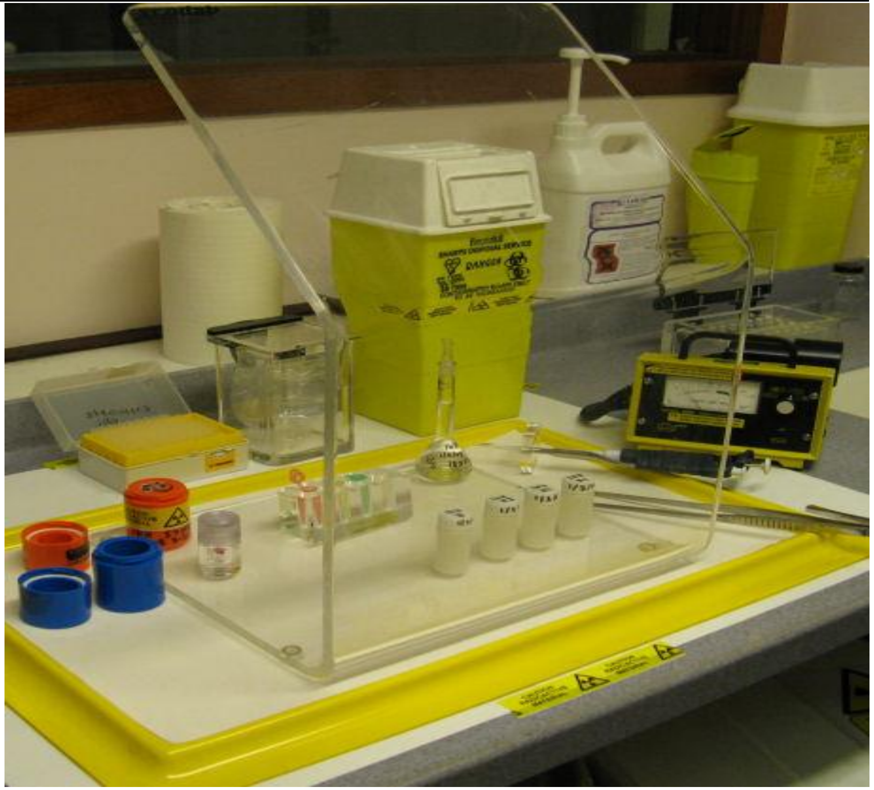
RADIATION PROTECTION SERVICE

DEPARTMENT OF WELLBEING, SAFETY AND HEALTH

UNIVERSITY OF LEEDS



‘RADIATION EMPLOYERS’ GENERIC PRIOR RISK ASSESSMENT FOR PRACTICES UTILISING UNSEALED PHOSPHOROUS-32

INTRODUCTION

This prior risk assessment has been prepared to assess the hazards arising through the use of open (unsealed) radioactive sources containing phosphorous-32 (^{32}P), 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 Part A, (highlighted in blue); workers must read this part and be fully conversant with the application of the control measures contained therein.

Version	Author	Checked	Date of issue	Date of review
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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 phosphorous-32 (^{32}P) in the following 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 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).
Dispensing activity (user) External irradiation of body and extremities (hands & fingers) during transfer. Skin contamination from spillages or dropping activity. *Dose rates are very high and even short exposures to unshielded radiation could cause biological damage.*	 (1) Wear PPE (lab coats, gloves, lab specs). (2) Dispense at a workstation (see image above) in a Supervised Area, ensure sufficient Perspex® shields are being used to shield radiation emissions. Use pipette shields. (3) Do not handle Eppendorfs containing radioactivity directly, use tongs, long handled tweezers or other similar devices. (4) Do not work if under pressure, stressed or not confident. (5) Allow sufficient time and practice the dispensing technique before using activity. (6) 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).

Exposure pathway (person at 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) Use Perspex® boxes for holding radioactive materials. (3) Wear PPE (lab coats, gloves and lab specs). (4) Guard against contamination by working over drip trays lined with Benchkote®, and also by carrying / storing materials in sealable plastic boxes or suitable trays. (5) 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.

Exposure pathway (person at risk)	Risk control measures
Storage (user / other workers) External irradiation through exposure to stored materials. 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. Materials must be stored with plenty of space around them and not cramped or crushed in. (2) 'As received' sources must be stored in their containers / transport packs. (3) Sub-stocks or aliquots must be stored in leak-proof containers and shielded by 1 cm Perspex®. In addition, all radio-labelled materials must held on small drip trays or in plastic boxes. (4) All materials must be labelled with the radionuclide, activity, owner, date of creation (traffic light labelling is advised against) and stock or sub-stock reference number allocated by the inventory. (5) 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). (6) PPE must be worn when handling radioactive materials (lab coats, gloves, specs).

