RADIATION PROTECTION SERVICE

DEPARTMENT OF WELLBEING, SAFETY AND HEALTH

UNIVERSITY OF LEEDS

‘RADIATION EMPLOYERS’ GENERIC PRIOR RISK ASSESSMENT FOR PRACTICES UTILISING UNSEALED SOFT BETA-EMITTING RADIOISOTOPES AND LOW-ACTIVITY GAMMA-EMITTING SOURCES (I.E. RADIOIMMUNOASSAY KITS & CR-51)

INTRODUCTION

This prior risk assessment has been prepared to assess the hazards arising through the use of open (unsealed) radioactive sources containing soft-beta emitting radionuclides (e.g. ^{14}C, ^{33}P, ^{35}S) and low levels of <0.5 MBq ^{125}I or ^{51}Cr) and to determine appropriate control measures and mitigations.

WHO SHOULD READ THIS ASSESSMENT?

The radiation employer has written this risk assessment in three parts, the most relevant of which to radiation workers and their line managers is

Version	Author	Checked	Date of issue/review	Date of review
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Part A, (highlighted in blue); workers must read this part and be fully conversant with the application of the control measures contained therein.

Workers and line managers may read parts B and C **if they wish**, although there is no requirement to do so. These parts present the underlying reasoning and the basis for decision making as well as addressing statutory matters such as those raised in paragraph 44 of the Approved Code of Practice (ACoP) to the Ionising Radiations Regulations 1999 (IRR99).

Part A: to be read by radiation workers, line managers, Radiation Protection Supervisors (RPSs) and Radiation Safety Coordinators (RSCs).

This section summarises the risk assessment and presents the control measures that must be acted upon by the radiation user. It is the responsibility of the line manager to ensure that this is done. The RSC will check that the control measures are implemented, or give practical assistance in their implementation if necessary.

Part B: to be read by the radiation employer and radiation protection practitioners

By systematically addressing the issues identified in paragraph 44 of the ACoP to the IRR99, the radiation employer (after consulting its Radiation Protection Adviser; RPA) has made an assessment of the major hazards and laid down the guiding principles to be followed in controlling risk. Particular attention has been given to matters of local control, area designation, practical protection measures, administrative control measures, dose investigation levels, and the use of personal protective equipment (PPE).

Part C: to be read by radiation protection practitioners and be accessible to workers, line managers and safety practitioners

In this section the Head of Radiation Protection has presented a determination of the most likely exposure pathways, the potential dose, level of risk and the practical steps that must be taken to mitigate the risk.

THIS RISK ASSESSMENT

This risk assessment relates to the use of soft beta-emitters and low activity gamma / EC emitters in routine applications:

- *in vitro* labelling of nucleic acids and proteins,
- immunoassay,
- receptor second messenger assays
- ion channel assays
- sub cellular localization of biological molecules,
- radioligand binding techniques,
- enzyme assays
- general labelling, metabolic and probe studies

PERSONS AT RISK OF EXPOSURE

Laboratory workers

The persons most at risk of exposure are users and other laboratory occupants who are risk to exposure via internal irradiation pathways (radioisotopes transferred via ingestion, inhalation and skin absorption).

Cleaners, service engineers, visitors

Cleaners, Estates Services personnel (plumbers, electricians, etc.) and other visitors are at risk through the potential intake of contamination via internal irradiation pathways.

Members of the public, family (including breastfeeding infants and children), friends and work colleagues

The likelihood of members of the public etc. becoming exposed to lost or stolen radioactive material is rare, however the consequences could be severe if activity were to become released then inadvertently taken into the body. Similarly there is a need to be vigilant over the inadvertent transfer of contamination out of a laboratory on clothing or skin and into the home / public arena.

