Australian Government
Australian Radiation Protection and Nuclear Safety Agency

A Survey of the Capabilities of Australasian Radioanalytical Laboratories

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Technical Report Series No. 168

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by

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Technical Report No. 168
ISSN 0157-1400
June 2014

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ISSN: 0157-1400

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Acknowledgments

The authors wish to thank all of the laboratories that participated in the survey.

Executive Summary

A survey of eight Australian and New Zealand radioanalytical laboratories was undertaken in order to establish their capabilities in the event of a significant radiological incident. International experience has shown that the response to a significant radiological incident could generate a large number of samples for analysis. Such a high workload could easily overwhelm the capacity of any single laboratory.

The survey found that there was significant capability for radio-analysis in Australasia:

- Seven of the eight laboratories were found to have a sufficient number of high-resolution gamma-ray spectrometers to provide significant support
- Seven of the eight laboratories surveyed were found to have radiochemical capabilities
- All eight laboratories were found to have the capability to measure beta-emitting radionuclides
- Seven of the eight laboratories were found to have the appropriate equipment to use Liquid Scintillation Counting (LSC) for rapid screening of samples
- All eight laboratories were found to have the capability to measure alpha-emitting radionuclides

However, the survey also found that there were some limitations to the capabilities and capacity of the laboratories:

- Only four of the laboratories surveyed have equipment appropriately calibrated for general gamma-spectrometry due to specialisation in particular measurements by the other four laboratories.
- Considerable specialisation in the radionuclides analysed means that it is unlikely that laboratories would have procedures in place for the treatment of all radionuclides of interest
- There are few standard methods for the rapid screening of samples by LSC
- Only three laboratories reported having more than 16 alpha-spectrometers and, therefore, there is limited capacity for the measurement of alpha-emitting radionuclides
- Only four of the laboratories have sufficient staff to provide 24-7 laboratory support

The capability of laboratories could be enhanced by:

- Providing appropriate gamma-spectrometry calibration standards
- Conducting annual Proficiency Test Exercises at minimal cost to participants
- Promulgating a standard set of radiochemical procedures
- Developing procedures for the rapid screening of samples by LSC

Contents

1. Introduction

International experience with significant radiological incidents has shown that extensive measurement of environmental samples is required in response to the incident. During the initial response to such an incident, the measurement of environmental samples must be conducted as rapidly as possible in order for timely decision-making. Later, during the recovery phase, the measurement time-frames may increase, but so too does the number of samples requiring measurement. This high workload can easily overwhelm the capacity of a single radioanalytical laboratory.

The potentially high workload is demonstrated by Japan's response to the Fukushima Dai-ichi nuclear power plant accident. The total number of food samples measured in Japan exceeded 137,000 in the twelve months following the accident (1). The number of food samples measured in Japan increased to nearly 280,000 in the following twelve months (2) and over 170,000 food samples have already been measured in the six months since April 2013 (3). These numbers do not take into account the numbers of water, soil and air samples required to respond to the incident.

While such a widespread incident is not anticipated to occur in Australia, even small-scale incidents can produce high workloads. For example, the radiological accident in Goiânia (4), required 1300 environmental samples to be measured over a period of a few weeks, even though only a few hectares were contaminated.

ARPANSA maintains a radiochemistry laboratory, in part, to respond to radiological incidents. Theoretically, this laboratory has the capacity to measure about 100 samples per day (for gamma-emitting radionuclides). However, even this capacity would be overwhelmed by the response required by a significant radiological incident. Therefore, assistance from other laboratories would be required to respond to a significant radiological incident.

In order for ARPANSA to call upon the assistance of other Australasian laboratories, their capability and capacity would have to be known. Therefore ARPANSA contacted all of the known radiochemistry laboratories within Australasia in order to determine their capabilities and capacities. This report summarises the results of this survey.

