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Foreword

Work involving the use of ionizing radiation originating from radionuclides or technical equipment such as X-ray sources or accelerators is governed by the Swedish Radiation Protection Act (SFS 1988:220).

In addition, the following regulations from the Swedish Radiation Safety Authority – SSM, are applicable:

SSMFS 2008:9 (former SSI FS 2006:2)
Control of High-Activity Sealed Radioactive Sources

SSMFS 2008:10 (former SSI FS 2006:1)
Import and Export as well as Reporting of Radioactive Substances

SSMFS 2008:25 (former SSI FS 2000:8)
General Advice on Radiography

SSMFS 2008:27 (former SSI FS 2000:9)
Accelerators and Sealed Sources

SSMFS 2008:28 (former SSI FS 2000:7)
Laboratory Work with Unsealed Radioactive Substances

SSMFS 2008:51
Protection of Workers and Public during Activity with Ionizing Radiation

SSMFS 2010:2 (in English at www.ssm.se 2014??)
Radioactive Waste and Discharge from Activity with Unsealed Radioactive Substances

SSMFS 2011:2 Strålsäkerhetsmyndighetens föreskrifter om friklassning av material, lokaler, byggnader och mark vid verksamhet med joniserande strålning (translated to English)

SSMFS 2011:4 Strålsäkerhetsmyndighetens föreskrifter och allmänna råd om naturligt förekommande radioaktivt material

According to these regulations, a Radiation Safety Manual must be made accessible to everyone actively involved in work with ionizing radiation. This manual will also be available on www.su.se.

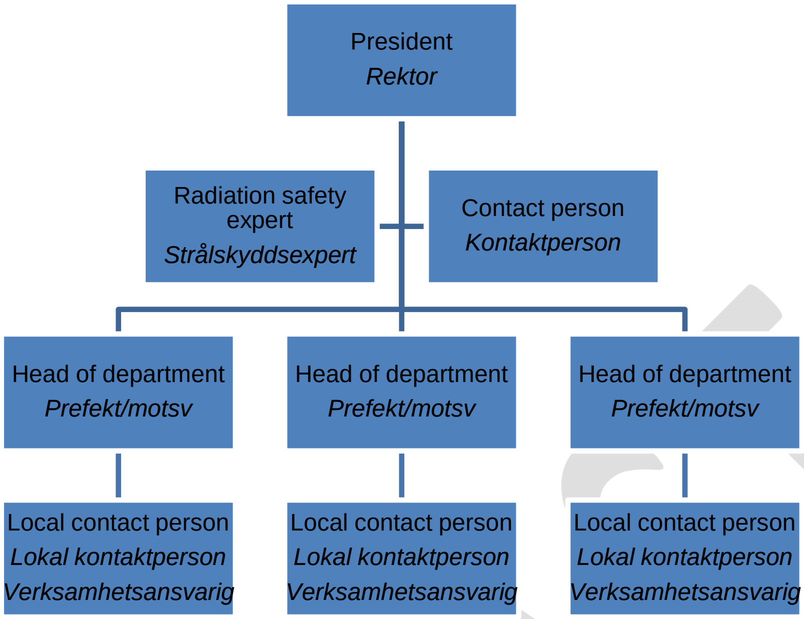
All regulations can be found on www.ssm.se

Stockholm, 2015-05-12

Mats Jonsson
Radiation Safety Expert KTH and SU

Radiation safety organization

The radiation safety organization is described by the following general scheme:



The president has the overall responsibility for the radiation safety within the university while the head of the department has the responsibility for the radiation safety within a department. The head of the department is responsible for assigning local contact persons and that they follow the instructions given by the radiation safety expert. The roles and responsibilities of the different categories involved in the radiation safety organization are listed below:

Radiation safety expert: (can be identical to the contact person)
The radiation safety expert is responsible for the quality of the radiation safety work within the university including organization, routines, internal regulations and education. The radiation safety expert can also be of assistance when planning new activities and improving the radiation safety within a department.

Contact person:
The contact person acts as a link between departments, university and radiation protection authorities (SSM). Individual laboratories should communicate with the contact person before contacting SSM. If the contact person is not identical to the radiation safety expert, the contact person must make sure that all correspondence is forwarded to the radiation safety expert.