PART A: PRIOR RISK ASSESSMENT – A SUMMARY FOR RADIATION WORKERS

Exposure pathway (person at risk) Risk	**Risk control measures**
Opening a package (user) Skin contamination	Packages should be held on drip trays or Benchkote® until they are opened in case they are leaking. Open on Benchkote® following the correct procedure, monitoring each layer of packaging with a Mini Instruments type EP15 monitor (or similar) for beta-emitters and a scintillation monitor (e.g. Mini Instruments type 44) for ^{51}Cr and ^{125}I.
Dispensing activity (user) Skin contamination from spillages or dropping activity.	(1) Wear PPE (lab coats, gloves, lab specs). (2) Dispense high activity stocks at a workstation (see image above) in a Supervised Area. Activity in RIA kits may be dispensed at workstations in Undesignated Areas. (3) Do not work if under pressure, stressed or not confident. (4) Allow sufficient time and practice the dispensing technique before using activity. (5) Monitor work surfaces and the source pot for spills and contamination after dispensing. To check the source pot wipe with tissue paper then present the paper to a monitor (indirect monitoring). **(6) If handling volatile forms work in a fume cupboard.**

Exposure pathway (person at risk) Risk	**Risk control measures**
Using dispensed activity (user / other workers) External irradiation of body and extremities. Skin contamination and ingestion. Contamination of work place.	(1) Work in a Supervised Area at a fully equipped designated workstation set up as shown in the image at the top of this document. (2) If using ^{51}Cr or ^{125}I give consideration to the use of lead-impregnated Perspex® screens. (3) Use leak proof boxes for holding radioactive materials. (4) Wear PPE (lab coats, gloves and lab specs). (5) Guard against contamination by working over drip trays lined with Benchkote®, and also by carrying / storing materials in sealable plastic boxes or suitable trays. (6) Monitor work surfaces, equipment, lab coats and hands frequently. Monitoring regime: • Prior – to check the previous user has not left contamination. • During – repeated monitoring when working so as to ensure contamination isn't generated and spread. • After – to ensure the area is left clean. At the end of the work monitor floors, benches, taps, equipment, pipettes, waste bin lids, sink, etc. to confirm they remain clean. (7) Irrespective of whether contamination is found when monitoring, periodically swab all work areas, screens, boxes, fridges, etc. with paper towel moistened with Decon®. (8) Take steps to ensure contamination is minimised by having a disciplined laboratory cleaning regime / rota. (9) Do not touch your face or mouth when working with radioactive materials. Wash hands before leaving radiation labs. **(10) If handling volatile forms work in a fume cupboard.**

Exposure pathway (person at risk) Risk	**Risk control measures**
Storage (user / other workers) Skin contamination and ingestion.	(1) Ideally radioactive materials should be stored in dedicated facilities. Where this is not possible they must be stored in clearly identified areas and not on the same shelves as non-active materials. (2) Materials must be stored with plenty of space around them and not cramped or crushed in. (3) ‘As received’ sources must be stored in their containers / transport packs. (4) Sub-stocks or aliquots must be stored in leak-proof containers. In addition, all radio-labelled materials must held on small drip trays or in plastic boxes. (5) All materials must be labelled with the radionuclide, activity, owner, and date of creation (traffic light labelling is advised against) and stock or sub-stock reference number allocated by the inventory. (6) Fridges and freezers should periodically be defrosted and all storage locations periodically cleaned with Decon®, and monitored to confirm they are clean. Source pots etc. must be indirectly monitored before storage (wipe the source container with a tissue then monitor the tissue for removable contamination). (7) PPE must be worn when handling radioactive materials (lab coats, gloves, specs).