The government laboratories surveyed were:

- Radiation Protection Branch, South Australian Environmental Protection Agency
- Queensland Radioanalytical Measurement Services, Queensland Department of Health
- ANSTO Environmental Radioactivity Measurement Centre
- Environmental Research Institute of the Supervising Scientist
- National Centre for Radiation Science, New Zealand

ARPANSA also surveyed two commercial laboratories:

- Western Radiation Services
- SGS Australian Radiation Services

The reported results also include the capability and capacity of the ARPANSA laboratory.

It should be noted that many of these laboratories exist to fulfil specific needs and are, therefore, not funded or specifically tasked with providing analyses in the event of general radiological incident. For example, the Environmental Research Institute of the Supervising Scientist (ERISS) is specifically charged with undertaking independent scientific research and monitoring into the impact of uranium mining on the environment of the Alligators Rivers Region. Therefore, ERISS has particular expertise in analysing samples for naturally occurring radionuclides but has no requirement to measure anthropogenic radionuclides. Similarly, the two commercial laboratories provide only those analyses requested by their clients.

2. Gamma-ray emitting Radionuclides

The IAEA General Safety Guide (5) lists a range of radionuclides that may be required for screening following a radiological incident. A sub-sample of these radionuclides (based on their relevancy for Australia) was used in the laboratory survey. Most of these radionuclides emit gamma-rays, making them amenable to analysis by gamma-ray spectrometry. This method of analysis is preferable because it requires little sample preparation, is radionuclide specific and produces results within a few hours.

All of the laboratories surveyed reported that they had the necessary equipment for the analysis of samples by gamma-ray spectrometry. However, one laboratory reported that it had only two spectrometers and, therefore, had limited capacity in comparison to the other seven laboratories.

While all of the laboratories surveyed had the equipment necessary for the analysis of samples by gamma-ray spectrometry, this equipment must be appropriately calibrated for the measurement of these radionuclides. The appropriate calibration is based on three factors:

1. The material from which the sample is composed
2. The volume and shape of the container holding the sample
3. The radionuclides used in the calibration source

The most common sample materials requiring analysis subsequent to a radiological incident are water, soil and food/vegetation. Each of these three materials has significantly different elemental compositions and densities. Due to these differences, a spectrometer should have a different calibration for each material in order to produce accurate measurements.

However, in the response to a radiological incident, such a high level of accuracy is usually not required. This is because, in most cases, decision makers will have set reference levels above which the material is considered to be 'contaminated'. The purpose of the analyses is simply to determine whether the material from which the sample was taken is contaminated or not. Furthermore, most decision-makers would apply a conservative approach to the results. In other words, they would rather treat some 'uncontaminated' material as if it were 'contaminated', than risk the reverse error. Therefore, results with relatively large uncertainties (for example, 20%) would be acceptable so long as the estimate of the uncertainty is robust.

For most radionuclides, such a level of accuracy can be achieved by using a calibration based on water for all materials. Unfortunately, a calibration based on soil can lead to errors of more than 10% if used for low-density food/vegetation, and vice-versa. All but one laboratory reported that they have calibrations based on a water matrix. However, the laboratory that did not have calibrations based on water did have specific calibrations for soil and food. So, all eight laboratories have calibrations appropriate for use with samples generated from a radiological incident.

In order to minimise the time to analyse a sample by gamma-ray spectrometry, the sample container should maximise the amount of material in the sample, while minimising the distance between the outer contour of the sample and the detector. Therefore, the most appropriate container for samples from a radiological incident would be 500 ml or 1 litre re-entrant beakers (Marinelli-style). Six of the eight laboratories use this size and style of container. Of the other two laboratories, one uses 200 ml re-entrant beakers and the other uses 100 ml bottles.