Local contact person:
The local contact person (assigned by the head of the department) is responsible for the radiation safety work on a daily basis. The local contact person is the link between the radiation safety expert/contact person and the staff actively working with ionizing radiation. This involves responsibility of informing the staff about news from the radiation safety expert concerning safety regulations, courses and seminars and making sure that the current safety regulations are followed. It is also the responsibility of the local contact person to provide documentation regarding possession of open and sealed sources of ionizing radiation as well as technical equipment.

Staff:
The staff includes everyone actively working with open or sealed sources of radiation or technical equipment emitting ionizing radiation. The staff shall in general communicate directly with the local contact person. It should be emphasized that staff must have valid training in radiation safety. The staff is responsible for following instructions and reporting unexpected events or accidents directly to local contact person.

Contact information

Function	Name	Department	Phone	e-mail
Radiation safety expert	Mats Jonsson	KTH	08-790 9123	matsj@kth.se
Contact person	Mikael Corell	SU – Sektionen för Service	08-16 2251	mikael.corell@su.se
Local contact person	Per-Erik Tegnér	Fysikum, SU	08-55378682	tegner@fysik.su.se
Local contact person				
Local contact person				

Education

To be allowed to perform practical work utilizing ionizing radiation staff must undergo radiation safety education. The education in radiation safety is organized in collaboration between KTH and SU.

The education in radiation safety is composed by the following two compulsory parts:

Introduction course (1/2 day): An introduction for new personnel planning to work with ionizing radiation. The course covers the basics of radiation science including biological effects of ionizing radiation and rules and regulations for work with ionizing radiation. The course is followed by a written exam (via e-mail). The course is given 1-2 times per semester.

Seminars on radiation safety (1-2 hours per year): To maintain the competence and the license to work with ionizing radiation, staff must attend at least one seminar on radiation safety every second year. The seminars are organized in collaboration between KTH and SU.

Certificates: Certificates are normally not issued since lists of qualified personnel will be continuously updated (in connection to courses and seminars) and distributed to the local contact persons. If a certificate is needed for work at other universities, contact Mats Hansson.

Temporary visitors/New employees: Personnel may perform work with ionizing radiation for shorter periods (until the next radiation safety course is given) under the supervision of personnel who have passed the written exam. The local contact person is responsible for reporting such exceptions to the radiation safety expert.
Personnel having previous experience from work with ionizing radiation or having undergone courses in radiation safety can write the exam without attending the course. This can be arranged by contacting the radiation safety expert.

Details about forthcoming courses and seminars will be found at www.sakerhet.su.se

Contact: Mats Jonsson (08 – 790 9123, matsj@kth.se)

Radiation safety instructions

Applicable regulations can be found at www.ssm.se

All personnel actively working with ionizing radiation must have undergone the radiation safety course and attend at least one radiation safety seminar per year (see Section 4). The local contact person will be provided with updated lists of qualified personnel.

General
When working with ionizing radiation, one should always try to minimize the absorbed dose. This can be achieved by:

1. Minimizing the exposure time
2. Keeping a large distance to the radiation source
3. Shielding
4. Avoid contamination

Laboratories, storage rooms, refrigerators, sinks, equipment, glassware and instruments used in work with ionizing radiation must be clearly labelled. Labels can be purchased from: http://pre.ehandel.net/sv/category/17/varning_stralning

Dose rate
The dose rate in a laboratory where personnel spend considerable time must not exceed 2 μSv/h.

Practical guidelines

- The use of radioactive materials should be restricted to special locations
- All personnel in the radiation area must be informed. Use protective clothing and gloves. In case of stench risk, use eye and hair protection. Wash your hands after radiological work.
- Label all the material used for radioactive work with radiation stickers (Radionuclide, Activity, Date).
- Fume hoods should be used if there is the possibility of producing airborne radioactivity
- Cover surfaces with plastic backed absorbent paper. Replace the paper regularly.
- Eating, drinking and tobacco use are strictly prohibited within the laboratory.
- Work behind a plexiglass screen when using β-emitters or lead glass when using γ-emitters.
- Store radioactive material behind shielding.
- Monitor surfaces, tools and protective clothes using a suitable instrument.
- If possible, use only one sink for the washing of contaminated labware and dilution disposal of aqueous radioactive waste. The sink should be clearly labelled.
- Refrigerators, etc. where radionuclides are stored must be clearly labelled.
- Practise new experimental procedures using non-radioactive substances.