Exposure pathway (person at risk) Risk	**Risk control measures**
Waste disposal (user / other workers) Skin contamination and ingestion.	(1) Waste must be stored in the supplied yellow (solid waste) or blue (scintillant waste) bags as appropriate. (2) PPE must be worn when handling radioactive materials (lab coats, gloves specs). (3) When emptied the waste receptacles and bins should be monitored to check that they are free from contamination. (4) Bins, waste boxes and receptacles should be cleaned periodically with swabs moistened with Decon®. **(5) If handling volatile waste forms you will need to make special arrangements and must discuss the matter with your Radiation Safety Coordinator prior to starting work.**
Theft or loss (public) Skin contamination, ingestion and the inhalation of activity resulting from the release of radioactive materials. *Doses arising from intakes could cause significant biological detriment.*	(1) Radiation laboratories must be secured by Simons-Voss type locks or secured to a similar security standard. (2) Entry to radiation laboratories must be restricted to authorised persons only. (3) Acquired (purchased) radioactive materials must ONLY be delivered to departmental stores or other previously identified locations. (4) Delivered materials must be signed for and then stored under lock and key. (5) Ad hoc deliveries and informal arrangements are not permitted. (6) Signature based release processes must be in place to ensure materials are only released to authorised persons.

PART B: SOURCE DESCRIPTION, INHERENT CONTROL MEASURES, ETC. (ACOP PARAGRAPH 44)

Radioactive source and material data[i]

Radioisotope	energy; emission	physical half-life	biological half-life	critical organs
^{3}H	18.6 keV; β	12.35 y	12 days	body fluid
Most ^{3}H compounds are readily metabolised and excreted. Volatility risk: tritiated DNA precursors (e.g. thymidine) can become incorporated into DNA.				
^{14}C	156 keV; β	5730 y	10 days	whole body & fat
Most ^{14}C compounds are readily metabolised and excreted. ^{14}C readily penetrates the skin. ^{14}C labelled halogenated acids penetrate the skin and give high radiation doses. Volatility risk: $^{14}CO_2$.				
^{33}P	249 keV; β	25.3 days	257 days	whole body & bone
Radio-phosphorous compounds are not readily excreted and substantially decay in the body.				
^{35}S	167 keV; β	87 days	90-623 days[ii]	whole body & testes
^{35}S is not readily metabolised and tends to decay in the body.				

<table>
<tr><td rowspan="7"></td><td colspan="5">^{35}S-amino acids may be volatile and can be a particular contamination problem.
On account of the volatility and tendency to dissociate, it is recommended that ^{35}S sources are opened in fume cupboards.</td></tr>
<tr><td>^{45}Ca</td><td>257 keV; β</td><td>162.7 days</td><td>45 years</td><td>whole body & bone</td></tr>
<tr><td colspan="5">^{45}Ca is not excreted and mostly decays internally.</td></tr>
<tr><td>^{125}I</td><td>35.5 keV γ,
27 keV x-ray</td><td>60 days</td><td>120-138 days</td><td>thyroid gland</td></tr>
<tr><td colspan="5">Low pH causes dissociation and volatilisation.
Iodine strongly targets the thyroid; volatile forms must be handled in a fume cupboard.</td></tr>
<tr><td>^{51}Cr</td><td>320 keV γ,
5 keV x-ray</td><td>27.7 days</td><td>616 days</td><td>whole body</td></tr>
<tr><td colspan="5">Chromium is not strongly bound although a substantial activity would decay in the body, emitting a penetrating gamma component.</td></tr>
<tr><td>External irradiation dose rates from 1 mCi (37 MBq) source assuming that no radiation shielding is used (beta or gamma screens, pipette shields, Perspex waste containers, etc.).</td><td colspan="5">Beta emitters
Considered as an external irradiation source, beta particles having energies less than 0.3 MeV[iii] have insufficient to energy to penetrate the skin and therefore do not present an external irradiation hazard. The low energy electrons are mitigated by collision reactions in
• the solution (self-absorption),
• vessel / container walls,
• air,
• the stratum corneum (dead outer layer of skin).</td></tr>
</table>