Exposure pathway (person at risk)	Risk control measures
Waste disposal (user / other workers) External irradiation through exposure to accumulated waste. 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®.
Theft or loss (public) External irradiation of body and extremities. Skin contamination, ingestion and the inhalation of activity resulting from the release of radioactive materials. *Dose rates are very high and even short exposures to persons not familiar with these materials 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	Phosphorous-32: a 'hard' beta emitter that emits a particularly energetic beta particle of 1.709 MeV. *Beta particles having energies in excess of 0.3 MeV have been found to penetrate the stratum corneum (dead outer layer of skin) and irradiate tissue. Being so energetic, beta particles arising from the decay of ^{32}P are capable of penetrating deep tissue and delivering a significant radiation dose...* Biological half life (retention time in the body) = 257 days Physical half life (radioactive decay) = 14.3 days *This means that any ^{32}P taken into the body (ingested or inhaled) will decay almost completely in the body, delivering a substantial beta radiation dose to internal tissues.* Critical / target organs (preferential accumulation sites) = bone *This means that a radiological significant proportion of any intake will target skeletal tissue and potentially deliver a substantial dose to stem cells.* *This is of particular concern to pregnant women. Phosphorous is scavenged from the mother by the foetus, and so the risk of exposure of skeletal tissue is of high concern.*
Radiation dose rates from 1 mCi (37 MBq) ^{32}P assuming no radiation shielding (beta screens, pipette shields, Perspex waste containers, etc.) is used.	Dose rate to which the trunk of the body is exposed whilst standing at the bench = 4.4 mSv h^{-1} (data from Delacroix *et al*, 2002). *Estimated body dose whilst performing one transfer from an unshielded*

	source pot ~ 70 µSv. Dose to the fingers whilst holding a pipette = 884 mSv h^{-1}. *Estimated finger dose whilst performing one transfer from an unshielded source pot ~15 mSv.*
Unshielded radiation dose rates from 10 µCi (0.37 MBq) ^{32}P.	Dose rate to which the trunk of the body is exposed whilst standing at the bench = 44 µSv h^{-1} *Estimated body dose whilst performing one transfer from an unshielded source pot <1 µSv.*
Dose investigation or other trigger limits	The University has adopted a dose constraint of 1 mSv y^{-1} to the whole body and 10 mSv y^{-1} to the hands. The time averaged dose rates are 0.5 µSv h^{-1} and 5.0 µSv h^{-1} (both averaged over 8 hours) respectively. This dose constraint is based on more than 10 years of dosimetry data and observations of practice that indicate it is reasonable to expect that no radiation worker working under normal operational conditions should receive a radiation dose that exceeds a dose constraint. **Investigation triggers** Whole body: 0.4 mSv (a note is made on the dosimetry record), 0.6 (an investigation is undertaken by the RPO / RPA and a record made on Sentinel). Skin dose & extremities: 0.4 mSv (a note is made on the dosimetry record), 0.6 (an investigation is undertaken by the RPO / RPA and a record made on Sentinel).
Designated areas	Dose rate data (above) indicates that using ^{32}P without considering protective measures would cause users to receive radiation doses that not only exceed dose constraints, but also national dose limits specified in Schedule 4 of the Ionising Radiations Regulations 1999..

	In view of this, work with activities of phosphorous-32 that exceed 0.37 MBq (10 µCi) may only be carried out in Supervised Areas.
Shielding, exposure control measures or safety design features	Radiation work must only be carried out at a suitably equipped workstation such as shown in the image at the top of this document. Perspex body shields must be erected at the front edge of workstations, ‘hot’ materials must be held in Perspex boxes when not in use, waste pipette tips dropped into bench top Perspex bins and pipette shields used. Radioactive sources must at all times be held / stored in their proprietary source pots and not removed for dispensing. Long handled tongs and tweezers should be used wherever possible. Techniques should be rehearsed until familiar so as to minimise the duration of time activity is handled.
Risk of contamination	There is always the risk of contamination, the common causes being dropped or knocking over materials and sources, leakage and droplets. Personal behaviour is a root cause of many accidents. Work should be planned and carried out methodically and not when the user is being rushed or under stress. Rehearsing activities and techniques also helps familiarise the user and bring to light limitations and handling difficulties. **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 should be held in shielded Perspex boxes which,