Shielding
The proper material and thickness of the shielding depends on the type and energy of radiation. Some examples are given below:
β-radiation <300 keV no shielding necessary (e.g. ^{3}H, ^{14}C, ^{35}S)
β-radiation >1 MeV 10 mm plexi glass (e.g. ^{32}P)

γ-radiation lead

Protection against internal irradiation

- Food should not be stored or eaten in the laboratory. The use of tobacco products in the laboratory is strictly prohibited.
- Use protective papers on surfaces (tables etc.)
- Volatile substances and powders must be handled in fume hoods.
- Use protective clothes and gloves. In case of stench risk, use eye and hair protection.
- Surfaces, equipment, clothes and hands should be checked for contamination after finishing the experiment.

Protection against skin contamination

- Always use gloves
- Check for contamination
- In case of contamination, see Section 6.

Categorization

Personnel must undergo categorization if humans may get radiation doses such that:
-The annual effective dose exceeds 1 mSv or
-The annual equivalent dose to the lens of the eye exceeds 15 mSv or
-The annual equivalent dose to the hands, fore-arms or the skin exceeds 50 mSv
See Section 15.

Commonly used radionuclides

(3H: β 18 keV)
Protection:
<50 MBq: No particular extra protection
50 – 400 MBq: Work in fume hood. Contamination control
400 MBq – 4 GBq: Use thick gloves. Measure airborne activity
Internal contamination: 40 MBq $\rightarrow$ 1 mSv/week

(14C: β 156 keV)
Protection:
<40 MBq: No particular extra protection
40 – 400 MBq: Work in fume hood. Contamination control
400 MBq – 4 GBq: Urine tests. Measure airborne activity

(32P: β 1.71 MeV)
Protection: Shielding, glasses
<40 MBq: Shielding, Dose meter
40 – 400 MBq: Shielding, Dose meter
400 MBq – 4 GBq: Shielding,Urine tests, Dose meter
Internal contamination: 8 MBq $\rightarrow$ 50 mSv/year

Checklist for accidents/incidents (unexpected events)

Contaminated personnel (accident)

1. Remove contaminated gloves, clothes, shoes, etc.

2. Use a suitable instrument to monitor skin contamination.

3. Contaminated skin should be washed with water (large amounts) and mild soap. Do not use abrasives, detergents or organic solvents! Wash affected area until no further reduction in contamination can be achieved.

4. If the affected remains contaminated after extensive decontamination, contact a hospital.

5. Contact your local contact person and the radiation safety expert. The accident **must** be reported to the radiation safety expert who will also report to SSM. Use the Incident/accident-form (see Section 18) when reporting the accident.

Spill without contamination of personnel (incident)

1. Monitor the affected area using a suitable instrument.

2. Use paper to absorb radioactive liquid.

3. Monitor the affected area.

4. If the affected area cannot be effectively decontaminated, the radiation safety expert should be contacted.

5. The incident must be documented and reported to the local contact person. Use the Incident/accident-form (see Section 18) when reporting the incident.

Kompletteras med SAMIR-info/länk

Routines for documentation

Controlled area
All activities must be documented. The following information must be included:
-Radionuclide and activity
-Date
-Who performed the work
-Accidents/Incidents (unexpected events)
-Results from dose monitoring

Laboratory where open sources are used
The following must be documented:
-Received and stored radionuclides
-Results from dose monitoring (contamination control)
-Results from personal dosimetry and estimation of internal doses
-List of calibration sources

Sealed sources, X-ray sources and Accelerators
Log book must be used including name of user, date (and time if applicable) and type of work (if applicable).
For HASS-sources additional documentation is required.

Waste
Waste streams and stored waste must be documented.

Forms
Forms (see Section 18) must be used for the annual update of the inventory of open/sealed sources and technical equipment. Forms must also be used both when you plan to purchase, and when you dispose technical equipment. When the forms are complete and signed, the local contact person sends them to the university contact person.

Routines for purchase of radionuclides

1. To make sure that the total radionuclide inventory does not exceed the limit stated in the license from SSM, all purchases of radionuclides must be coordinated by the local contact person. When increasing the radionuclide inventory by more than 10 % (compared to the previously reported inventory) the radiation safety expert or the contact person for the university must be consulted.

2. Order directly from the supplier. Sometimes you need to send the supplier a copy of the radiation licence (see Section 2).

