Local Radiation Safety Instructions at Karolinska Institutet

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Sofia Skyttner, KI radiation protection expert

Contents

Abbreviations

Assistant (Radiation Protection Assistant)
K (Karolinska University Hospital)
KI (Karolinska Institutet)
Representative (Radiation Protection Representative)
RPE (Radiation Protection Expert)
SSM (Strålsäkerhetsmyndigheten, Swedish radiation safety authority)

Introduction

Purpose

This document describes local radiation safety instructions for work and research involving ionizing radiation at Karolinska Institutet (KI). These instructions are combined with radiation safety training and annual radiation safety meetings the foundation for radiation safety at KI.

KI's radiation safety instructions contain procedures and useful information for staff who uses either radioactive materials or X-ray producing machines in a laboratory setting at KI. The instructions also reflect the requirements of relevant national regulations. The instructions complement but do not replace the required radiation safety training which all staff involved with ionizing radiation must receive.

Legal requirements

These local instructions for radiation safety at KI are in line with the Swedish radiation protection act (Strålskyddslagen), the Swedish radiation protection ordinance (Strålskyddsförordningen) and the regulations of the Swedish Radiation Safety Authority (Strålsäkerhetsmyndigheten, SSM).

- Radiation Protection Act 2018:396
- Radiation Protection Ordinance 2018:506
- SSM's regulations on license required work with ionizing radiation SSMFS 2018:1
- SSM's regulations on work subject to notification SSMFS 2018:2
- SSMs regulations on exemptions and on clearance of materials, building structures and areas SSMFS 2018:3

Exemptions from these instructions

Karolinska University Hospital premises
KI research groups and core facilities located on the Karolinska University Hospital (K) premises shall primarily follow radiation safety instructions provided by K (see KI's staff portal http://staff.ki.se/radiation-safety). Collaboration in radiation safety between KI and K is regulated by a general radiation safety agreement (2-4335/2021), and a cyclotron and radiochemistry dedicated agreement (2-926/2021).

Non-ionizing radiation
Safety instructions for non-ionizing radiation (e.g., radio waves, microwaves, laser light, ultraviolet light) are accessible at KI's staff portal (http://staff.ki.se/radiation-safety).

Nuclear holding
Safety rules for nuclear holding (e.g., substances containing Thorium or Uranium) are described in a separate document (Föreskrifter för kärnämneskontroll inom KI, 1-861/2020) accessible at KI's staff portal http://staff.ki.se/radiation-safety).

Request for exception due to other causes
Should any ionizing radiation-related task require an exception from these instructions, an exemption request shall be sent to KI's radiation protection expert (RPE) for assessment.

Radiation safety organization

Staff working with ionizing radiation shall have knowledge of KI's radiation safety organization (see Figure 1). The organization is described more in detail in Strålsäkerhetsorganisation för Karolinska Institutet (1-926/2020). Contact information for specific functions within the radiation safety organization is listed on KI's staff portal (http://staff.ki.se/radiation-safety). Three roles are of particular interest:

- radiation protection expert (henceforth referred to as RPE)
- radiation protection representative (henceforth referred to as the "representative")
- radiation protection assistant (henceforth referred to as the "assistant").

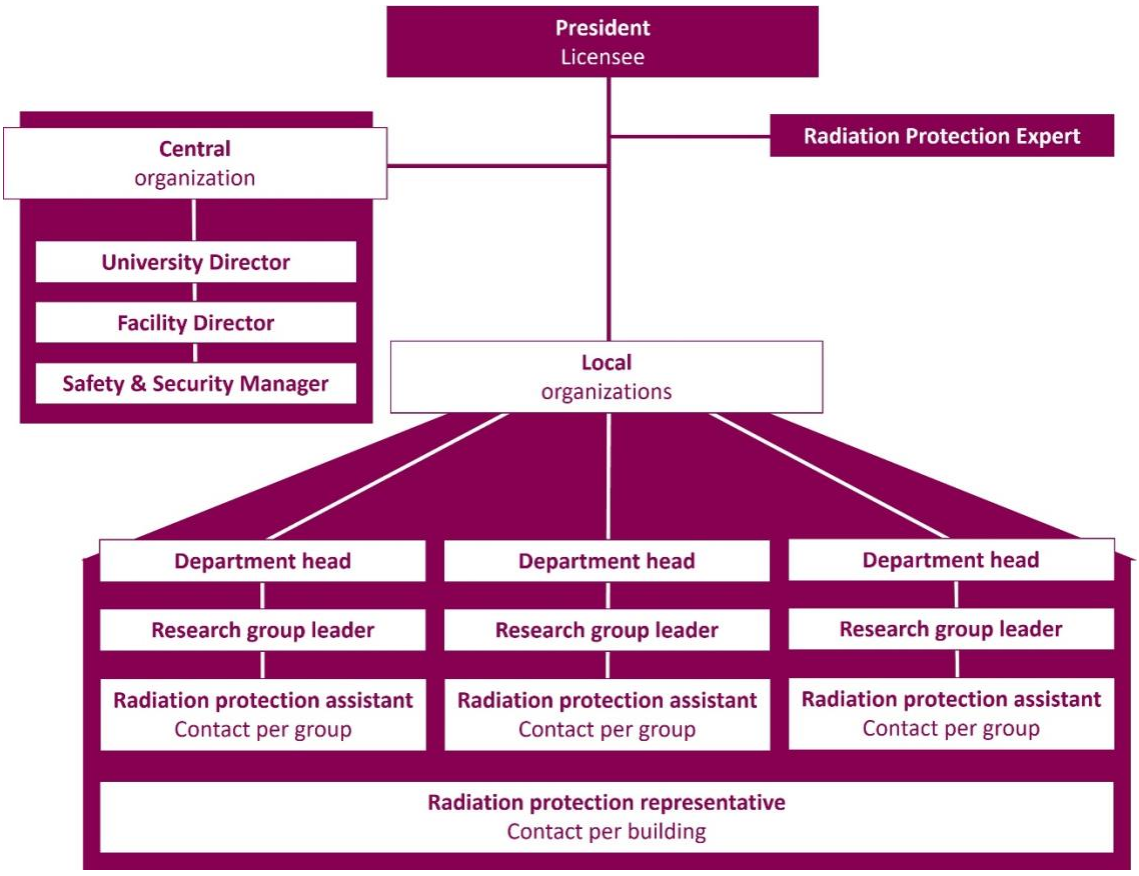

Figure 1 KI's radiation safety organization

Radiation protection representative

There shall be a signed delegation for a representative for each building within KI's geographical area (e.g., ANA Futura, Biomedicum, KM-A/B, KM-F and Neo). In buildings outside KI's geographical areas (e.g., BioClinicum, Novum or other hospital buildings) there shall – as far as possible and reasonable – be a signed delegation for a representative for each department.

