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A Simple Method For The Verification of Clearance Levels For Non-Radioactive Solid Waste.

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Abstract.

ANSTO's radiopharmaceutical production laboratories generate 25 m^3 of solid waste per month. Most of this waste is not radioactive. Up until recently the non-radioactive waste was cleared from the controlled area and stored for 10 halflives prior to disposal as normal solid refuse.

To eliminate the storage and "double handling" of the large quantities of non-radioactive waste a simple clearance method was devised to allow direct disposal. This paper describes how clearance levels were determined. Here the term "clearance level" is used as a general term for the release of material regardless of whether it was previously subject to regulatory control. This contrasts with the IAEA definition of a clearance level and highlights a potential problem with the implementation of exemption levels to keep material out of regulatory control and the use of clearance levels to allow removal of materials from regulatory control.

Several common hand held contamination monitors were tested to determine their limits of detection and ability to meet these clearance levels. The clearance method includes waste segregation and size limitation features to ensure the waste is monitored in a consistent manner, compatible with the limits of detection.

The clearance levels achieved were subsequently found to be compatible with some of the unconditional clearance levels in IAEA-TECDOC-855 and the measurement method also meets the required features of that document.

The ANSTO non-radioactive waste clearance system has been in operation for more than 12 months and has proved simple and effective to operate. Approximately 12 m^3 of the solid waste is now been treated directly as normal solid refuse.

This paper describes the ANSTO clearance system, the contamination monitor tests and details practical problems associated with the direct monitoring of solid waste, including averaging of the activity in the package. The paper also briefly highlights the potential problem with the use of exempted material in a contamination controlled area and subsequent need for clearance from that area.

Introduction.

Australian Radioisotopes (ARI), radiopharmaceuticals Division, ANSTO produces medical radioisotopes for use in Australia and overseas. The production laboratories

are classified as supervised and controlled areas in terms of potential external radiation and contamination levels. All material leaving these areas must be monitored for both dose rate and contamination and a clearance certificate issued. Radioactive waste is sent to the Waste Management Section for compacting and storage. For many years this included solid waste monitored as being "background". This latter waste category was stored for a period of ten half-lives based on the potential radioactive contaminant, prior to disposal as normal solid refuse.

Due to the reduction of available storage space, the additional unnecessary handling of the "non-radioactive waste" and the costs incurred for storage, attempts were made to reduce the quantity of material going to the Waste Management Section for treatment. The first step was to reduce the amount of non-essential material entering the laboratories. This lead to only a relatively small reduction of the non-radioactive waste and 25 m^3 per month still required treatment. The second step was to devise a simple monitoring system which would confirm waste as non-radioactive waste ie., below appropriate clearance levels, and allow it's disposal as normal refuse with out further treatment. (The distinction between exemption and clearance levels is only covered briefly in the report. Clearance levels will be used as a general term and not the IAEA definition. However this distinction may raise a problem of interpretation when Regulat!!ory Authorities implement clearance levels.)

Determination of Appropriate Clearance Levels.

ARI is situated at the Lucas Heights Science and Technology Centre (LHSTC), an Australian Commonwealth Government research organisation, located on Australian Commonwealth territory within the State of New South Wales (NSW). Although not subject to NSW State legislation, LHSTC complies with the Australian National Health and Medical Research Council (NHMRC) Codes of Practice, and the recommendations of the International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection (ICRP) which are the basis of the State regulations. A government appointed independent group of experts form a Safety Review Committee which reviews operations at LHSTC to ensure they are carried out to the highest safety standards.

To ensure the treatment of ARI's non-radioactive waste would meet appropriate legislation and recommendations, the following three documents were examined.

- NSW Radiation Control Act 1990-Regulation. (Radiation Control Regulation 1993). 1993-No 434.
- NHMRC Code of Practice for the Disposal of Radioactive Wastes by the User (1985).
- IAEA International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. Interim Edition. Safety Series No 115-1.

The most restrictive of the "waste package limits", "prescribed activities" or "exemption levels" from these documents were selected as clearance levels.

The NSW Environment Protection Authority (EPA). NSW Radiation Control Act

1990-Regulation. (Radiation Control Regulation 1993). 1993-No 434, detail "prescribed activities", below which a material would be outside regulatory control.

Package limits from the NHMRC Code of Practice for the Disposal of Radioactive Wastes by the User (1985) were also examined. However these levels would require the waste to be sent to a tip licensed to receive radioactive materials. The intention of the proposed system was to confirm the waste in question was non-radioactive and outside regulatory control. The NHMRC levels were therefore only examined as a guide to be met if the waste could not be classified by direct measurement as non-radioactive under other recommendations.

