RP/RA6 - LABORATORY TRACER WORK USING GAMMA-EMITTING NUCLIDES

Foreword

This is a generic risk assessment for use by persons involved in or effected by the application of radiation outlined in the Scope section below. It must be read together with the relevant completed and countersigned Proposed Scheme of Work form PSoW/US6. Together they make up the risk assessment of each application for each person working with radiation in the University. The specific control measures for each application are recorded in the relevant Local Rules.

Where risks are recognised with an application that are not included in this assessment the University Radiation Protection Adviser must be informed.

Note that this assessment refers only to the risk arising from radiation. There might be other risks arising from this work and these must be properly assessed using the University's risk assessment approach. Guidance can be obtained from the Health and Safety Department.

Scope

This risk assessment concerns work using typical amounts of unsealed radioactive material in the laboratory for the purposes of tracing or quantifying chemical or biological pathways or reactions. It applies only to the gamma-emitting nuclides listed below and in a liquid form:

Sodium-24	Rubidium-86	Iodine-131
Iron-59	Technetium-99m	
Zinc-65	Ruthenium-106	

Work with gaseous forms of these radionuclides is excluded from this assessment, except for small amounts of gas or aerosol formed as part of the experiment or determination. Laboratory tracer work with other categories of radionuclides, including hydrogen-3 (tritium), have their own generic risk assessments.

Hazards

- Irradiation of part or the whole of the body from external exposure to gamma and possibly beta radiation.
- Uptake into the body by ingestion, inhalation or absorption of small amounts of radioactivity, resulting in irradiation of the internal organs, possibly for long periods of time.
- Uptake into the body by ingestion, inhalation or absorption of large amounts of radioactivity as a result of an accident, resulting in irradiation of the internal organs, possibly for long periods of time.

Persons likely to be exposed to the hazard: University staff, research staff, students and other workers. Pregnant women and persons less than 18 years old would be at particular risk.

Risk before the implementation of control measures:

Category of Person	High	Medium	Low
University staff, research staff, students and other workers	○	⦿	○
Members of the public	○	○	⦿
Persons particularly at risk: pregnant women and young persons	○	⦿	○

The dose coefficients for these radionuclides for occupational exposure are shown for ingestion and for inhalation in tables 1 and 2 respectively, together with the amount that would have to be ingested/inhaled to receive a committed effective dose of three-tenths of the relevant maximum permitted annual dose.

Table 1 – Ingestion Dose Coefficients

Nuclide	Chemical Compound	Dose Coefficient (Sv Bq^{-1})	Activity giving rise to relevant maximum permitted annual dose (MBq)
Na-24	All	4.3×10^{-10}	14
Fe-59	All	1.8×10^{-9}	3.3
Zn-65	All	3.9×10^{-9}	1.5
Rb-86	All	2.8×10^{-9}	2.1
Tc-99m	All	2.2×10^{-11}	270
Ru-106	All	1.9×10^{-10}	32
I-131	All	2.2×10^{-8}	0.27

Table 2 – Inhalation Dose Coefficients

Nuclide	Chemical Compound	Dose Coefficient (Sv Bq^{-1})		Activity giving rise to relevant maximum permitted annual dose (MBq) [1]
		1 µm AMAD	5 µm AMAD	
Na-24	All	2.9×10^{-10}	5.3×10^{-10}	11
Fe-59	Oxides, hydroxides and halides	3.5×10^{-9}	3.2×10^{-9}	1.7
	All other	2.2×10^{-9}	3.0×10^{-9}	2.0
Zn-65	All	2.9×10^{-9}	2.8×10^{-9}	2.1
Rb-86	All	9.6×10^{-10}	1.3×10^{-9}	4.6
Tc-99m	Oxides, hydroxides, halides and nitrates	1.9×10^{-11}	2.9×10^{-11}	210
	All other	1.2×10^{-11}	2.0×10^{-11}	300
Ru-106	Halides	2.6×10^{-8}	1.7×10^{-8}	0.23
	Oxides & hydroxides	6.2×10^{-8}	3.5×10^{-8}	0.10
	All other	8.0×10^{-9}	9.8×10^{-9}	0.61
I-131	All	7.6×10^{-9}	1.1×10^{-8}	0.54

[1] Based on the aerodynamic median activity diameter with the most restrictive value.