	if necessary, are themselves held in sealable plastic containers or placed on small trays. If radioactive materials are stored in fridges or freezers they should be in leak-proof containers and not crammed in. Source pots should be held on small trays before placing in fridges / freezers. Aerosols are occasionally generated, however these do not travel any distance, mostly being intercepted on the 'hot' side of body screens and on the drip trays. **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** Volatile materials are not frequently encountered or generated with typical ^{32}P applications. Volatility factor in Delacroix *et al* (2002) is very low. However, the information supplied with sources should be read thoroughly as this will indicate any volatile or other potential problems. 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** Radioactive phosphorous volatilises 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 encountering Supervised Areas that are on fire should assume there is radioactive contamination in the flame / smoke and that fridges and freezers are 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	Control measures are structural and unlikely to fail. However, crazed, scratched or damaged Perspex should not be relied upon and must be replaced. Checking regimes for PPE should ensure that suspect equipment is identified and disposed of.
PPE required	Laboratory coats (sacrificial layer), safety specs and gloves (e.g. nitryl) must be worn in radiation laboratories.
Radiation dosimetry required	Users should wear body TLD badges on the trunk of the body, between the waist and shoulders, ideally clipped onto the top pocket of the user's lab coat. Uses should wear finger stalls on the right and left hand, with the dosemeter 'chip' on the underside of the forefinger.
Systems of work, administrative controls and other relevant	Local rules and contingency plans have been prepared to direct the safe uses of ^{32}P.

information	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 dose & ingestion.	From surface contamination at 0.1 µCi (3.7 kBq) cm^{-2} Skin dose = 1.2 mSv. Ingestion[i] = 10 µSv.	**Health: Low.** Leakage during shipment is rare (one instance of low level contamination of packaging every 5 years[ii]). 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 ^{32}P is easily detectable by monitoring with an EP-15 type monitor and so timely detection is possible if proper procedures are followed. • Procedure for opening packages. • Monitoring. • 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 ^{32}P is supplied in activities of 1 mCi (37 MBq), 3 mCi (111 MBq) and 5 mCi (185 MBq) from which aliquots of up to 1 mCi are dispensed.			
<u>User.</u> External irradiation of body and extremities during transfer of activity from source pot to experiment.	Body dose whilst performing one transfer from an unshielded source pot = 70 µSv[iii]. Extremity dose (fingers) whilst holding an unshielded pipette = 15 mSv[iv].	**Health: Medium** Doses are relatively high and cumulative doses or single exposures resulting from repeated poor lab practice could become significant[v]. **Statutory: Medium – High** It is reasonably practicable to shield or otherwise minimise accessible dose rates. Failure to do so would breach the ALARP requirement (IRR99 Reg 8).	<u>Protective measures are area control, time and shielding.</u> This operation may only be undertaken in a Supervised or Controlled Area. Users should practice their dispensing technique before they work with radioactivity. Dispensing must be undertaken at a workstation set up as illustrated in the image at the top of this document, i.e. behind body shields that are sited at the front of workstation, or in an enclosed and shielded area such as a fume cupboard or a Betacab®. Pipette shields must be used to reduce the extremity dose.
<u>User.</u> Skin exposure 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. Skin dose = 12 Sv[vi]. Ingestion = 0.1 Sv.	**Health: High** Spilling 1 mCi of activity onto the skin will result in a very high skin dose, and would possibly cause a radiation erythema and blistering. There could also be the enhanced risk of genetic damage.	<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,

Exposure pathway & persons at risk	Potential radiation exposure (without protective measures)	Level of risk	Risk control measures
		Statutory: High HSE would consider competence, supervision and dose limitation. (IRR99 Regs 8, 9, 11, 12, 14, & 18).	• 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 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.
<u>User / other lab workers.</u> Skin contamination (skin dose & ingestion) from activity spilt by a previous user.	From surface contamination at 0.1 µCi (3.7 kBq) cm^{-2} Skin dose = 80 µSv[vii]. Ingestion = 9 µSv[viii].	**Health: Low – Medium** 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).	<u>Protective measures are PPE, competence and monitoring</u> 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.