The proposed exemption levels in the IAEA International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. Safety Series No 115, were also examined as potential appropriate clearance levels. **These exemption levels were considered as appropriate clearance levels as the intention of the system was to exclude the non-radioactive waste from regulatory control rather than clear materials which were already under regulatory control.**

Table 1 gives the EPA prescribed activities, NHMRC package limits and IAEA exemption levels for the radioisotopes under consideration.

Table 1. EPA prescribed activities, NHMRC package limits and IAEA exemption levels

ISOTOPE.	NSW EPA PRESCRIBED ACTIVITY.		NHMRC PACKAGE LIMIT.	IAEA EXEMPTION LEVEL.	
	Bq	!!Bq g^{-1}	Bq	Bq	Bq g^{-1}
rdrrPhosphorus-32	4 E 06	100	8.3 E 07	1 E 05	1 E 03
!!rw15 Chromium-51	4 E 06	100	5.5 E 09	1 E 07	1 E 03
Gallium-67	4 E 06	100	1.1 E 09	not quoted	!!not quoted
Yttrium-90	4 E 06	100	7.4 E 07	1 E 05	1 E 03
Molybdenum-99	4 E 06	100	1.7 E 08	1 E 06	1 E 02
Technetium-99m		4 E 07	100	9.1 E 09	1 E!! 07 cell 1 E 02
Iodine-125	4E 05	100	1.3 E 07	1 E 06	1 E 03
Iodine-131	4 E 05	100	9.1 E 06	1 E 06	1 E 02
!!Thallium-201	4 E 06	100	2.1 E 09	1 E 06	1 E 02

In general the NSW EPA prescribed activity levels were similar to or more restrictive than those in the other documents. The NSW levels were therefore used as the initial levels to meet.

It should be noted that subsequent to the implementation of the non-radioactive clearance system the IAEA-TECDOC-855; Clearance levels for radionuclides in solid materials. Applications of exemption principles. Interim report for comment. January 1996, was also examined. Although this TECDOC covered unconditional clearances many of the levels quoted in it were consistent with the levels which could be achieved using the ANSTO non-radioactive waste clearance system. Table 2 details selected single value clearance level suggested in IAEA-TECDOC-855. As the ANSTO non-radioactive waste would be treated as normal refuse and sent to a landfill site, the disposal of this waste could be considered as conditional on it being sent to a landfill site. The level used for the clearance of non-radioactive waste could therefore be considered as conditional clearance levels.

Table 2 Single value clearance level suggested in IAEA-TECDOC-855.

ISOTOPE	UNCONDITIONAL CLEARANCE LEVELS $Bq\ g^{-1}$
Chromium-51	90
Gallium-67*	18
Molybdenum-99*	15
Technetium-99m	30
Iodine-131	9
Thallium-201	60

The single value clearance level for each isotope was calculated as recommended in TECDOC-855, by multiplying the low range value in table I.6. of the TECDOC by 3.

*The low range value for these isotopes were calculated using the formula in TECDOC-855.

Test of Monitoring Equipment to Meet Clearance Levels.

To reduce the amount of handling required prior to clearance it was intended that the waste would be monitored in the plastic waste bags normally used in the laboratories. A problem with testing the limit of detection of monitors for waste in a package was to try to allow for both homogeneous and inhomogeneous contamination in the waste. It was decided that averaging the activity over a relatively small package and carrying out a number of measurements at different locations was acceptable and consistent with Exemption Orders used elsewhere. (The averaging was also found later to be consistent with the approach in IAEA-TECDOC-855.)

Five commonly used radiation monitors were examined to determine if their limits of detection could meet the clearance levels proposed. The limit of detection was taken to be equivalent to 2 x background count rate on the monitor ratemeter.

The beta emitters were expected to be difficult to monitor in a package, however it was decided to examine the level of bremsstrahlung which would be generated and

monitored.

Most of the non-radioactive solid waste generated in the laboratories is paper or thin walled plastic bottles. Two of the plastic bags used in the laboratory were filled to their normal volume, one with paper and the other with plastic bottles. The mass and diameter of each of these bags was 3kg and 50cms.

The following procedure was carried out in turn for each of the contamination monitors and each of the radioisotopes detailed in table 1. The background count rate in the test area was measured using the contamination monitor. A small bottle containing the radioisotope, with an activity equal to the NSW prescribed activity level, was placed in the centre of a waste bag containing paper. The contamination monitor was used to measure the count rate at 4 sides and the top and bottom of each bag. The net count rates were calculated and the average of the six readings recorded. The average value was divided by the activity of the radioisotope used in the test bottle to obtain a cps Bq^{-1} conversion factor for the monitor and that radioisotope. To estimate the lower limit of detection (LLD) in Bq for the monitor and radioisotope, the background count rate measured by the monitor was multiplied by 2 and then divided by the radioisotope conversion factor. The LLD!! in Bq g^{-1} was calculated by dividing the LLD in Bq by 3kg, the weight of the bag. The LLDs in Bq and Bq g^{-1} were then divided by the Bq and Bq g^{-1} prescribed activity levels and converted to a percentage. This was then repeated for the waste bag containing plastic bottles. The results of the tests are detailed in Appendix 1.