Radiation protection assistant

There shall be a signed delegation for an assistant for each research group/core facility involved in ionizing radiation. The delegation is mandatory regardless of whether the group/facility is active within KI's or K's geographical area.

Start-up/changes/decommissioning

Start-up

Research groups/core facilities are required to send an application to KI's RPE before the start-up of any new operation involving ionizing radiation at KI for an assessment of the prerequisites for adequate radiation protection.

Application for open/sealed radioactive sources

Applications for open radioactive sources (i.e., liquid or solid radioactive substances) or sealed radioactive sources (i.e., radioactive substances permanently sealed in a solid container) shall specify the following:

- department, research group/core facility and research group manager
- building, floor, and room
- radiation protection assistant
- list of staff members involved in the isotope work
- list of radioactive isotopes

An approved application qualifies for a local license that is reviewed annually by the RPE.

Application for X-ray systems
The RPE shall be informed well ahead of X-ray system purchases. The information shall specify the following:

- department, research group and research group manager
- radiation protection assistant
- building, floor, and room
- X-ray source
    - supplier, purchase date
    - manufacturer, type, serial number
    - max tube voltage (kV), max tube current (mA).

The RPE shall assess the required radiation protection and provide advice for purchase.

Operational changes

The RPE shall be contacted in the event of any operational change that could affect radiation safety in order to ensure that KI implements the required measurements, calculations, or assessments of any possible radiation-related consequences for staff, public and/or environment.

Decommissioning

The RPE shall be informed before any decommissioning of the premises and/or equipment involving ionizing radiation. The RPE assesses the clearance requirements and ensures that any possible clearance application for premises and/or deregistration of X-ray sources will be sent to SSM. The assistant should coordinate the required measures and possible disposal of radiation sources and/or potentially contaminated material in consultation with the RPE. For open radioactive sources, there is a dedicated decommissioning plan (see Appendix 1).

General radiation safety requirements

Access to radiation sources

The assistant shall ensure, in consultation with the manager and representative, that only authorized staff are given access to a radiation source.

Competence

Only authorized staff is allowed to work with ionizing radiation. The staff shall have knowledge not only about these instructions but also the instructions specified in the mandatory radiation safety courses and during the practical on-site introduction. Research group leaders shall assess the competence of their staff in consultation with the assistant. The RPE shall be contacted if any doubts exist.

Course requirements for open/sealed radioactive sources
Three mandatory course subjects are required for working with open/sealed radioactive sources. Course access is provided after login with KI credentials at KI's staff portal (http://staff.ki.se/radiation-safety). The mandatory course subjects are

- web course Introduction to radiation protection
- teacher-led course on Open radioactive sources
- on-site introduction with the assistant
- refresher course within five years.

Course requirements for X-ray sources
Three mandatory course subjects are required for working with X-ray sources. Course access is provided after login with KI credentials at KI's staff portal (http://staff.ki.se/radiation-safety). The mandatory course subjects are

- web course Introduction to radiation protection
- web course for the specific X-ray source
- on-site introduction with the assistant
- refresher course within five years.

Registration of radiation sources

KLARA radiation
KLARA radiation is KI's central register for radiation sources. KI's RPE is the administrator of KLARA radiation. The assistant shall register a radiation source (X-ray, open/sealed radioactive source) in KLARA radiation without delay upon purchasing and deregister sources upon decommissioning. For radioactive isotopes, registration is only required if half-life is at least 14 days. The RPE shall assess whether the registration/deregistration is required to SSM.

Local licenses
KI's RPE shall keep a register of the local licenses involving work with radiation sources at KI. At a minimum this register shall specify (but not be limited to) the following:

- local license number
- building, floor, room (excl. design of premises, which is documented by KI's premises department)
- department and research group/core facility
- manager/principal investigator, representative and assistant
- type of radiation source and extent of work
- date for annual check-ups incl. possible measures required
- staff categorization and premises classification.

The RPE shall review local licenses annually. Risk categories shall be assessed according to Appendix 2.

Fundamental radiation safety rules

There are different types of ionizing radiation. The characteristics of each type of radiation will require certain radiation protection measures. However, three fundamental components of the radiation safety rules are always valid regardless of radiation source: time, distance and shielding.

Minimize time

Radiation exposure is directly proportional to exposure time, which in practice means that half exposure time results in a half radiation dose. Hence, staff shall always

- practice new and difficult procedures in advance without radiation source
- work quickly, safely, and methodically.

Maximize distance

The decrease in the intensity of radiation is inversely proportional to the square of the distance (inverse square law) which in practice means that the radiation decreases very quickly as the distance to the radiation source increases. Hence, staff shall as far as possible and reasonably

- work at the greatest possible distance from the radiation source
- use distance tools when handling high-energy radiation sources of high activity
- step outside the room when imaging with X-ray systems.

Use adequate shielding

The intensity of the radiation can easily be reduced by adequate shielding. Shielding includes different types of radiation protection, for example screens, glasses, and aprons. The material and thickness of the shielding should be assessed by the RPE.