Exposure pathway & persons at risk	**Potential radiation exposure (without protective measures)**	**Level of risk**	**Risk control measures**
Using dispensed activity at a workstation Once activity has been dispensed into samples etc. the potential risks are external irradiation (1), and contamination (2).			
<u>User.</u> External irradiation of body and extremities during manipulations.	Body dose whilst working at the bench manipulating 1 mCi (37 MBq) of activity = 1.5 mSv[ix]. Extremity dose (fingers) whilst handling beakers, vials etc. = 13 mSv[x].	**Health: Medium** Doses are relatively high and cumulative doses or single exposures resulting from repeated poor lab practice could become significant[xi]. **Statutory: High** Risk of enforcement action as dose rates that breach requirements for ALARP and dose limitation (IRR99 Regs 8 & 11).	<u>Protective measures are area control, time and shielding.</u> This operation may only be undertaken in a Supervised or Controlled Area. Users should practice their dispensing technique before they work with radioactivity. Work must only be carried out at a workstation set up as illustrated in the image at the top of this document, i.e. behind body shields that are sited at the front of workstation, or in an enclosed and shielded area such as a fume cupboard or a Betacab®. Shielding boxes, Eppendorf stands / blocks etc. must be used. Pipette shields must be used to reduce the extremity dose.
<u>User / other lab user.</u> Skin contamination (skin dose & ingestion) from activity spilt by a previous user.	From surface contamination in the order 0.1-10 µCi (3.7-370 kBq) cm^{-2} Skin dose = 0.8-8[xii] mSv. Ingestion = 0.001-1 mSv.	**Health: Low-Medium** Contamination and cross contamination are ever-present risks, arising as accidental spills or aerosols or resulting from poor practice. The dose range reflects the potential magnitude and relates to activities handled (labels to	<u>Protective measures are PPE, competence and monitoring</u> PPE must be worn when handling radioactive materials (lab coats, gloves specs). Radiation users must be competent scientists and confident about working with radiation before they commence work with radioactivity. Monitoring regime: • Prior – to check the previous user has not left contamination.

Exposure pathway & persons at risk	Potential radiation exposure (without protective measures)	Level of risk	Risk control measures
		probes). Gross contamination has been encountered in the past, and is the result of poor practice. **Statutory: Medium** Issues are competence, training, regular monitoring and formal monitoring under supervision (IRR99 Regs 8, 9, 14 & 19).	• During – repeated monitoring when working so as to ensure contamination isn't generated and spread. • After – to ensure the area is left clean. Regular formal monitoring of the floors, benches, taps, equipment, pipettes, waste bin lids, sink, etc. at the end of work to confirm they remain clean. Ensure contamination is minimised by having a disciplined laboratory cleaning regime / rota.
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] = 0.36 mSv	**Health: Low** Although sources are shipped in shielded containers, removal of the Eppendorf containing the radioactivity could result in exposure to relatively high dose rates. **Statutory: Low – Medium** Requirement for appropriate storage facilities (IRR99 Reg 29).	Protection measures are shielding and appropriate storage 'As received' sources must be stored in their containers / transport packs. Sub-stocks or aliquots must be stored in leak-proof containers and shielded by 1 cm Perspex. All materials must be held on small drip trays or in plastic boxes.
User. Skin contamination; skin dose &	From surface contamination in the order 0.1-10 µCi	**Health: Low-Medium** Contamination and cross	Protection measures are PPE, monitoring and suitable storage PPE must be worn when handling radioactive materials (lab