	Gamma emitters Iodine-125 Whole body: 0.014 mSv h^{-1} Extremities: 0.13 mSv h^{-1}		Chromium-51 Whole body: 0.002 mSv h^{-1} Extremities: 0.003 mSv h^{-1}	
Internal irradiation doses derived from the inhalation, ingestion or absorption through the skin of 1 mCi (37 MBq) of activity.[iv]	**Radioisotope**	**Inhalation (mSv)**	**Ingestion (mSv)**	**Skin absorption (mSv)**
	^{3}H	1.5	1.5	1.5
	^{14}C	22	22	22
	^{33}P	52	8.9	no sorption
	^{35}S	48	28	no sorption
	^{45}Ca	100	28	no sorption
	^{51}Cr	1.3	1.5	92[v]
	^{125}I	270	555	130[vi]
Foetal exposures resulting from a maternal intake of 10 µCi (0.37 MBq) of activity, representing an intake of 1% of the maximum activity likely to be handled in a Supervised Area.[vii]	**Radioisotope**	**Foetal dose (mSv)**		
	^{3}H	0.03		
	^{14}C	0.4		
	^{33}P	2.0[viii]		
	^{35}S	0.6		
	^{45}Ca	4.0		
	^{51}Cr	-		
	^{125}I	6.0		

Dose investigation or other trigger limits	The University dose constraint is 1 mSv y^{-1} to the whole body and 10 mSv y^{-1} to the hands, with 8-hour time averaged dose rates being 0.5 µSv h^{-1} and 5.0 µSv h^{-1} respectively. Evidence supporting this position is derived from the historical dosimetric record and observations of practice, all of which support the view that it is reasonable practicable to restrict exposures without compromising operational effectiveness. With respect to the soft beta emitting radionuclides, where dosimetry is an unreliable measure, constraint is achieved through practical protection, monitoring and intervention.
Designated areas	The criteria for establishing Supervised Areas are derived from International Commission for Radiological Protection guidelines (particularly those promulgated in ICRP 25, ICRP 73) and consideration of the GSK / Pharmaceutical Industry model. **Supervised Areas** > 3.7 MBq of ‘soft’ beta-emitters (<0.3 MeV): ^{3}H, ^{14}C, ^{33}P, ^{35}S, ^{45}Ca and the gamma emitter ^{51}Cr. >0.37 MBq of gamma emitters (e.g. ^{22}Na, ^{137}Cs, ^{204}Tl), radioiodines and uranyl / thorium compounds. **Undesignated Areas** Low risk work, i.e. where radioisotopes are chemically stable (no volatile forms) and activities are less than those specified for Supervised Area limits, may be undertaken at work stations in Undesignated Areas. When deciding whether work should be carried out in Supervised or Undesignated Areas, careful consideration should also be given to: • preventing the spread of contamination, and, • controlling and / or venting volatile forms.

Shielding, exposure control measures or safety design features	In both Supervised and Undesignated Areas radiation work must only be carried out at suitably equipped workstation such as shown in the image at the top of this document. Although Perspex body shields are not necessary to shield from exposure to beta-emitting radionuclides they should be considered if there is a risk of aerosols or splashes being generated and contaminating the users clothing. Lead impregnated Perspex body shields should be used when dose rates arising from gamma emitting or electron capture radioisotopes exceed 0.5 µSv h^{-1} at 30 cm from the source.
Risk of contamination	The risk of contamination is always present and can never be wholly minimised, and it must be assumed that contamination or spillage will occur, albeit infrequently. Common contamination events include the dropping or knocking over materials and sources, leakage, aerosol generation (particularly when using septum-sealed source vials) and the spread of droplets. **Behavioural contamination control** To minimise risk work should be properly planned, then carried out methodically and with care. Furthermore, users should not work if under stress / adverse pressure or there is a likelihood of being rushed to complete an experiment. Rehearsal will familiarise the user with the technique and likely reveal any limitations or handling difficulties. **Practical contamination control** Work must be carried out in drip trays that are fitted with suitable liners, and the drip trays must be underlain with Benchkote® or a similar absorbent layer. The image at the top of this document shows a well laid out workstation designed to control any potential contamination events. **Storage in use and short term storage in fridges / freezers**