For the analysis of samples from a range of radiological incidents, the spectrometers would be required to be calibrated for the energy range of 50 – 2000 keV. Based on the answers to the survey, seven of the eight (and probably all) laboratories are calibrated for this energy range. However, the actual radionuclides used for the calibration are important. Several laboratories reported that their calibrations are bases on radionuclides in the Uranium and Thorium decay chains. Calibration with these radionuclides does not provide a measurement of the true detection efficiency of the detector due to an effect called True Coincidence Summing. True Coincidence Summing is caused when the radioactive decay of a radionuclide produces two or more gamma-rays (e.g. Bi-214) and both of these gamma-rays are simultaneously detected. If the calibration source includes such radionuclides, this effect leads to an underestimation of the detection efficiency. This under-estimation is unimportant when measuring the same radionuclides as those in the calibration source. However, it leads to an over-estimation of the activity of other radionuclides.

Taking into account all three requirements, only four of the eight surveyed laboratories can be relied upon to produce reliable results for the broad range of gamma-emitting radionuclides listed in the IAEA guidance document (5).

The primary focus of the other four laboratories is on specialised measurements and they have no incentive to meet the requirements discussed here. However, these four laboratories do have a latent capability for more generalised gamma-ray spectrometry. With assistance, these four laboratories might be able to produce reliable measurements in response to a radiological incident.

3. Radiochemistry

Radionuclides that do not emit gamma-rays require chemical separation from the material containing them prior to analysis. The radionuclides that fall into this category include isotopes of strontium, uranium, thorium and polonium.

This chemical separation usually requires digesting or leaching the sample with strong acids as a first step. Seven of the eight laboratories surveyed indicated that they had the capability to leach or digest samples. The use of hydrofluoric acid (in association with other acids) or fusion is used to achieve a total digestion. However, only two laboratories reported that they could use hydrofluoric acid and no laboratories use fusion techniques. Four of the eight laboratories reported that they had microwave-digestion equipment, which enables rapid chemical digestion but the sample mass that can be digested is limited.

Once the radionuclide of interest has been brought into solution, it has to be separated from the interfering elements and other radionuclides in the solution. Unfortunately, there is no general procedure for this because it relies on the specific chemical properties of the element to be separated and the specific measurement technique. The number of laboratories able to separate the radionuclides that are most commonly included in planning for a radiological incident is shown in Table 1.

Table 1: *Number of laboratories able to separate particular radioactive elements.*

Element	Number of laboratories
Strontium	6
Uranium	6
Thorium	6
Radium	4
Polonium	5
Plutonium	4

Even though several laboratories report being able to separate each of these elements, the actual procedure used by each laboratory may differ and their procedures may only be suitable for particular sample types. In the response to a radiological incident, it would be preferable that all laboratories used the same radiochemical procedures so that questions as to inter-comparability would not arise. Promulgation of a standard set of radiochemical procedures would encourage such uniformity in Australasian laboratories.

4. Beta-emitting Radionuclides

Most beta-emitting radionuclides also emit gamma-rays and, so, are amenable to measurement by gamma-ray spectrometry. However, some, particularly tritium and some isotopes of strontium, do not. Also, some, such as Pb-210, emit gamma-rays at very low rates, making their measurement by gamma-ray spectrometry difficult. These radionuclides are usually measured by Liquid Scintillation Counting (LSC) after chemical separation.

Seven of the eight laboratories surveyed indicated that they have the necessary equipment for LSC. There are two main types of LSC instruments used: Tricarb™ and Quantulus™. Five laboratories reported using Tricarb™ instruments and five reported using Quantulus™, with several laboratories using both.

There is significant capacity and capability within Australasian laboratories for the measurement of beta-emitting radionuclides, particularly radio-strontium for some sample types.

5. Alpha-emitting Radionuclides

The most difficult radionuclides to measure are those that emit only alpha-radiation. This is because alpha-radiation is rapidly absorbed in only a few microns of material. Therefore, such radionuclides have to be carefully separated from all other elements and prepared for measurement in such a way that there is no significant matter between the atoms of the radionuclide and the detector. Unfortunately, several radionuclides that may be present in a radiological incident fall into this category. This group of radionuclides includes isotopes of uranium, thorium, plutonium, americium and polonium.