Exposure pathway & persons at risk	Potential radiation exposure (without protective measures)	Level of risk	Risk control measures
ingestion.	(3.7-370 kBq) cm^{-2} Skin dose = 0.8-8 mSv. Ingestion = 0.001-1 mSv.	contamination are ever-present risks, arising as accidental spills or aerosols or resulting from poor practice. The dose range reflects the potential magnitude and relates to activities handled (labels to probes). **Statutory: Medium** Issues are PPE, monitoring and suitable storage conditions (IRR99 Regs 9, 19 & 29).	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 external irradiation and contamination.			
User. External irradiation of body through exposure to accumulated waste.	The exposure would depend on the time spent in the lab in proximity to the waste, which is difficult to estimate. The dose rate 1 mCi (37 MBq) from unshielded waste is readily estimated[xiv] = 4.4 mSv h^{-1}.	**Health: Low - High** In general waste bins have sufficient inherent shielding, and transfers from labs to holding stores to the central waste store are all made using shielded bins. However, failure to use the appropriate containers could result in significant exposures, hence the wide risk range. **Statutory: Low** Issues are proper storage conditions (IRR99 Reg 29).	Protection measure is shielding Waste must be stored on the bench top in Perspex® containers and accumulated in the supplied blue plastic or metal bins.
User. Skin contamination (skin dose & ingestion) from contamination of source containers.	From surface contamination in the order 0.1-10 µCi (3.7-370 kBq) cm^{-2} Skin dose = 0.8-8 mSv. Ingestion = 0.001-1 mSv.	**Health: Low-Medium** Contamination resulting from a failure to follow good lab practice is an ever-present risk. **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 external irradiation and contamination.			
<u>Employees / public</u> External irradiation of body and extremities. Skin contamination (skin dose & ingestion) from release of contents and contamination.	Potential dose arising from direct contact with an <u>unshielded</u> 5 mCi (185 MBq) source. Extremity (hand) dose rate[xv] 4.4 Sv h^{-1}. From surface contamination at 5 mCi (185 MBq) cm^{-2} Skin exposure dose rate = 350 Sv h^{-1}. Ingestion = 0.5 Sv.	**Health: High** Given the high dose rate, any prolonged exposure could result in harm and genetic damage, with the 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

[i] Ingestion would be through a user contaminating their hands, not washing, then smoking or eating.

[ii] 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.

[iii] From Delacroix et al (2002) the external radiation dose rate from a point source at 30 cm is 1.18 10^{-1} mSv h^{-1} per MBq. Thus 37 MBq = 4.4 mSv h^{-1}, and if a transfer takes 1 second the received dose = 73 µSv.

[iv] From Delacroix et al (2002) the external radiation dose rate when holding a syringe is 2.39 10^{1} mSv h^{-1} per MBq. Thus 37 MBq = 4.4 mSv h^{-1}, and if a transfer takes 1 second the received dose = 15 mSv.

[v] Significant is defined as 200 mSv in a single exposure, this being the received dose at which chromosome aberrations begin to appear.

[vi] From Delacroix et al (2002) the contamination skin dose from a uniform deposit is 1.89 mSv h^{-1} per 1 kBq cm^{-2}. Thus 37 MBq = 69 Sv h^{-1}. If contamination is removed after 10 minutes the effective dose would be 12 Sv.

[vii] From Delacroix et al (2002) the contamination skin dose from a droplet is 1.33 mSv h^{-1} per 1 kBq cm^{-2}. Thus 3.7 kBq = 4.9 mSv h^{-1}. If contamination is removed after 10 minutes the effective dose would be 80 µSv.

[viii] From Delacroix et al (2002) the CEDE for ingestion is 2.4 10^{-9} Sv Bq^{-1}. Thus an intake of 3.7 kBq would result in an internal dose of 8.9 µSv.

[ix] From Delacroix et al (2002) the external radiation dose rate from a point source at 30 cm is 1.18 10^{-1} mSv h^{-1} per MBq. Thus 37 MBq = 4.4 mSv h^{-1}, and if a manipulation takes 20 minutes received dose = 1.5 mSv.

[x] Extrapolating from the 30 cm point source dose in Delacroix et al (2002) to a distance of 10 cm, external radiation dose rate is 1.06 mSv h^{-1} per MBq. Thus 37 MBq = 39 mSv h^{-1}, and a manipulation takes 20 minutes then the received dose = 13 mSv.

[xi] Significant is defined as 200 mSv in a single exposure, this being the received dose at which chromosome aberrations begin to appear.

[xii] Dose estimation follows the rationale given in vii, above.

[xiii] From Delacroix et al (2002) the external radiation dose rate from a point source at 30 cm is 1.18 10^{-1} mSv h^{-1} per MBq. Thus 185 MBq = 22 mSv h^{-1}, and so, for a

1 minute exposure the body would receive a dose of 0.36 mSv.

[xiv] From Delacroix et al (2002) the external radiation dose rate from a point source at 30 cm is 1.18 10^{-1} mSv h^{-1} per MBq. Thus 37 MBq = 4.4 mSv h^{-1}.

[xv] From Delacroix et al (2002) the external radiation dose rate from contact with an plastic syringe, which has a similar same shielding efficiency to an Eppendorf, is 2.39 10^{1} mSv h^{-1} per 1 MBq, which equates to 4.4 Sv h^{-1}.