Radiation risk assessment

All research groups/core facilities shall do a radiation risk assessment (RADRA, form available at http://staff.ki.se/radiation-safety) before introducing work involving ionizing radiation. The RADRA shall be updated whenever there is a method change having a possible impact on radiation protection. All staff working in the facility must be very knowledgeable about

the RADRA, which must be kept in an easily accessible location in the laboratory.

Radiation-related anomaly

Generally

A radiation-related anomaly is an unintentional exposure of the staff, public or environment, including cases in which a defect is identified even though no incident has occurred. Staff shall always contact the assistant without delay in the event of a radiation safety-related anomaly (e.g., a radioactive spillage, see Appendix 7). Staff shall thereafter record the anomaly in KI's incident reporting system, preferably together with the assistant.

Severity assessment

The severity differs between incident categories. The assistant shall always be informed about all incidents without delay. Depending on the severity level of an incident/near incident (see **Table 1**) the representative or/and the RPE should be informed without delay. The information may only await the annual radiation safety meeting, if the severity level is Low.

Severity level	Incident description	To be informed without delay
Low	Minor spillage of open radioactive sources, e.g., a drop on gloves or bench paper. Purchase of radioactive isotopes not registered upon delivery. Error message on X-ray irradiator.	Assistant
Mid	Extensive spillage of open radioactive sources, e.g., floor/wall in isotope premises. X-ray equipment accidently crashed into wall/door.	Assistant & Representative
High	Spillage involving staff contamination, e.g., contaminated face/hand. Spillage involving the public, e.g., spillage during transport.	Assistant & Representative & RPE
Radiological Emergency Situation	Staff/public has been, or risks being exposed to radiation doses motivating the implementation of immediate measures to avoid serious health effects.	Assistant & Representative & RPE & Head of Safety and security

Table 1 *The severity differs between incident categories.*

Radiation dose estimates

The RPE reviews reported radiation-related incidents and assesses whether a radiation dose estimate is required. If so, the RPE ensures that the radiation dose is estimated and sent to the accountable head of department.

Radiation dose monitoring

Radiation dose concepts

In monitoring the staff's radiation dose, the two most common dose terms are "equivalent dose" and "effective dose". Equivalent dose and effective dose represent two completely different dose concepts, although they share the same unit (Sievert, Sv).

Equivalent dose

Equivalent dose to an organ/tissue is the average value of absorbed energy (from ionizing radiation) per mass unit weighted with the biological effect for the specific radiation type of the radiation source. Equivalent dose enables comparison of radiation dose to organs/tissues regardless of radiation source, for example comparing radiation dose to eye lens when working with two different radioactive isotopes.

Effective dose

Effective dose is the sum of all equivalent doses to exposed organs and/or tissues, weighted with the radiosensitivity of each organ/tissue. Effective dose enables comparison of risk for different radiation exposure scenarios regardless of radiation source and exposed body part.

Radiation dose limits

Radiation dose limits differ between staff categories and risk groups. Staff shall inform the RPE of possible sub-operational changes that could have an impact on radiation dose and require certain categorization. Staff categorization shall be assessed by the RPE.

Staff in category A

Staff shall be categorized A if the risk is not negligible that they annually can exceed an

- effective dose of 6 mSv
- equivalent dose of 15 mSv to eye lens
- equivalent dose of 150 mSv to extremities
- equivalent dose of 150 mSv/cm^2 to skin.

Category A staff is required to wear a dosimeter. The radiation dose reports shall be reviewed by the RPE. There are lower investigation radiation dose

limits at KI. The RPE investigates possible causes for increased radiation doses if category A staff monthly exceeds an

- effective dose of 0.5 mSv (0.15 mSv for pregnant staff)
- equivalent dose of 0.5 mSv to eye lens
- equivalent dose of 5.0 mSv to extremities
- equivalent dose of 5.0 mSv/cm^2 to skin.

Staff in category A require an approved annual health declaration (incl. medical check-up every third year), which is described in a separate document (Anvisning för tjänstbarhetsbedömning av personal tillhörande kategori A, 1-699-2020).

Staff in category B
Staff shall be categorized B if the risk is not negligible that they annually can exceed an

- effective dose of 1 mSv (but less than 6 mSv)
- equivalent dose of 50 mSv to extremities (but less than 150 mSv)
- equivalent dose of 50 mSv/cm^2 to skin (but less than 150 mSv/cm^2).

The RPE shall assess if category B staff shall be required to wear dosimeters during a limited period to ensure they are in the correct category.

Non-categorized staff
No categorization of staff is required if the risk of exceeding the radiation dose limits for category B is negligible. This applies, for example, to staff working with X-ray irradiators (a.k.a. X-ray cabinets).

Pregnant staff
Pregnant staff shall contact the RPE without delay as soon as pregnancy is established for a risk assessment. The foetus is not only extra sensitive to radiation, but also legally interpreted as being part of the public, for which a lower dose limit applies. Pregnant staff always has the right to be reassigned to work not involving more exposure than what is allowed for the public. However, they are allowed to continue their work involving ionizing radiation as long as the equivalent dose to the uterus does not risk to exceed 1 mSv (for the remainder of the pregnancy).

Breastfeeding staff
Breastfeeding staff involved in work with open radioactive sources shall contact the RPE without delay for advice and risk assessment. There shall not be any possible non-negligible risk for a breastfed child to ingest radioactive substances during breastfeeding.

Medical examinations
No dose restrictions apply for patients exposed to ionizing radiation during medical examinations, but the radiation dose shall be kept As Low As Reasonably Achievable (ALARA). The possible risk (with each exposure) shall be weighed against the medical benefit, and the benefit-to-risk ratio shall be kept As High As Reasonably Achievable (AHARA).

Studies involving test subjects
Special dose restrictions apply for test subjects exposed to ionizing radiation within research, due to test subjects not being expected to receive any medical benefit from the exposure. Dose restrictions are set by the Swedish Ethical Review Authority.

X-ray requirements

Signage

Entrances shall be marked with a sign indicating the appropriate classification (see Figure 2). The RPE shall assess which classification is required. The assistant shall ensure, in consultation with the manager and representative, that only authorized staff is given access to controlled areas.