The measurements are further complicated by the high inhalation and digestion dose coefficients associated with alpha-emitting radionuclides. This means that the required detection limits are low and, therefore, long count times are required. For a laboratory to have significant sample throughput, it requires a large number of detectors. While all laboratories reported having some alpha-spectrometers, only three reported having more than 16. Therefore, there is limited capacity for such measurements in most laboratories.

6. Staffing

The response to a radiological incident not only requires sufficient equipment, but also the staff to run it. It is likely that, at least for a few weeks following a significant incident, laboratories would be required to operate on a 24-hour basis in order to process the number of samples in the short time-frames required.

Two laboratories reported having only 1 or 2 full-time equivalent staff, two reported having between 2 and 5 staff and four laboratories reported having between 5 and 8 staff. Therefore, only the four largest laboratories would have sufficient staff to run on a 24-hour basis.

7. Rapid Screening

All radionuclides emit either beta- or alpha-radiation. The significant attributes of LSC are:

- it can measure beta-emitting radionuclides;
- it can also be used to measure alpha-emitting radionuclides; and
- it has a very high detection efficiency

These attributes mean that LSC can be used for rapidly screening samples where the contamination is due to only one radionuclide and the screening levels are much higher than those due to naturally occurring radionuclides. For more complex contamination scenarios, extraction and/or separation would be required.

The challenges faced in the rapid determination of these radionuclides are:

- rapid digestion or dissolution of non-aqueous samples
- rapid separation of the required radionuclide from the sample matrix
- rapid counting to a sufficient detection limit

Ideally any standardised rapid methods would be applicable to the majority of Australian radiochemistry laboratories. Therefore consideration should be given to techniques and equipment currently being employed. Given that so many laboratories have LSC capability, there is potentially a significant capacity to use LSC for rapidly screening samples.

A review of the literature reveals that there are few standard methods utilising LSC for rapid screening. Australia would have to develop and promulgate such methods in order to take advantage of this capability.

The time and effort involved in the development and validation of rapid methods could be considerable. The task would include:

- prioritising the radionuclides of interest, the sample matrix and the required detection limits
- reviewing the literature for available methods
- trialling suitable methods
- selection of method
- validation (including inter-laboratory testing)
- promulgation of the method and training

Once the methods have been adopted, regular proficiency testing would be required to maintain the capability of laboratories. This is particularly important for the analysis of many of the anthropogenic radionuclides that are not normally analysed.

8. Conclusion

Eight Australasian radionuclide laboratories were surveyed as to their capabilities and capacity to perform analyses in the event of a radiological incident. The survey found that there was significant capability for radio-analysis in Australasia.

Seven of the eight laboratories were found to have a sufficient number of high-resolution gamma-ray spectrometers to provide significant support. However, three of these laboratories do not currently have this equipment appropriately calibrated for general spectrometry due to their specialisation in particular measurements. Assistance with the provision of appropriate calibration standards and conducting annual Proficiency Test Exercises at minimal cost to participants may encourage all laboratories to develop and maintain generalised gamma-spectrometry capabilities.

Seven of the eight laboratories surveyed were found to have radiochemical capabilities. However, there is also considerable specialisation in this area and it is unlikely that laboratories would have procedures in place for the treatment of all radionuclides of interest. Promulgation of a standard set of radiochemical procedures might encourage inter-comparability and greater breadth of radiochemistry capability in Australasian laboratories.

The survey found that there is significant capacity and capability within Australasian laboratories for the measurement of beta-emitting radionuclides, particularly radio-strontium in common sample types.

The survey also found that there is significant capacity to use Liquid Scintillation Counting for rapidly screening samples. Unfortunately, there are few standard methods utilising LSC for rapid screening.

While all laboratories reported having some alpha-spectrometers, only three reported having more than 16. Therefore, there is limited capacity for the measurement of alpha-emitting radionuclides in most laboratories.

Only four of the eight laboratories were found to have sufficient staff to provide 24-7 laboratory support in the event of a significant radiological incident.

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