	Sources and materials must be held in stable, leak-proof, sealable plastic containers. Source pots should be held on small trays before placing in fridges / freezers. Materials should not be crammed into fridges and freezers. **Personal protective equipment (PPE)** Laboratory coats, lab specs and nitryl (etc.) gloves must always be worn when working in radiation labs. **Monitoring** Work surfaces, clothing, equipment, pipettes, benches, sinks, taps, the floor, fridges, etc. should be monitored frequently. Workstations and clothing must be monitored before commencing work, frequently during work, and after work has been cleared away.
Risk of the release of airborne or surface contamination during normal operational use, storage or stowage.	**Aerosols** Aerosols may be released when using septum source pots and syringes. The 'hot' side of body screens and drip tray should be checked for contaminating droplets after dispensing activity. **Volatile forms** Certain tritiated, ^{35}S and ^{125}I forms are known to occur in volatile forms. Users must read product information supplied with these radioisotopes. If there are potential problems with volatility then work must be carried out in a fume cupboard (not a recycling type fume hood).
Risk of the release of radioactivity in a laboratory fire	**Risk to University personnel** These radioisotopes volatilise at a sufficiently low temperature for it to be assumed that any sources held in storage cupboards or fridge / freezers will so do, even in a relatively low-temperature fire. Therefore, in the event of a laboratory fire it must be assumed that contamination is widespread and that specialised clearance work is required.

	Risk to fire fighters Fire fighters entering Supervised Areas that are on fire should assume there is radioactive contamination in the flame / smoke, and that fridges and freezers will be contaminated. Breathing equipment should be used before entry. The use of high pressure hoses will cause contamination to be spread.
Consequence of failures of control measures or associated equipment	Checking regimes for PPE should ensure that suspect equipment is identified and either repaired or disposed of.
PPE required	Laboratory coats (sacrificial layer), safety specs and gloves (e.g. nitryl) must be worn in radiation laboratories.
Radiation dosimetry required	Beta-emitters: none. Gamma and electron capture: dependent upon activities handled. In general, users of hard beta and gamma emitting radionuclides working in Supervised Areas should wear dosemeters. Exceptions include persons handling RIA kits (low risk), who would not be required to wear dosemeters irrespective of where the kit was used.
Systems of work, administrative controls and other relevant information	Local rules and contingency plans have been prepared. Standard Operating Procedures and other guidance notes are available on the VLE. Radioactive sources are supplied with safety instructions that identify all general and specific hazards associated with a particular isotope and compound.
Training	Prospective users must be given a laboratory induction that should include local training on techniques and radiation safety measures. In addition to the ‘on the job’ training, users must attend such courses and refresher instruction as are required by the Dean of Faculty and / or the Radiation Protection Service. Typically, refresher training should be provided every three years.

PART C: DOSE ASSESSMENT AND HAZARD / RISK EVALUATION

Exposure pathway & persons at risk	Potential radiation exposure	Level of risk	Risk control measures
Opening a package Opening a transport package.			
User. Skin contamination; skin absorption & ingestion.	From surface contamination at 0.1 µCi (3.7 kBq) cm^{-2} Committed dose: ^{51}Cr - 10 µSv ^{125}I - 60 µSv	Health: Low. Leakage during shipment is rare (one instance of low level contamination of packaging every 5 years[ix]). Low level contamination is possible, although the radiological effects are negligible. Statutory: Low. The risk from received packages is low as packaging and transport is the responsibility of the consignor. The risk to a consignor is high.	Protection measures are monitoring and contamination control With the exception of ^{3}H and ^{14}C, contamination from soft beta emitters and gamma emitters is relatively easy to detect using an EP-15 type monitor or scintillation probe respectively. ^{14}C can be detected using an EP-15 if monitoring is undertaken slowly and carried out with care, but ^{3}H can only be detected by swabbing and liquid scintillation counting. Proper procedures must always be followed when opening packages and users must be vigilant in looking for signs of leakage (damp packaging, tide marks, etc.). Protection is secured by; • following procedures for opening packages, • monitoring where practicable, • training. Received packages should be held on small drip trays, or Benchkote®, both in stores and in the lab, until opened.