Figure 2 Sign for a supervised area (left) and a controlled area (right).

Personal protective equipment

Radiation protection requirements differ between X-ray systems and their usage. A radiation protection apron shall generally be worn when standing next to X-ray equipment during exposure, except for X-ray cabinets which are completely shielded. Other requirements shall be clarified in system-specific courses.

Quality assurance requirements

X-ray equipment

X-ray equipment shall always undergo a quality assurance (QA) check upon delivery. QA check shall include (but not be limited to) performance and function control and checks for possible leakage radiation. The assessment shall be made by the RPE. The assistant shall ensure that regular preventive maintenance (PM) is carried out according to the manufacturer's recommendations. The assistant shall inform the RPE without delay regarding any intervention that might have an impact on the properties of the radiation source. The RPE shall assess whether a QA check is required.

At least once per year, the RPE shall assess the parameters and procedures of importance in terms of radiation protection for each X-ray source intended for exposure. This QA check shall include but not be limited to

- the premises
- radiation protection equipment
- safety systems
- signage and labeling
- dosimetry.

Dosimetry instruments
The RPE shall monitor the annual functional checks (description in Appendix 3) and five-year calibrations (description in Appendix 4) of the dosimetry instruments (e.g., ionization chambers and electrometers).

Radiation protection aprons
Functional checks of lead-equivalent radiation protection aprons shall be done regularly by the assistant. Checks shall include but not be limited to

- ensuring that labels (incl. individual marking) are correct
- checking for visible damages
- taking an X-ray image of radiation protection aprons (to check for cracks etc.)
- recording the check-up.

Radioactive sources requirements

Signage

Entrance to isotope laboratory

Premises for working with radioactive isotopes shall be classified as supervised or controlled areas depending on the risk category (see Appendix 2). Signage (see Figure 3) is required at all entrances. Possibilities for exemptions (for example, to only consider a fume hood as a supervised or controlled area and not the whole premises) shall be assessed by the RPE. The assistant shall ensure, in consultation with the manager and representative, that only authorized staff is given access to controlled areas.

Figure 3 Mandatory entrance signs for supervised (left) and controlled areas (right).

Storage of radioactive substances

Radioactive substances shall be labelled with the radioactive isotope, reference activity, time of reference activity, and research group/core facility. The substances shall be kept in a separate box (or on a tray) to minimize risk of possible contamination of the freezer/fridge/locker. All holding shall be recorded by the assistant (see chapter on Mandatory registration). All holding shall be adequately shielded.

Furthermore, signage is required for all storage locations for radioactive substances. Doors to cupboards, freezers or fridges shall be labelled with the sign in Figure 4.

Figure 4 Mandatory storage sign for radioactive material. Please note that the name of the assistant shall be specified, too.

Sealed radioactive sources
The assistant shall annually check that all sealed radiation sources intended for exposure are in their registered storage area, in good condition and marked with the

- manufacturer name, product name, and identification number
- radioactive isotope, reference activity, reference date, and research group/core facility
- warning symbol for ionizing radiation.

Minimizing risk of contamination

Ventilation
Separate ventilation systems shall be used when there is a risk for airborne radioactive substances. Special ventilation requirements apply when for example

- labelling with volatile I-125
- working with volatile PET isotopes (e.g., C-11, O-15 and F-18)
- performing work that might cause airborne radioactivity (e.g., incubating or mixing chemical substances)
- exceeding isotope specific activity levels (assessment by the RPE).

Control of ventilation shall be booked by the assistant at start-up and regularly thereafter according to KI practices.

Cleanliness and tidiness

All surfaces shall be kept clean and tidy by laboratory staff. Radioactive substances shall be returned to dedicated storage areas between work sessions. Absorbent paper with a plasticized underside shall be used on workbenches dedicated to work with radioactive substances. The protective paper shall be changed regularly (depending on workload) and whenever there is any splash or spill.

Cleaning staff is only allowed to

- clean floors (not move anything except chairs)
- empty paper towel trash bins (never any laboratory waste bins)

provided clear and concise radiation safety instructions (use gloves, wash hands afterwards, etc.). Any radioactive spillage shall always be cleaned by laboratory staff (instructions in Appendix 7).

Contamination check

Contamination checks (method description in Appendix 6) shall be carried out regularly according to the risk level of the isotope laboratory (see Table 2). However, staff shall always check for contamination whenever there is a non-negligible risk of contamination, e.g., computer or mobile phone that has been used in the laboratory. Documentation of contamination checks shall be recorded by the staff in folders at the isotope laboratory.

Risk level	Contamination check of work surfaces	Contamination check of hands	Required documentation
1	Recommended both before and after work	Before and after work	Always for work surfaces. For other checks when a non-negligible risk of contamination exists
2	Controlled areas: recommended both before and after work Supervised areas: after work	After work	At least four times per year and when a non-negligible risk of contamination exists
3	Not regularly, only when a non-negligible risk of contamination exists (e.g., change of protective desk paper or spillage)	Not regularly, only when a non-negligible risk of contamination exists	At least annually and when a non-negligible risk of contamination exists

Table 2 Contamination checks differ between risk level categories.

Furthermore, the assistant shall annually do a more thorough contamination check of the isotope laboratory. Checkpoints for this inspection shall at a minimum include but not be limited to

- door handles
- cabinet handles and surfaces of sliding doors
- knobs, handles or similar on equipment (e.g., beta counters, cupboards)
- mouse, keyboard, or touch displays
- work surfaces (e.g., tables, shelves)
- work chairs or trollies
- sink/basin.

A Geiger Müller tube (a.k.a. radiation protection instrument or radiation monitor, to the left in Figure 5) shall be used to measure possible contamination of gamma and high-energy beta emitters. Functional check shall be done before each use by staff (instructions in Appendix 3). The RPE shall monitor annual calibration (instructions in Appendix 4).

