could be higher than 3/10 of the dose limit. Where doses are not expected to approach this level, longer monitoring intervals up to about 60 days could be used. For these longer monitoring intervals, intake time assumptions other than the commonly-used "mid-point" assumption have some benefit in terms of reduced bias and uncertainty in assessed dose. The use of this method has been demonstrated for tritium monitoring, but could be applied for any radionuclide.

For *$^{60}$Co monitoring*, annual whole body monitoring is recommended for routine monitoring purposes; routine urine monitoring is not recommended. For special monitoring, whole body monitoring is the preferred method. Uncertainties in assessed dose would be minimised if most measurements are made at least 4 days after intake. Urine monitoring can provide useful additional data, but could result in significant overestimates in dose unless material-specific data on absorption characteristics is available.

For *routine $^{125}$I/$^{131}$I monitoring*, direct measurements of iodine-in-thyroid are recommended rather than urine monitoring. Monitoring intervals of 90 days and 15 days are recommended for $^{125}$I and $^{131}$I exposures, respectively.

For *routine $^{137}$Cs monitoring*, both whole body and urine monitoring can be used to confirm annual doses below 1 mSv, even when whole body retention half times and absorption parameters are highly variable. Uncertainties would be reduced if material-specific information on absorption characteristics is obtained.

For *uranium monitoring*, the main conclusions are: chemical limits for exposure to natural uranium, and the currently acceptable concentration of uranium in the kidneys, should be re-appraised. Investigation levels for the more soluble compounds of uranium should take account of constraints imposed by both chemical solubility and radiation dose. Material-specific data should be used when designing monitoring programmes, and when assessing doses from monitoring data. Urine monitoring is the preferred

method for soluble compounds such as the nitrate, tributylphosphate and peroxide, although for health protection purposes it may be more useful to assess the concentration of uranium in the kidneys rather than radiation dose. Both urine and faecal monitoring are appropriate for the trioxide and tetrafluoride. Lung and faecal monitoring are the most important methods for the poorly soluble compounds such as the octoxide and dioxide. Recommendations have been made for monitoring methods and monitoring intervals for the most important uranium compounds.

For *thorium nitrate monitoring*, the main conclusions are: lung monitoring is inappropriate because of the rapid absorption from the lung of Th decay products; urine monitoring is of some practical value for special monitoring, although not for routine monitoring; but the greatest sensitivity in terms of assessed dose is obtained from faecal measurements for both routine monitoring (180 day or 360 day monitoring intervals) and special monitoring. For *thorium dioxide monitoring*, lung monitoring is again inappropriate because of low dose sensitivity; thoron-in-breath measurements can be used to demonstrate that annual doses are less than 6 mSv $y^{-1}$; urine monitoring is of little value because of low dose sensitivity; but the greatest sensitivity in terms of assessed dose is again obtained from faecal measurements for both routine monitoring (180 day or 360 day monitoring intervals) and special monitoring.

For *plutonium nitrate monitoring*, the main conclusions are: lung monitoring is of little value, while urine and faecal monitoring can both be used to confirm that annual doses are less than 6 mSv $y^{-1}$, although faecal measurements have greater sensitivity for both routine and special monitoring. For *plutonium dioxide and MOX monitoring*, lung monitoring can be used only to confirm that doses from acute exposures are no greater than about 20 mSv, and then only when measurements are carried out soon after the exposure and the $^{239}$Pu:$^{241}$Am is less than about 9:1. Urine monitoring can be used to demonstrate that annual doses are less than 6 mSv $y^{-1}$, but the greatest sensitivity in terms of assessed dose is obtained from faecal measurements for both routine monitoring (90-360 day monitoring intervals) and special monitoring. For plutonium bearing dusts present at nuclear power plants, annual doses of less than 1 mSv $y^{-1}$ can be confirmed from annual $^{60}$Co or $^{137}$Cs whole body measurements, or from annual $^{137}$Cs in urine measurements.

## Implications

Methods have been developed by which uncertainties in measurement procedures can be reduced, and the design of monitoring programmes optimised. These methods have been applied to monitoring for exposures to a number of important radionuclides/compounds. The advice and recommendations developed should be of specific use to dosimetry services that are required to provide monitoring for these materials. More generally, the approaches developed could in principle be applied to monitoring for exposures to any radionuclide/compound. The project has shown that, if all the factors that can affect the interpretation of monitoring data are taken into account (e.g. uncertainty in intake pattern, variability in particle size, absorption parameter values, differences in retention functions, and realistic MDAs), then clear judgements can be made on the most effective monitoring procedures, and on whether assessments of dose have sufficient sensitivity and accuracy to meet the appropriate legal requirements.