Exposure pathway & persons at risk	**Potential radiation exposure (without protective measures)**	**Level of risk**	**Risk control measures**
Dispensing Activity from a source pot Radioisotopes are frequently supplied in activities of 1 mCi (37 MBq), 3 mCi (111 MBq) and 5 mCi (185 MBq): for the purposes of this assessment it is assumed that aliquots of up to 1 mCi are dispensed from the stock.			
<u>User.</u> External irradiation of body and extremities during transfer of ^{51}Cr and ^{125}I from source pot to experiment.	Body dose whilst performing one transfer from an unshielded source pot = <1 µSv[x]. Extremity dose (fingers) whilst holding an unshielded pipette = <10 µSv.	Health: Low Doses are negligible. Statutory: Low Doses are negligible.	No measures are necessary on the grounds of exposures through external irradiation.
<u>User.</u> Skin exposure (external irradiation and absorption) resulting from spillage or dropping a source / aliquot during transfer.	Potential dose arising from the spillage of 1 mCi (37 MBq) of activity on the skin. Committed dose: ^{51}Cr & ^{125}I ~130 mSv[xi].	Health: Medium Spilling 1 mCi of activity onto the skin would result in a relatively high skin dose. Statutory: Medium In the event of an occurrence that was not properly detected or dealt with, the HSE would consider competence, supervision and dose limitation. (IRR99 Regs 8, 9, 11, 12, 14, & 18).	<u>Protective measures are PPE and competence</u> Suitable PPE (gloves, lab specs, lab coats) and sufficient clothing that covers any exposed skin (at risk). Users must: • be competent to work, • understand the level of risk, and risk control measures, • not work when under pressure or stress, and sufficient time must be allowed for the work to be completed, • rehearse dispensing technique until they are familiar, • only dispense at designated workstations, • be familiar with the contingency (emergency) plans. Workstations must be set up in such a manner that they can

Exposure pathway & persons at risk	Potential radiation exposure (without protective measures)	Level of risk	Risk control measures
			reasonably be expected to minimise the outcomes of a spillage or source dropping onto the floor (body screens, drip trays, Benchkote® (absorbent side up). In the event of a spillage onto PPE, clothing or the skin time is of the essence. Contaminated clothing should be removed as soon as possible and placed in the lab (wear a clean lab coat for the sake of decency) and contaminated skin washed.
User / other lab workers. Skin exposure (external irradiation dose) or ingestion of activity spilt onto the skin (internal dose) resulting from contamination spilt by a previous user.	From surface contamination at 0.1 µCi (3.7 kBq) cm^{-2} Skin dose = <4 µSv[xii]. Ingestion = 56 µSv for ^{125}I and <3 µSv for all soft beta emitters and ^{51}Cr.	Health: Low Cross contamination is an ever-present risk, usually resulting from carelessness when storing materials combined with a failure to monitor properly. Statutory: Low Issues revolve around competency, training and effective monitoring (IRR99 Regs 8, 9, 14 & 19).	Protective measures are PPE, competence and monitoring PPE must be worn when handling radioactive materials (lab coats, gloves specs). Users must be competent in the handling of radioactive materials and understand contamination control procedures. Users must ensure that materials being placed in storage are not leaking and are free from contamination. Source containers etc. removed from storage should be wipe tested for leakages (indirect monitoring). Group leaders should ensure a laboratory cleaning regime / rota is in place.
Storage			
User. External irradiation of body and extremities through exposure to stored materials.	Potential dose arising from an unshielded 5 mCi (185 MBq) source. Assuming an exposure if 1 minute, the body dose[xiii] = 1.2 µSv	Health: Low No risk to significant exposure through external irradiation of tissue.	Protection measures are appropriate storage 'As received' sources must be stored in their containers / transport packs. Sub-stocks or aliquots must be stored in leak-proof containers. All materials must be held on small drip trays or in plastic