A liquid scintillation beta counter (to the right in Figure 5) shall be used to measure possible contamination of low-energy beta emitters (ex. H-3, C-14 and S-35). Samples shall be taken by wipe tests (instructions in Appendix 5). Functional check and calibration of a beta counter shall be arranged by the assistant in accordance with the manufacturer's recommendations.

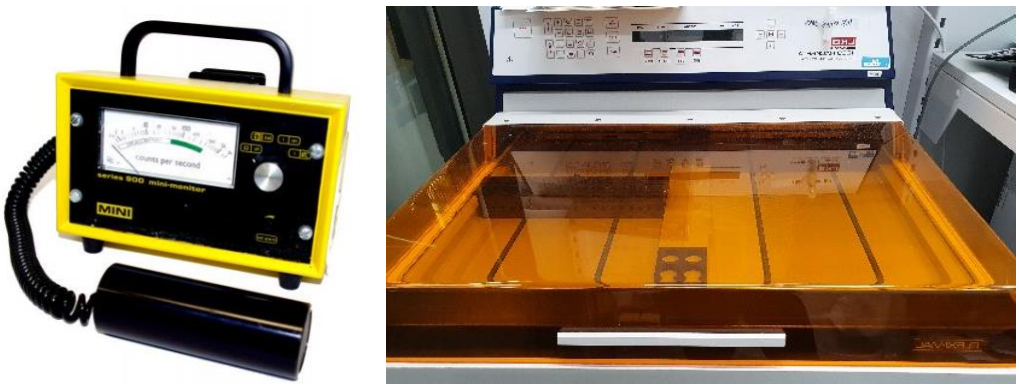

Figure 5 A radiation protection instrument (left) shall be available for measuring contamination of gamma (ex. Cr-51) or high-energy beta (ex P-32) emitters. A beta counter (right) shall be available for measuring contamination of low-energy beta emitters (ex. H-3, C-14 and S-35).

Food and drink prohibited

It is forbidden to eat, drink, or use chewing gum/snuff in premises where open radiation sources are handled. It is also forbidden to store/bring drinks, food, chewing gum or snuff into these premises. Violating these rules will increase the risk of internal contamination.

Personal protective equipment

Lab coat

Always wear a lab coat. The assistant shall ensure that lab coats are changed regularly.

Eye and hair protection

Eye and hair protection shall be worn if there is a risk of splashes. The RPE shall assess if radiation protection glasses are required.

Gloves

Always use gloves. Used gloves shall be treated as radioactive waste. Always wash hands afterwards. Use double gloves when cleaning contaminated surfaces and change immediately if a radioactive spillage (see Appendix 7).

Standalone shielding

Staff shall always use adequate shielding for radioactive preparations. Shielding dimensions shall be assessed by the RPE (e.g., 10 mm plastic shield for high-energy beta emitters, 10 mm lead equivalent shield for Cr-51). Working behind an adequate screen also protects against splashes.

Pliers or tweezers

Pliers/tweezers (see Figure 6) shall preferably be used when working with gamma or high-energy beta emitters. Syringe shields shall be used when withdrawing into a syringe or injecting.

Figure 6 Pliers/tweezers shall be used when handling gamma or high-energy beta radiation.

Radioactive waste

Waste containers

Green waste containers shall as far as possible and reasonable be used for all radioactive waste. In case of combinations of waste, such as contagious radioactive waste, the measures in Table 3 shall be carried out.

The RPE shall assess if radioactive waste of gamma or high-energy beta emitters requires extra shielding, e.g., plexiglass is required for high-energy beta emitter P-32 (see Figure 7), whereas adequate lead equivalent shielding is required for gamma emitters. Different isotopes should preferably not be mixed, and the RPE shall be contacted if research work requires isotope mixtures.

Figure 7 Green containers might require extra shielding, e.g., plexiglass for high-energy beta emitters (ex. P-32) or lead (ex. Cr-51).

Bin colour	Mixed radioactive waste	Measures
Green	Mixed radioactive isotopes	Isotopes shall preferably not be mixed. The RPE shall be contacted if research work requires isotope mixtures. The formula for how to estimate total activity of mixed radioactive waste is described in Appendix 9.
Green	Chemical radioactive waste	Waste containers that, in addition to radioactive waste, also contain chemical waste shall be labelled with their corresponding label, e.g., containers for scintillation solution shall be labelled as both chemical and radioactive waste. Such containers require storage in the radioactive waste room until decayed to activities below limits for incineration. Then they shall be treated as chemical waste.
Yellow	Infectious/stingy radioactive waste	Waste containers that, in addition to radioactive waste, also contain infectious/stingy waste shall be labelled with their corresponding label. Such containers require storage in the radioactive waste room until decayed to activities below limits for incineration. Then they shall be treated as infectious/stingy waste.
Black	Biological radioactive waste	Radioactive organs/tissues shall be disposed of in black plastic boxes labelled as both radioactive and biological waste. The freezer shall be labelled accordingly. The RPE shall be contacted if waste involves gamma-emitting nuclides, as extra shielding might be relevant. Biological-radioactive waste requires storage in freezer until decayed to activities below limits for incineration. Then they shall be treated as biological waste.

Table 3 Mixed radioactive waste or other waste combinations that require certain measures.

Radioactive waste labels

The assistant shall label the radioactive waste container (the label to the left in Figure 8) when transporting waste to the radioactive waste room. The outside of the radioactive waste container shall be kept clean (checked for contamination before transport) and with the lid properly closed. The representative shall label decayed containers (the etiquette to the right in Figure 8) before ordering the transport to an external waste facility.

Figure 8 Label for radioactive waste containers (left), label for decayed radioactive waste containers (right).

Empty canisters and packaging material

Empty plastic/glass/lead canisters or other packaging materials require clearance once they have contained radioactive substances. If not contaminated, radioactivity labels shall be removed, and canisters can be treated according to general waste regulations.

Logbook at radioactive waste bin

The assistant shall keep a logbook at each radioactive waste container to estimate total activity per container (instructions in Appendix 9). The assistant shall order internal transport of radioactive waste containers to the buildings radioactive waste room when the container is either full or has reached its allowed activity limit, crucial for some isotopes (see Table 4).