3. Ordered radionuclides must be delivered directly to the laboratory in question.

4. Purchased radionuclides must immediately be registered (radionuclide, activity and date)

Routines for storage of radionuclides

- Storage of radioactive substances: Under lock in a way that prevents access by unauthorized persons. The storage shall be safe in case of fire.
- The storage shall be shielded so that the dose rate does not exceed 20µSv/h where persons temporarily might be, or 2 µSv/h where they permanently might be.
- Radioactive material must be labelled (radionuclide, activity and date).
- The storage room (facility) must be clearly marked with warning signs. The warning sign must contain information about the type of source (i.e. open or sealed source, radiography source).

For an **open source** there shall also be information about the radionuclide content:

For a **sealed source** there shall be information about the type of shielding and if it is fire proof:

For a **radiography source** there shall be information about the location of the main power switch:

You can find/purchase signs at: http://pre.ehandel.net/sv/category/17/varning_stralning

Kompletteras med ytterligare info om vad som ska skyltas för brandförsvaret

Routines for internal control

Contamination control

Hand instrument
After finishing an experiment, surfaces and clothes must be checked for contamination using a suitable instrument. Contamination should be documented and reported to the local contact person.

Wipe test
^{3}H contamination should always be monitored using wipe test (four times per year). The results must be documented.

Instruments
All instruments for dose monitoring must be calibrated once every year using a calibration source. If a calibration source is not available, contact the university contact person/radiation safety expert. The annual calibration must be documented. A company where you both can buy new instruments and calibrate your old is:
http://www.wedholmmedical.se/survey-monitors

Instructions for personal dosimetry

Personal dosimetry is compulsory for personnel in category A. For personnel in category B, personal dosimetry can be used to make sure that categorization has been correctly performed.

Transports

Internal transports

1. Radioactive material must be labelled (Radionuclide, Activity and Date).
2. Radioactive material must always be under surveillance during transport.
3. Transport containers must be sealed and shielded (maximum 2 μSv/h).
4. In case of an accident/incident, the area must be evacuated and the local contact person must be contacted. The incident must be documented and reported to the radiation safety expert.

Waste handling

Waste handling is described in SSMFS 2010:2

All waste handling must be documented.

Contact the university contact person or the radiation safety expert in case of problems or questions.

Radioactive waste

Classification/separation

Radioactive waste can be divided into:

• Gaseous radionuclides

• Solid radioactive waste

• Liquid radioactive waste

• Scintillation waste

• Radioactive substances in the form of sealed radiation sources

As far as possible, radioactive substances must not be mixed with other kinds of waste.

Written procedures for the handling of radioactive waste, the estimation of the activity in the waste, the measurement of the surface dose rate and the estimation of the activity of the air emissions are set out in the University's ”Radiation Safety Manual” (joint quality manual for radiation protection for the Royal Institute of Technology KTH and Stockholm University) .

Documentation

There must be documentation of:

-stored waste of radionuclides with a half-life of >10 h, stating the nuclide, activity and surface dose ratio on a particular date, origin and identity with traceability to a waste container

- annual activity of radionuclides with a half-life of >10 h that have been sent to a combustion plant or have been washed down a drain

- annual activity that has been released to the air

- activity of waste that has been sent to an approved waste plant

The documentation must be retained for at least five years after the final disposal of the waste.

Handling/storage

Radioactive substances must be stored under lock and key so that they are not accessible to unauthorised persons. The storage must be satisfactory in terms of fire protection. The storage site must be screened off so that the dosage rate does not exceed 20 μSv/h in areas where people circulate or no more than 2 μSv/h in areas used by someone on a permanent basis. The storage site must be easy to clean. If volatile substances are held there, or if there is a risk that such substances may be formed, the storage site must be well ventilated. The storage site must be marked with a warning sign for ionising radiation, the text “Storage site for radioactive substances” and “Storage site for radioactive waste” respectively, and the name and phone number of the person who is responsible for the storage site. A container for radioactive waste must be of a suitable material and design in the light of the chemical and physical properties of the substance being stored. The container must be marked with the designation of the radionuclide and information about its activity on a given date. What is said above shall also apply to the storage of radioactive waste pending final disposal.

Gaseous radionuclides

In activities where gaseous radionuclides are produced or generated from systems with labelled radioactive substances, the contribution to the radiation dose from the emissions to a representative person is estimated and the information and the method used to calculate the correlation between the activity released and the effective dose must be documented. A party who conducts such activities shall make a report to the Radiation Protection Authority no later than 1 March each year of the activity released per radionuclide for the previous calendar year. The radiation protection expert must always be consulted before an activity that can give rise to air emissions is started.