Exposure pathway & persons at risk	Potential radiation exposure (without protective measures)	Level of risk	Risk control measures
		Statutory: Low – Medium Requirement for appropriate storage facilities (IRR99 Reg 29).	boxes.
User. Skin contamination (including external irradiation and absorption) leading to ingestion.	From surface contamination in the order 0.1 µCi (3.7 kBq) cm^{-2}. Committed dose: ^{51}Cr & ^{125}I Skin dose = 13 mSv. Ingestion = 56 µSv. ^{14}C, ^{33}P, ^{35}S, & ^{45}Ca Skin dose = nil Ingestion ~3 µSv ^{3}H Skin dose = nil Ingestion = 0.2 µSv	Health: Low Contamination and cross contamination are ever-present risks, arising as accidental spills or aerosols or resulting from poor practice. However, infrequent small contamination doses would not give rise for undue concern. Statutory: Medium Despite potential exposures being of low concern to health, there are statutory requirements to prevent contamination being spread, and therefore the provision (and use) of PPE, monitoring capabilities and suitable storage conditions are paramount (IRR99 Regs 9, 19 & 29).	Protection measures are PPE, monitoring and suitable storage PPE must be worn when handling radioactive materials (lab coats, gloves specs). All materials held on small drip trays or polythene boxes that are leak-proof and suitable for restricting the spread of contamination or leakages. Radioactive materials are ideally stored in dedicated facilities. Where this is not possible they must be stored in clearly identified areas and not on the same shelves as non-active materials. Materials are stored with plenty of space around them and not cramped or crushed in. All materials are labelled with the radionuclide, activity, owner, date of creation (traffic light labelling is advised against). Fridges and freezers should periodically be defrosted and all storage locations periodically cleaned with Decon® (or similar). Fridges are periodically emptied and monitored directly. Indirect monitoring of source pots etc. (wipe the source container with a tissue then monitor the tissue for removable contamination).

Exposure pathway & persons at risk	Potential radiation exposure (without protective measures)	Level of risk	Risk control measures
Waste disposal Disposing of radioactive waste can give rise to the risk of contamination being spread.			
User. Internal irradiation through the inadvertent ingestion of contamination in accumulated waste.	Exposure could arise from contamination of the skin with activity released from leaking vials or contact with contaminated waste. From surface contamination in the order 1.0 µCi (3.7-37 kBq) cm^{-2}. Committed dose: ^{51}Cr & ^{125}I Skin dose = 130 mSv. Ingestion = 560 µSv. ^{14}C, ^{33}P, ^{35}S, & ^{45}Ca Skin dose = nil Ingestion <30 µSv ^{3}H Skin dose = nil Ingestion = <2 µSv	Health: Low-Medium Contamination resulting from a failure to follow good lab practice is an ever-present risk, and in certain cases (^{51}Cr & ^{125}I) can lead to significant localised skin exposures or internal doses. Statutory: Medium Issues are PPE and monitoring (IRR99 Regs 9 & 19).	Protection measures are PPE, monitoring and suitable storage PPE must be worn when handling radioactive materials (lab coats, gloves specs). Indirect monitoring of the bins (wipe the source container with a tissue then monitor the tissue for removable contamination). Periodic cleaning of facilities, bins and waste boxes.