Summary of the Results of the Measurements.

The response of each monitor was obviously dependent on the type of detector and the detector size. As the LLD (or activity equal to "2 x background") was determined by the background count rate on the monitor, in some cases the advantage of the sensitivity of a larger volume detector was cancelled by the increased detector background.

The results showed that the 100 Bq g^{-1} value quoted in the NSW EPA prescribed activity values was the more restrictive value to detect.

As expected the bremsstrahlung generated by the beta emitters was not sufficient to allow the prescribed activity levels to be measured. However subsequent measurements did show that bremsstrahlung could be used to indicate that following a sufficient decay period the activity would be below the prescribed activity levels. Similarly, although a bag of plastic bottles potentially contaminated with Chromium-51 could not be released immediately as being below the prescribed activity level, following a short decay period the estimated activity would be below that level and the waste treated as normal refuse. An alternative to the decay in the case of Chromium-51 would be to move the waste to be monitored in a building with as lower background.

The selection of the monitor to be set aside solely for the clearance of non-radioactive

waste was made by comparing the results of the monitoring and the cost and availability of the monitor. It was also determined that waste potentially contaminated by Iodine-125 was only a small fraction of the total and could be segregated and sent to the Waste Management Section with out being included in this clearance system. The ratemeter and 2.5 cm diameter 1.7cm thick NaI crystal was selected as being a suitable monitor for use with this particular clearance system.

As additional information the LLDs in Bq g^{-1} for the monitor incorporating the 2.5 cm diameter 1.7cm thick NaI crystal have been detailed in Appendix 2 for comparison with the TECDOC-855 unconditional clearance levels. The results show that generally the system devised can meet levels similar to the TECDOC-855 levels. The system outlined in the paper allows measurements to be made in an area where the background is 15 cps and the LLD (2 x background) is therefore equal to 30cps. If measurements were made in an area where the background was 5 cps the LLD would be equal to 10 cps and the equivalent Bq g^{-1} figure would be one third of the LLD values in Appendix 2. The system would therefore easily meet the TECDOC -855 unconditional clearance levels.

Controls To Ensure Correct Monitoring Of The Waste.

A Standing Operating Procedure (SOP) was produced to control the monitoring of the non-radioactive waste. The SOP includes the following quality control requirements to ensure the monitoring of the waste will detect the selected radioisotopes below the prescribed activity levels.

- To ensure the waste has not been part of regulatory control the non-radioactive waste is kept segregated from potentially contaminated waste.
- The non-radioactive waste is segregated so that only waste from areas using those isotopes which have been shown to be detectable at prescribed activity levels is cleared under this method.
- Only non-radioactive waste containing paper or plastic bottles can be cleared by this method.
- Waste bags must fit into a container used to ensure their diameter does not exceed 50cms.
- The dose rate in the area where measurements are carried out should not exceed 15cps on the monitor used for clearance.
- Each bag is monitored on 4 sides, the top and bottom. If all measurements are below 2 x background count rate the waste is confirmed as non-radioactive and disposed of as normal solid refuse.
- Each bag of waste is numbered and records are kept of their monitoring.

Conclusion.

The introduction of the non-radioactive clearance system in the ANSTO radioisotope production laboratories has reduced the amount of waste being treated by Waste

Management Section by 50% or 12.5 m^3 per month.

By using suitable monitoring and control methods direct measurement on bags of solid waste can be used for the clearance of waste containing typical photon emitting radioisotopes used in medical facilities. A simple set of tests similar to those described in this paper can be used to confirm the ability to monitor appropriate clearance levels.

If it was necessary for the clearance system outlined to meet the TEDOC-855 unconditional clearance levels, this could be achieved by monitoring the solid waste in an area with a lower background.

Discussion.

While examining appropriate levels for the clearance of radioactive waste there appeared to be potential problems with the implementation of Exemption levels and Clearance levels.

1. The Clearance levels "shall not be higher than the exemption levels—" Basic Safety Standards (BSS) This obviously implies they will be equal to or less than Exemption levels. However if the sources are below the levels in Table I-I of the BSS they are "automatically exempt without further consideration ---" This implies they have met the limitations on dose criteria. If the pathways used in the assessment of the exemption levels are typical of those expected to be encountered why should a Clearance level be below an Exemption level? Should the acceptable pathways be stated?