The approximate external dose rates arising from these radionuclides are shown in table 3, at 30 cm from an unshielded point source, at 30 cm from a 10 ml glass vial [2] containing the source, and from a droplet of the source on the surface of the skin. Owing to the possible contribution from β as well as γ radiation, figures are given in columns 2 and 3 for both the skin and depth doses. When the material is in a glass vial the beta radiation will be shielded for many isotopes, but for some, notably Na-24 and Ru-106, there is still a significant beta contribution. The values in the final column are the dose to the skin.

Table 3 – External Dose Rate from 1 MBq Activity

Nuclide	Dose Rate ($\mu Sv h^{-1}$ / MBq)			
	At 30 cm distance			To skin
	From point source		From 10ml glass vial	From 50µl droplet on skin
	Depth Dose	Skin Dose		
Na-24 *	5.4	120	5.1	1.3×10^6
Fe-59	1.9	35	1.8	3.0×10^5
Zn-65	0.93	0.52	0.88	1.5×10^4
Rb-86 *	0.15	110	0.20	1.2×10^6
Tc-99m	0.26	-	0.25	8.8×10^3
Ru-106 *	0.37	100	4.4	1.4×10^6
I-131	0.73	86	0.71	5.7×10^5

There is also a risk of significant bremsstrahlung radiation with those isotopes marked with an asterisk. The dose contribution from bremsstrahlung is not included in the above values.

Table 4 shows the time of exposure at these dose rates to reach three-tenths of the maximum permitted annual dose for the whole body, from the point and vial sources, and for the skin from the droplet source.

Table 4 – Exposure Time to receive $^3/_{10}$ ths of the Maximum Permitted Annual Dose

Nuclide	Exposure time (h) to receive $^3/_{10}$ ths of the Maximum Permitted Annual Dose			
	Point source at 30 cm		Vial at 30 cm	Droplet at surface
	Depth Dose	Skin Dose		
Na-24	1,110	1,250	1,180 †	0.11
Fe-59	3,160	4,290	3,330	0.50
Zn-65	6,450	288,000	6,820	10
Rb-86	40,000	1,360	30,000 †	0.12
Tc-99m	23,100	-	24,000	17
Ru-106	16,200	1,500	1,360 †	0.11
I-131	8,220	1,740	8,450	0.26

[2] Based on a model of a 23mm dia. x 25mm h cylinder inside a 1.5 mm thick glass envelope of density 2.7 g cm^{-3}.

† These values will be a slight underestimate since the contribution of dose by the beta radiation will actually be mainly absorbed by the skin. The values however do not include the contribution from bremsstrahlung.

Reasonably foreseeable accidents:

Type of Incident	Possible Effects
Known spillage of radioactive material	Skin contamination, ingestion, inhalation or absorption of significant quantities of radioactive material, skin and depth irradiation
Unknown leakage of radioactive material	Skin contamination, ingestion, inhalation or absorption of small quantities of radioactive material, skin and depth irradiation
Accident resulting in a cut to the skin	Absorption of significant quantities of radioactive material
Breach of containment or failure of extract ventilation	Inhalation of small quantities of radioactive material
Flooding	Skin contamination, ingestion, inhalation or absorption of small quantities of radioactive material, skin and depth irradiation
Fire	Skin contamination, ingestion or inhalation of small quantities of radioactive material, skin and depth irradiation
Loss of radioactive material	Skin contamination, ingestion, inhalation or absorption of small quantities of radioactive material by members of the public, skin and depth irradiation

Justification and Optimisation

It is assumed that the use of unsealed radioactive material is needed to fulfil the desired work. The amount of activity should however be minimised, and a justification made for the desired choice of isotope.