Radioactive isotope	Half-life		Max activity per container (MBq)	Max activity concentration (MBq/kg)
H-3	12.3	years	1000	1000
C-14	5730	years	10	10
P-32	14.3	days	0.1	1
P-33	25.6	days	100	100
S-35	87.5	days	100	100
Cr-51	27.7	days	10	1
Se-75	119.8	days	1	0.1
Rb-86	18.6	days	0.1	0.1
Zr-89	78.4	hours	1	0.01
In-111	2.8	days	1	0.1
I-125	59.9	days	1	1
Lu-177	6.7	days	10	1

Table 4 Maximum activity levels for radioactive waste listed as activity per container and activity concentration. Please note: 1 MBq = 0.027 mCi = 27 µCi. The RPE shall be contacted for radioactive isotopes not listed in this table.

Registration in RadWaste

The representative shall register the radioactive waste on the website RadWaste upon transport to the radioactive waste room. Registration is only required for radioactive isotopes with half-lives of at least 14 days.

RadWaste will confirm when waste has decayed below the isotope-specific threshold values (listed in Table 4). Threshold values that are too high can be addressed by dividing packages, but never by diluting.

Sink disposal

The possibility of disposing liquid radioactive waste shall be assessed by the RPE. Each disposal site shall have a sign including the information in Figure 9. Both before and after release, the drain must be generously flushed with water to avoid radioactivity remaining nearby (e.g., water trap).

A logbook for releases shall be kept at each disposal site. Registration shall be done for all isotopes with half-lives longer than 10 hours. The assistant shall report to the RPE if a local license's maximum activity per month is exceeded. KI's total average monthly disposals shall be annually assessed by the RPE.

The waste may not contain chemical compounds or biohazardous materials that are not permitted to be poured into sinks.

Ensure that **activity** flushed does **not exceed** the **limit** stated according to this sign, and flush with water both BEFORE and AFTER each disposal.

Please, remember to **fill in** the sink **disposal log sheet**.

Site for release of liquid radioactive waste

Room: RoomNumber

Radiation protection representative: NameName

Research group and local licence: ResearchGroup, LicenseNumber

Radionuclide	Max at a time discharge to sink	Max monthly discharge to sink
xxx	xxx MBq	xxx MBq

0.1 MBq = 0.003 mCi

Figure 9 Sign for release of liquid radioactive waste shall be posted at the disposal site.

Radioactive waste rooms

There are three permanent radioactive waste rooms on the KI premises (listed below). Temporary waste rooms (e.g., freezer rooms) shall be arranged in consultation with the RPE. The representative shall perform an annual contamination check of the radioactive waste room (equal to contamination checks for isotope laboratories; see chapter on Contamination check).

- ANA8, floor 3, room 31301
- Biomedicum, floor 2, room C0218
- Neo, floor 3, lattice cage

Doors to radioactive waste rooms shall be labelled with the sign in Figure 10.

Figure 10 Mandatory storage sign for radioactive waste. Please note that the name of the assistant shall be specified, too.

Transport

Internal transport

Internal transport of radioactive substances within KI's and K's geographical areas shall be included in the risk assessment. Generally, staff shall

- ensure that the transport package is well sealed and shielded (instructions in Appendix 8)
- preferably use culverts (with roller cart/kick-bike if required, assessment by the RPE) and avoid public areas
- carry a phone in case of an incident
- establish a transport routine in writing.

External transport

External transport of radioactive substances is regulated by the Swedish Civil Contingencies Agency's (Myndigheten för samhällsskydd och beredskap, MSB) regulation on the transport of dangerous goods (ADR-S). Radioactive substances can only be transported between KI Solna/North and KI South with an authorized transport company (see KI's staff portal, https://staff.ki.se/transport-of-biological-specimens-and-chemical-products).

Appendix 1

Decommissioning plan for open radioactive sources at KI

Introduction

KI's decommissioning plan shall be applied to future actions required for clearance of premises used for open radiation sources at KI.

Radioactive isotopes at KI

The system of local licenses ensures that knowledge exists of the extent of open radioactive sources at KI. Table A1 lists the total amount of possible max holding per radioactive isotope at KI as registered in 2022.

Radioactive isotope	Total amount of allowed holding (MBq)
F-18	41 GB
C-11	24 GB
H-3	16 GB
Ga-68	12 GB
P-32	4 GB
S-35	4 GB
C-14	3 GB
Cr-51	3 GB
Cu-64	1.5 GB
Co-55	1 GB
Ti-45	1 GB
Tc-99m	1 GB
Zr-89	800 MBq
P-33	200 MBq
I-125	100 MBq
Rb-86	60
In-111	50
Lu-177	0
O-15	0
I-131	0
Se-75	0

Table A1 *List of the total amount of possible max holding per radioactive isotope at KI as registered in 2022.*

Decommissioning plan

A radiological survey is required before premises/buildings used for open radioactive sources can be passed to other operations. The survey shall be based on the register of local licenses, including information on the premises, isotopes, and amount of activity used, including disposal sites. The RPE shall assess the risk categorization according to KI's measurement program for the clearance of premises and buildings (2-5566/2017). The risk

categorization shall determine whether measurements are required prior to applying for exemption from the Swedish Radiation Safety Authority (Strålsäkerhetsmyndigheten, SSM). Laboratory equipment and materials on the premises shall be treated accordingly. Radioactive materials exceeding clearance levels shall be sent for disposal at an approved waste facility.

Estimation of radioactive waste and associated cost

Possible quantities of generated radioactive waste (in case KI shall leave a major building; e.g., ANA Futura, Biomedicum or Neo) is estimated not to exceed national limits (SSMFS 2018:3 Appendix 1, third column); therefore, a majority of generated radioactive waste is assumed to be sent for incineration at a waste facility, except for a small amount of long-term radioactive waste kept in each building's radioactive waste room (until declined or sent for disposal).