Exposure pathway & persons at risk	**Potential radiation exposure (without protective measures)**	**Level of risk**	**Risk control measures**
Theft or loss Loss or theft of radioactive materials from a laboratory or stores potentially exposes the general public of to the risks of contamination.			
<u>Employees / public</u> Internal irradiation through skin contamination (skin dose & ingestion) from release of contents and contamination.	From surface contamination at 5 mCi by ^{125}I: skin absorption dose =750 mSv ingestion = 2.8 Sv.	Health: High Given the high dose rate, any significant intake could cause harm and genetic damage, with the remote possibility of morbidity. Statutory: High Failure to secure radioactive materials would almost certainly result in prosecution.	<u>Protection measures are security and written instruction</u> Radiation laboratories must be secured to a standard provided by the fitting of Simons-Voss type locks. Entry to radiation laboratories must be restricted to authorised persons only. Acquired (purchased) radioactive materials must ONLY be delivered to departmental stores or authorised named persons and signed for. Delivered materials must be stored under lock and key. Ad hoc deliveries and informal arrangements are not permitted. Signature based release processes must be in place to ensure materials are only released to authorised persons.

FOOTNOTES

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[i] http://ehsrms.uaa.alaska.edu/RSDS/RSDSStartPage.htm

[ii] http://ehsrms.uaa.alaska.edu/RSDS/35S.pdf

[iii] www.sciencegateway.org

[iv] Radiation exposures calculated using most restrictive DPUIs in Delacroix et al (2002); CEDE (Sv) = activity (Bq) x DPUI (Sv/Bq).

[v] From Delacroix et al (2002) the contamination skin dose from a uniform deposit is 1.49 10^{-2} per 1 kBq cm^{-2}. Thus 37 MBq = 551 mSv h^{-1}. If contamination is removed after 10 minutes the effective dose would be 92 mSv.

[vi] From Delacroix et al (2002) the contamination skin dose from a uniform deposit is 2.11 10^{-2} per 1 kBq cm^{-2}. Thus 37 MBq = 781 mSv h^{-1}. If contamination is removed after 10 minutes the effective dose would be 130 mSv.

[vii] Based on the use of the most restrictive DPUI coefficients in ICRP 88 and HSE contract report 397/2001.

[viii] Based on the use of the most restrictive DPUI coefficient in HSE contract report 397/2001

[ix] There have been two instances in 10 years, one transport package that was uniformly contaminated by 10 cps iodine-125 (non-removable contamination), possibly by volatile radioiodine that had impregnated the cardboard in a transit warehouse, and a tritium source that had leaked and only been partially contained by the packaging...small amount of contamination (<5 Bq) on a storage shelf in a stores department.

[x] From Delacroix et al (2002) the external radiation dose rate from a point source at 30 cm is 1.4 10^{-2} mSv h^{-1} per MBq for ^{125}I and 2.0 10^{-3} mSv h^{-1} per MBq for ^{51}Cr. Thus 37 MBq = 0.5 mSv h^{-1} for ^{125}I and 0.07 mSv h^{-1} for ^{51}Cr, and if a transfer takes 1 second the received dose = <1 µSv.

[xi] From Delacroix et al (2002) the contamination skin dose from a uniform deposit is 1.49 10^{-2} mSv h^{-1} per 1 kBq cm^{-2} for ^{51}Cr and 2.11 10^{-2} per 1 kBq cm^{-2} for ^{125}I. Thus 37 MBq = 781 mSv h^{-1}. If contamination is removed after 10 minutes the effective dose would be 130 mSv.

[xii] From Delacroix et al (2002) the contamination skin dose from a droplet is 5.65 10^{-4} per 1 kBq cm^{-2} for ^{51}Cr and 6.3 10^{-3} for ^{125}I. Thus 3.7 kBq = 0.02 mSv h^{-1}. If contamination is removed after 10 minutes the effective dose would be 4 µSv.

[xiii] From Delacroix et al (2002) the external radiation dose rate from a ^{125}I point source at 30 cm is 3.90 10^{-4} mSv h^{-1} per MBq. Thus 185 MBq = 70 µSv h^{-1}, and so, for a 1 minute exposure the body would receive a dose of 1.2 µSv.