Solid radioactive waste

All solid waste (paper balls, plastic, glass, etc) and solutions, precipitates, filtrates, etc. containing radioactive substances must be disposed of as radioactive waste. Work with radioactive substances must be planned so as to minimise the quantity of waste that must be disposed of as radioactive waste.

The radioactive waste must be packed in a waste container, a well-sealed internal plastic bag and, if the waste is or can become a liquid, absorbant corresponding to twice the quantity of waste in liquid form.

Maximum permitted activity level per waste package The total quantity of radioactive substances per waste package must not exceed the quantity of activity specified in SSMFS 2010:2. The dosage rate on the surface of a waste package submitted to a combustion plant must not exceed 5μSv/h.

Summation rule When several radioactive substances are placed in one and the same waste package the following restriction is applicable

$$\boldsymbol{\Sigma_k(A_k/L_k) \leq 1}$$

Where A_k is the activity of radionuclide k and L_k is the limit value for the same nuclide.

The total activity of the waste submitted to a combustion plant from a laboratory during a calendar month must not exceed ten times the activity stated in SSMFS 2010:2.

Example: Can 1 MBq P-32 and 5 MBq C-14 be placed in the same container and sent for waste combustion for final disposal as radioactive waste?

Reply: Divide each activity value by the corresponding limit value from SSMFS 2010:2 and add up the result: 1 MBq/0,1 MBq = 10 for P-32 and 5 MBq/10 MBq = 0.5 for C-14, the sum of 10 + 0.5 gives the value 10.5.

This value exceeds the summation rule value of no more than 1, so the container must not be sent for waste combustion, at least not yet.

Measure: In this specific case the container and its contents have to decay for 16 weeks. P-32 has a half-life of 14 days, which means that the summation rule value will fall under 1 after 8 half-lives and the container can be marked and sent for combustion.

Liquid radioactive waste and scintillation liquids

For example, organic and environmentally hazardous/harmful solvents such as liquid scintillation solutions must not be poured out in the slop sink for liquid radioactive waste and must be packed in plastic or glass bottles placed in a waste container together with a sufficient quantity of absorbent to prevent leaks.

The total activity of the waste washed out in drains from a laboratory during a calendar month must not exceed ten times the activity stated in SSMFS 2010:2. The waste washed out at one and the same time must not exceed the activity stated in SSM FS 2010:2. The same summation rule as for waste for combustion applies to releases to drains. Each discharge must be washed down with plenty of water. At every discharge point there must be a clearly visible sign saying that liquid radioactive waste may be washed down the drain.

NOTE: Solvents containing NPE (nonyl phenol ethoxylate), such as scintillation liquids like Optiphase 'Hisafe' 2 are listed in Council Directive 2003/53/EC and must not be discharged into any water system in the European Community and must always be sent for final disposal by combustion.

Flammable scintillation solutions must always be packed in small plastic and glass bottles with an aggregate volume of no more than 1 litre per waste container. Absorbent must be added to the vessel; the quantity must correspond to a capacity to absorb at least double the quantity (2 litres) of liquid.

For non-flammable liquid scintillation solutions, no more than 5 litres may be packed in a waste container with a sufficient quantity of absorbent.

Radioactive substances in the form of sealed radiation sources

Under the regulations (SSM FS 2010:2) sealed radiation sources with an activity quantity of no more than 50 kBq may be sent for waste combustion. If there is the slightest uncertainty about the activity of the sealed radiation source to be disposed of, contact the University's radiation protection expert Mats Jonsson (08-790 9123, matsj@kth.se) or Mats Hansson at the Section for Safety *[Sektionen för Säkerhet]* (08-16 2251, mats.hansson@su.se).

Marking / labelling

Stockholm University waste label filled in with:

• Storage, room temperature: (x)

• Type of waste, specification: “Radioactive” and specification

• Submitting department, section and department number (and activity and project number if so required by the department)

• Submitter’s name and phone no and date

The warning symbol for ionising radiation must also be stuck on the waste container.

The following information must be given on the waste label:

- Radionuclide and activity and surface dosage rate on a specified date

- Identity designation with a link to the documentation of the waste.

The quantity of activity in each individual waste package must not, on deposit for transportation to the waste recipient, exceed the limit value given in SSM FS 2010:2.

Hand-over / transport

Radioactive waste in accordance with these restrictions can be deposited on Thursdays at 10.30–11.00 in room A205 (opposite the SU Shop). The waste contractor then transports the waste for destruction.