2. An Exemption level is used to exempt a source from Regulatory control while a Clearance level releases a source from Regulatory control. If an exempt source is taken into an area which is subject to regulatory control does the source now have to meet a Clearance level (which may be lower than the Exemption level) to leave the area? This does not seem to be reasonable. If this is not the intention it should be specifically stated, otherwise some Regulatory Authorities might require that approach.

Both problems would be resolved if the term clearance was used to indicate meeting exemption levels and the definition of these Exemption is expanded to include levels for the release of a source from Regulatory control. Exemptions could have Unconditional levels to exempt a source from Regulatory Control, even if it had previously been under Regulatory Control. Conditional Exemptions, with higher levels, could be used for specific uses of sources eg, smoke detectors, or on the disposal conditional eg, the use of a Licensed landfill site for hazardous materials.

It is suggested that the IAEA consider setting up a Working Group which would give specific advice on methods for the monitoring waste to meet Exemption levels. This Working Group should make recommendations on topics such as;

- the mass or volume of material the activity can be averaged over when monitoring.
- methods to confirm monitoring meets exemption levels.

- quality control aspects to ensure the monitoring is consistent with the confirmation tests.

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Disclaimer.

The views expressed in this paper are those of the author and do not necessarily represent those of ANSTO.

Appendix 1. Results of tests of clearance monitoring.

ISOTOPE !!	MONITOR	% OF NSW PRESCRIBED ACTIVITY LIMIT		% OF NSW PRESCRIBED SPECIFIC ACTIVITY LIMIT	
		paper	plastic	paper	plastic
rbChromium-51	I	7.3	8.3	100	110
!!sdrw30	2	53	100	700	1370
ntbl_3		*17*	*32*	*230*	*430*
	4	*38*	*43*	*500*	*570*
	5	*41*	*42*	*550*	*560*
Gallium-67	*1*	*1.5*	*2.3*	*20*	*30*
		2	*13!!ell 13*	*170*	*170*
	3	*2.8*	*4.0*	*40*	*50*
	4	*1.8*	*2.3*	*20*	*30*
	5	*3.5*	*4.3*	*50*	*60*
Molybdenum-99	*1*	*1.3*	*1.3*	*20*	*20*
	2	*6.8*	*9.0*	*90*	*120*
	3	*2.5*	*3.3*	*30*	*40*
	4	*1.5*	*1.8*	*20*	*20*
	5	*2.3*	*4.5*	*30*	*60*
Technetium-99m	*1*	*0.2*	*0.3*	*30*	*40*
		!!			
nowidctlpar	*2*	*0.6*	*NDA*	*80*	*NDA*
	3	*0.4*	*0.5*	*50*	*60*
	4	*0.2*	*0.2*	*20*	*30*
	5	*0.4*	*0.5*	*50*	*60*
Iodine-125	*1*	*880*	*NDA*	*!!1170*	*NDA*
	2	*100*	*140*	*140*	*180*
	3	*200*	*240*	*220*	*320*
	4	*28*	*43*	*40*	*60*
	5	*NDA*	*NDA*	*NDA*	*NDA*
	2	*85*	*NDA*	*110*	*NDA*
	3	*28*	*45*	*40*	*60*
	4	*33*	*45*	*40*	*60*
	5	*38*	*53*	*50*	*70*
!adjustright					
Thallium-201	*1*	*4.8*	*6.3*	*60*	*80*
	2	*10*	*15*	*130*	*200*
	3	*3.3*	*3.5*	*40*	*50*
	4	*1.0*	*1.5*	*10*	*20*
!! brdrh	*5*	*4.3*	*5.3*	*60*	*70*

!!Details of Monitors:

Monitor 1: Ratemeter with a 2.5cm diameter 1.7 cm thick NaI crystal probe.

Monitor 2: Ratemeter with a 15 cm^{-2} area end window gm tube probe.

Monitor 3: *Ratemeter with a 5cm diameter 5 cm thick NaI crystal probe.*
Monitor 4: *Ratemeter with a 5cm diameter 0.1 cm thick NaI crystal probe.*
Monitor 5: *Ratemeter with internal 2.5cm diameter 2.5 cm thick NaI crystal detector.*
The results in bold text show the monitors which met the prescribed level.

Appendix 2. Comparison of the results for the 2.5cm diameter 1.7 cm thick NaI crystal probe with the TECDOC-855 unconditional clearance levels.

ISOTOPE.	*TECDOC-855 Clearance level. Bq g^{-1}*	*LLD Bq g^{-1}*	
		Paper	*Plastic*
!!rdrsChromium -51	*90*	*100*	*110*
*Gallium-67**	*!!lpar18*	*20*	*30*
*Molybdenum-99**	*15*	*20*	*20*
Technetium-99m	*owidctlpar30*	*30*	*40*
Iodine-131	*9*	*10*	*10*
Thallium-201	*60*	*60*	*80*