Based on KI's previous clearance of premises (upon moving into Biomedicum, when no major clean-up measures were required, except for radioactive waste, including calibration sources sent for disposal) the cost of clearance is estimated to be max 20 kSEK/room. An extra cost of about 5 kSEK/room is estimated for the disposal of each radioactive calibration source. Measures that may be required for cleaning contaminated areas (floor and surface layer replacement or flushing of drains) is not included in this cost estimation.

Appendix 2

Isotope laboratory risk categories

Research with open radioactive sources is divided into the four risk categories specified in Table A2. Each risk level corresponds to a risk assessment by the RPE based on Table A3. Tabled data provided by Karolinska University Hospital.

Risk category	Supervision	Premises classification	Staff categorization	Assessment
1 Extensive work	Annual	Controlled area	A	Minimum activity values of Table A2 Column 1 or Column 2 are/might be exceeded.
2	Annual	Supervised area (Controlled area if risk of airborne radioactivity)	B	Max activity values of Table A2 Column 2 (but not Column 1) are/might be exceeded.
3 Low activity	Annual	Supervised area	Non-categorized	Max activity values of Table A2 Column 3 could not be exceeded.
4 Non-active license	Semi-annual	Supervised area	Non-categorized	Holding only, and not exceeding Table A2 Column 2.

Table A2 *Risk categories for radioactive isotope laboratories at KI.*

Radioactive isotope	Column 1 Minimum handled activity (MBq)	Column 2 Minimum holding (GBq)	Column 3 Maximum handled activity (MBq)
H-3	1000	50	1000
C-11	100	5	1
C-14	100	5	10
O-15	100	50	1000
F-18	100	5	1
P-32	25	5	0,1
P-33	250	50	100
S-35	100	50	100
Cr-51	1000	5	10
Cu-64	500	5	1
Ga-66	500	5	1
Ga-67	500	5	1
Ga-68	100	5	0,1
Y-90	25	5	0,1
Tc-99m	500	5	10
In-111	250	5	1
I-123	250	5	10
I-125	5	5	1
I-131	5	5	1
Ra-223	Regardless of quantity	Regardless of quantity	NA

Table A3 *Activity levels specified for gamma isotopes are based on an activity that at 1 m distance from a source does not exceed 20 µSv/h, which for a 1.5 h/day and 200 days/year would annually correspond to 6 mSv. Activity levels for alpha and beta irradiation are based on internal contamination (intake/inhale) where limits are set to 10 % of an activity that would correspond to 6 mSv for a single intake/inhalation. This same limit is applied to combinations of gamma and alpha/beta. A holding of isotopes not listed shall be assessed by the RPE.*

Appendix 3
Functional check instructions

Radiation protection instruments
Functional check-ups of radiation protection instruments shall be carried out before each experiment by the users.

- Check that the probe looks intact and that there are no visible holes or damages on the probe's entrance window. If damage is detected, contact the RPE without delay.
- Switch to the BAT position to check that the batteries are charged. If the indicator shows less than 30%, the batteries shall be replaced with fully charged batteries (or recharged if rechargeable batteries) before the next step.
- Switch to ON position. There shall be an audible sound to indicate that the system is on. If no sound is heard when selecting the "on" mode or if no radiation is detected at all (when checking a known source), contact the RPE without delay.

Ionization chamber and electrometer
Functional check-ups of ion chambers and electrometers shall be carried out annually by the RPE. Check-ups shall be documented by the RPE.

- Check that ionization chamber is safely stored in a dedicated storage area.
- Check that there is no visible damage to either the chamber or contacts. Do a visual check of the electrometer. If any damage is detected, the instruments shall be calibrated.
- Connect the ion chamber to the electrometer. Turn on the electrometer. Select the correct ion chamber ID. Check that no error messages appear on the display. If any error message appears, a calibration shall be carried out.

Appendix 4
Calibration instructions

General calibration information

- Measured values shall be compared against the average value of the original and previous measurements, where the tolerance level is 20% and the action level is 50%.
- If the measured value exceeds tolerance the level, but is lower than the action level, the interval between checks must be reduced.
- If the measured value exceeds the action level or exceeds the tolerance level three times in a row, the instrument shall be taken out of service. The RPE shall assess whether instruments should be sent for service, calibration (by a second standard dosimetry laboratory), or be decommissioned.
- Calibrations shall be documented by the RPE.

Radiation protection instruments

KI's radiation protection instruments shall be calibrated annually.

- The radiation protection instrument's probe window shall be placed facing the calibration radiation source (pen source, Eckert & Ziegler Nuclitec, type QCRB1282, s/n BC-7137). The distance between radiation source and probe shall be kept identical between measurements.
- Perform the measurement with and without the source's protective cap for 30 seconds. Record the measured values. Evaluate.

Ionization chamber and electrometer

One electrometer and ionization chamber pair shall be calibrated every five years by a second standard dosimetry laboratory and thereafter used for cross-calibrating the remaining electrometer and ion chamber pairs.

- Connect all ion chambers to each electrometer respectively.
- Turn on all the electrometers (voltage and polarity: -400 V) and allow them to warm-up for at least 15 minutes before measurement.
- Place an ion chamber in the X-ray cabinet on FSD 60 cm.
- Irradiate (with 300 kV and 195 kV respectively, and filtration of interest) for 60 seconds and record the measured values. Evaluate.

Appendix 5

Wipe test instructions

Possible contamination from low-energy beta emitting isotopes (e.g., H-3) shall always be measured with wipe tests. Although some medium-energy beta emitters might be possible to detect with certain radiation protection instruments (e.g., C-14 and S-35), the measurement efficiency of these measurements are generally very low; hence possible contamination of medium-energy beta emitting isotopes shall also be measured with wipe tests.