Radioactive waste that does not meet the restrictions according to these instructions and SSMFS 2010:2 must be taken charge of by Studsvik Nuclear AB. In such cases the University’s radiation protection expert, and/or Ragnsells’ radiation protection expert Erik Gustafsson (070-927 2539), must always be contacted since other requirements under the ARD-S transport regulations and requirements concerning reporting to the permit authority must also be complied with.

Final disposal

Combustion arranged by the waste contractor.

Specific legislation

SFS 1988:220 Radiation Protection Act

SFS 1988:293 Radiation Protection Ordinance

SFS 2007:193 Ordinance on Producer Liability for Certain Radioactive Products and Orphan Radioactive Sources

SSMFS 2009:1 Control of Cross border Transports of Radioactive Waste and Spent Nuclear Fuel

SSMFS 2010:2 Handling of Radioactive Waste and Discharges from Activities with Open Radiation Sources

Safety/risk analysis

<u>Risk assessment in lab-work (example on what to take into consideration):</u>

- Shall be performed by personnel with good knowledge in the subject

- Scope/limitations – From start to finish?
  Which premises, personnel and procedures?
  (preparation, performance, waste handling, dishes, store/archive)

- Substances – Risk- & Safety-phrases/info
  For both used reactants and formed products

- Physical factors
  (quantity, concentration, temperature, volatility, forming of dust, static electricity etc)

- Fire/explosion-hazards or other specific risks related to the substance

- Risky procedures
  (dilute, shake, warm, cool, distil, weigh/measure, transfer, move, high/low pressure etc)

- Reported incidents, accidents and illness

- Exposure ways – Which is the most probable?
  (inhalation, skin/eye-contact, digestion)

- Risk in case of exposure – Exposure risk?
  (hazard, quantity, physical properties, closed/open system, risk of incorrect handling)
  Acute damage and/or in the future?
  Reversible or irreversible damage?
  Occupational health limits?

- Protective measures and instructions
  (safety ventilation, eye/emergency-showers, fire-extinguishers, absorbent (vermiculite), personal protective equipment, alarms, signs, exposure measurements, external personnel)

- Unexpected events and accidents – Action plan

- Dated and signed by Head of Department or by the ones he have delegated to do this

Classification of laboratories and categorization of personnel

Laboratories can be classified as controlled area or protected area.

Controlled area
-Significant risk for contamination and/or personnel belonging to category A (see below).

Protected area
-Category A or B personnel

Personnel must undergo categorization if humans may get radiation doses such that:
-The annual effective dose exceeds 1 mSv or
-The annual equivalent dose to the lens of the eye exceeds 15 mSv or
-The annual equivalent dose to the hands, fore-arms or the skin exceeds 50 mSv

Workers should be classified into category A or B
Category A if (the probability is not negligible):
-The annual effective dose exceeds 6 mSv or
-The annual equivalent dose to the lens of the eye exceeds 45 mSv or
-The annual equivalent dose to the hands, fore-arms or the skin exceeds 150 mSv

Workers belonging to category A must undergo medical examination on a regular basis and use personal dose meter.

Workers not belonging to category A shall belong to category B. For those workers surveillance of doses shall be performed in such an extent that it is possible to demonstrate that this classification is correct.

The local contact person must consider categorization in connection to the risk analysis.

Local radiation safety instructions

The local contact person shall send a copy of the local radiation safety instructions to the university contact person, after every revision.

Methods for estimation of dose

When performing a new type of experiment it is important to estimate the maximum dose exposed personnel could receive. This can be achieved in the following way:

Necessary information: Radionuclide, activity, energy and type of radiation.

Assuming the source is a point source and not taking any shielding into account, we obtain the following equation (giving the dose in Gy):

$$Dose = \frac{A \times E \times t}{4\pi r^2 d}$$

where ***A*** is the activity in *Bq*, ***E*** is the energy in *J (1 eV = 1.6 x 10^-19^ J)*, ***t*** is the exposure time in *s*, ***r*** is the distance from the source in *dm* and ***d*** is the penetration depth in *dm*.

The penetration depth depends on the radiation energy. The following table can be used for rough estimates.

Type of radiation	Energy (MeV)	Range (mm in water)
β	0.018 (^{3}H)	0.0055
	0.167 (^{35}S)	0.32
	0.544 (^{90}Sr)	1.8
	1	4.1
	1.71 (^{32}P)	7.9
	3	15
	10	52
γ	0.66	81 (for absorption of 50%)
	1.2	111 (for absorption of 50%)