Control Measures

Technical

- The surfaces of all laboratories or parts of laboratories that are used for tracer work must be designed and installed to minimise the risk of radioactive contamination, including its long term build-up, and permit easy decontamination.
- Sinks, waste traps and pipework must be designed and installed to minimise the risk of contamination, including its long term build-up, and permit easy decontamination.
- There must be a separate hand basin for personal washing, supplied with hot and cold running water.
- Disposable towels, soap and nail brushes must be available at each hand basin.
- Disposable paper tissues must be readily available.
- Suitable and sufficient fume cupboards must be provided where there is the possibility of any amounts of airborne radioactivity being created. They must be designed and installed so as to minimise the risk of contamination, including its long term build-up, and permit easy decontamination.
- Controlled area laboratories must have adequate facilities for storing personal protective clothing.
- There must be adequate storage facilities for the radioactive material, including space for refrigerators and/or freezers.
- Each laboratory or part thereof used for work with radioactive materials must be clearly marked in accordance with the Health and Safety (Safety Signs and Signals) Regulations.
- Each must also have a notice at the entrance that specifies its designation, the permitted radionuclides and corresponding maximum activity values, and a list of the authorised workers who may use the area.

- Radioactive material must be stored in a segregated and secure area that is clearly marked in accordance with the Health and Safety (Safety Signs and Signals) Regulations. It is acceptable for small amounts of radioactive material to be stored in a refrigerator or other location shared with non-radioactive material, but they must still be clearly segregated and marked. The material must be shielded by the use of a plastic or similar material that is thicker than the relevant maximum range of the β particles. They should also, where necessary, be positioned, shielded or a combination of both to ensure that the accessible dose rate arising from γ radiation outside the storage area does not exceed 3 μSvh^{-1}.
- There must be suitable and sufficient immediate storage facilities within the laboratory for radioactive waste. The storage must be segregated into the appropriate waste streams and clearly marked. Any storage containers must be shielded by the use of a plastic or similar material that is thicker than the relevant maximum range of the β particles. They should also, where necessary, be shielded to ensure that the accessible dose rate arising from γ radiation outside the containers does not exceed 3 μSvh^{-1}. Sinks used for the disposal of aqueously miscible radioactive waste must be clearly marked as such.
- If waste facilities outside of the laboratory are used, they must be secure, clearly segregated from other non-active material, and appropriately marked. The inner surfaces of the store must be designed and installed to minimise the risk of radioactive contamination, including its long term build-up, and permit easy decontamination. They must use distance, shielding or a combination of both to ensure that the accessible dose rate outside the facility does not exceed 3 μSvh^{-1}.
- All laboratory facilities must be adequately inspected and maintained so far as is necessary to ensure their continuing safe use.
- Appropriate contamination monitors should be available for all areas where radioactive materials are used, and kept in good condition, including free from contamination. They must be tested at annual intervals.
- There must be access to an appropriate means of measuring dose equivalent rates from these isotopes.
- Appropriate shields must be made available to shield persons against β radiation. These must be of sufficient thickness to totally absorb the beta radiation, be transparent where appropriate and minimise the generation of bremsstrahlung.
- Shielding against γ radiation whilst handling the material should not generally be necessary, but must be available on the bench for reducing external radiation levels if the material is to be temporarily left out.

Procedural

- Only those persons who have been authorised by the University Radiation Protection Adviser must be allowed to work with the radioactive material.
- Work to which this assessment applies must only be carried out within a segregated and designated laboratory area, except when:
    - transporting material in between such areas; or
    - using specialist equipment not available within a designated laboratory area.
- When the activities being handled are in excess of the relevant limits specified in Guidance Note GN011 – Controlled and Supervised Areas, the laboratory areas must be designated as shown in the Guidance Note.
- If persons are routinely working with activity values less than the stock solution, they do not need to be classified. However, if their work involves handling the stock solution activities all the time, then they might need to be classified and must contact the University RPA for further information.
- Where workers are not classified but work is carried out in a Controlled Area as described in the previous paragraph, then the following restrictions must be imposed:
    - undergraduates are not permitted to undertake the work;
    - entry to the Controlled Area must be in accordance with a written arrangement, which must be incorporated into the Local Rules;

- all visitors to the Controlled Area must be accompanied; and
- persons must only work in the area, once it is known that they are pregnant, in compliance with special control measures.