- Use protective gloves. Change gloves if any contamination is suspected.
- Create a numbered list with a number for each area/object to be measured including a number for the background.
- Take scintillation tubes and label the lids with the respective numbers.
- Start with the background wipe test, which shall undoubtedly be free of contamination.
- Wet a filter paper (or other absorbent material) with alcohol or count-off.
- Drag the filter paper over the surface with one even stroke in one direction. If the sampling is done on a larger surface: wipe a 10 X 10 cm^2 area. If sampling smaller objects: wipe the actual area. Use disposable tweezers if high contamination is suspected.
- Place the filter paper in a labelled scintillation tube and fill with scintillation fluid. Check that labels match the numbered list.
- Shake thoroughly before analysing the wipe test samples in a liquid scintillation beta counter.

Appendix 6

Contamination check

Use the radiation protection instrument located in the lab for gamma and high-energy beta radiation. Use wipe test for low-energy beta radiation (instructions in Appendix 5).

- Measure the background (i.e., make sure there is no source/contamination nearby) and record the value.
- Measure work surfaces, hands, and lab coat, and record the values. In case of suspected floor contamination, measure shoe soles, as well.
- If contamination exceeds three times the background value, record the values and clean the contaminated surfaces with soap and water (or count-off). Paper towels/cleaning cloths shall be treated as radioactive waste. Repeat measurement and cleaning until measured values are less than three times background. If contamination persists, contact the RPE.
- If contamination exceeds ten times the background value, contact the RPE without delay. Cleaning shall be carried out in consultation with the RPE.
- Record all measurements and keep the documentation in a folder at the isotope laboratory.

Appendix 7
Measures to take after a radioactive spillage

General

- Staff not involved in the spillage shall leave the premises without delay if they are not suspected of being contaminated. The cleaning staff shall never be asked to clean until clearance is confirmed.
- The contaminated area shall be marked, including a notice on the door. Employees in adjacent spaces shall be informed of the incident.
- Protective clothing (coat, double protective gloves, and shoe covers) shall be worn and changed without delay in case of suspected contamination.
- Contamination shall generally be checked according to the instructions in Appendix 6.
- Cleaning materials and contaminated clothing shall generally be handled as radioactive waste. If an excess quantity arises, the contaminated material shall be placed in a well-sealed and marked (date, isotope, amount of activity, and contact person) plastic bag.
- All staff involved in the cleanup shall be checked for contamination.
- Record all measurements and keep the documentation in a folder at the isotope laboratory.

Surface contamination

- Spills on surfaces shall be absorbed with absorbent material. Wipe from the outer edge of the contaminated surface inwards. Never rub as this may spread contamination to a larger area.
- When as much as possible has been absorbed, the surface shall be cleaned and checked for contamination after cleaning. Continue cleaning (according to Appendix 6) until further washing shows no sign on contamination.
- If contamination persists, the surface must be covered with plastic paper and labelled (radionuclide, estimated amount of activity that has been spilled, the latest measured value after cleanup, and the name and telephone number of the radiation protection assistant). The area must be marked with warning tape and the door with a note of the incident. The RPE shall be informed.

Personal contamination

- Splashed clothing shall be removed without delay. Remember that shoes might be contaminated as well.
- Remaining clothes and skin shall be checked for contamination (method described in Appendix 6). At this moment, staff shall help each other.
- Contaminated skin shall be rinsed (never scrubbed) repeatedly (at least three times) with lukewarm water (mild soap can be used, but never solvents or cleaning agents containing alcohol, which reduce the skin's own protective function). If a large part of the body is contaminated, contaminated staff shall put on non-contaminated shoes and go to the nearest changing room to shower. Continue washing/rinsing contaminated skin until contamination free.
- In case of suspected splashing in the eyes, repeated eye washes shall be carried out without delay.
- If possible, allow contaminated wounds bleed for a while, then rinse thoroughly with water.
- In case of suspected internal contamination (oral/inhalation) or if contamination persists despite extensive rinsing, the assistant shall contact the RPE (office hours) and the health care advisory service on phone number 1177 (after office hours). Occupational health care shall be contacted regarding follow-up.

Appendix 8
Transport instructions for radioactive substances

Package requirements
Packages containing a radioactive isotope shall

- be properly marked (radionuclide, activity and time at specified activity, contact info)
- be properly shielded and sealed (must withstand being dropped from a standing height)
- not irradiate more than 5 µSv/h at the surface
- not be contaminated (i.e., gloves shall not be required).

Surface dose rate measurement
Surface dose measurements are required for gamma or high-energy beta isotopes. A radiation protection instrument adequate for gamma and/or high-energy beta shall be used.

- Determine the background radiation level by measuring with the radiation protection instrument in a nearby room.
- Measure the surface of the package by slowly moving the probe of the instrument close to the surface of the package without touching it.
- If any measured value exceeds 5 µSv/h, the radiation dose rate is too high. Either increase the shielding or divide the package into several packages with a smaller amount of activity in each package and measure again. The RPE shall be contacted if the surface dose still exceeds 5 µSv/h.
- Record the measurement and keep the documentation in a folder at the isotope laboratory.

Appendix 9

Activity estimation for radioactive waste containers

The formula below shall be used to estimate the amount of activity A(t) at a certain time (t).

$$A(t) = A(t_0) \cdot e^{-(t-t_0)\cdot \ln(2)/T}$$

- $A(t_0)$ is total activity in the original stock solution at reference time t_0.
- T is the nuclide's half-life.

To estimate the amount of activity added to a radioactive waste container, use the original radioactivity of the stock solution to calculate the following:

- the amount (if any) remaining in the stock solution
- the amount (if any) that is lost as liquid waste
- the amount (if any) that is lost as scintillation liquid
- the amount (if any) that is lost as biological waste.

These amounts of radioactivity shall be subtracted from the original. The calculated activity shall be recorded on the logbook attached to the radioactive waste container. Rather overestimate than underestimate the amount of radioactivity.

If waste consists of more than one radioactive isotope, total activity shall be calculated using the formula below, where c_i is the amount of activity of radionuclide i, and $c_{FN,i}$, is the limit level for radionuclide i. The RPE shall be contacted for advice.

$$\sum_{i=1}^{n} \frac{c_i}{c_{\mathrm{FN}i}} < 1$$