- Personal dose monitoring of unclassified workers is not normally necessary. Occasional personal monitoring should be undertaken to identify any procedures that are giving rise to higher than normal doses. Classified workers must be provided with external personal dosemeters, whole body dosemeters being the most appropriate for external radiation assessment.
- All work to which this assessment applies must be in line with prepared Local Rules.
- All persons must wear appropriate protective clothing when handling or in the immediate vicinity of radioactive material. Confinement of laboratory coats to the designated areas is unnecessary except when contaminated or when working routinely with activities equal to or in excess of those requiring a Controlled Area. All personal protective equipment, save disposable equipment, must be adequately maintained, including any appropriate washing.
- Working and hygiene procedures must be such as to minimise the risk of personal or other contamination, whether by normal working practices or in case of accident.
- Any operation likely to produce small quantities of radioactive dust, gas or aerosol must be carried out in a fume cabinet or other safe enclosure.
- All apparatus used for handling radioactive material must be labelled to warn of the presence of the material so far as is reasonably practicable. Batch labelling may be used.
- Movement of the radioactive materials around or in between laboratories must be minimised. Where it is taken outside of the laboratory, double containment must be used to reduce the risk of spillage. Transport of radioactive material outside of the University premises must be in accordance with the Radioactive Materials (Road Transport) Regulations.
- Workers must monitor for contamination themselves and all appropriate surfaces of designated laboratories immediately before leaving the laboratory, routinely during the work and immediately after spillages. Records of the monitoring checks must be kept.
- Surface contamination must be removed as soon as practicable.
- Radioactive stock must be stored securely.
- Dose rates outside storage facilities must be monitored whenever there is a significant change in the amount being stored therein.
- There must be arrangements in place to ensure that radioactive material is both delivered to and transferred within the premises safely.
- The whereabouts of the radioactive material must be known at all times. Records must be kept of the activity on site, the consumption, the fraction disposed of to each of the permitted waste streams, and the identification of the persons undertaking the work to which the record relates.
- Unshielded sources must not be manually handled.
- The shields provided must be used to shield the whole body and where practicable the extremities against external β radiation.
- Stock sources must be kept in shielded containers when not in use.
- Labelled experimental material must not be left on the bench when not in use unless shielded.
- Persons must not stand close to sources for longer than necessary.
- Plans must be drawn up and included in the Local Rules for procedures in case of the accidents listed above.

Behavioural

- All persons handling unsealed radioactive material must be trained in the correct and safe method.
- All female workers must be instructed in the need to inform their line manager or the Occupational Health Department as soon as they are aware that they are pregnant.

- A Radiation Protection Supervisor must be appointed to provide suitable supervision of all work with unsealed radioactive material. He/she must be trained in the measures required to ensure compliance with the controls outlined in this risk assessment and with the Local Rules.
- All relevant workers must be trained in the action to be taken in order to implement the contingency plans made.

Dose constraint

No special dose constraint is required for work to which this risk assessment applies.

Dose Investigation level

The majority of the workers to which this risk assessment applies should not receive a dose in excess of the limit for non-classified persons. The dose investigation level for these workers is therefore set at 6 mSv per annum. In the case of the small number of classified workers, the work will be non-routine, and it is therefore likely that personal doses will not initially be predictable. The initial investigation dose level for these workers is therefore set at 15 mSv per annum.

Risk after the implementation of control measures:

Category of Person	High	Medium	Low
University staff, research staff, students and other workers	○	○	⦿
Members of the public	○	○	⦿
Persons particularly at risk: pregnant women and young persons	○	○	⦿

Name of Assessor	C.S. Farmery	Date of Assessment	July 2005
Reference No.	HS/RP/RA6.0	Review Date	Periodic review not required