C09 Ionizing Radiation Safety Guidelines

1. Introduction

Ionizing radiation sources, including radioactive substances and irradiating apparatus, are regulated by the Radiation Ordinance and its subsidiary regulations (Cap. 303, Laws of Hong Kong SAR) in Hong Kong. Valid license must be obtained from the Radiation Board for the following categories:

a) To possess and use radioactive substances; and

b) To possess and use irradiating apparatus

According to the legislation, owners and users of ionizing radiation sources must fulfill stringent radiation safety requirements. This document serves as guidelines for all concerned laboratories at the Science Park to meet legal requirements as well as to adopt good practices on radiation protection.

2. Ionizing Radiation Sources

Radiation, in the form of electromagnetic waves or particles, with energy high enough to remove electrons from an atom to create an electrically charged ion is called ionizing radiation. This ionizing process often results in chemical changes in living tissue, which may result in injury to the organism. Sources of ionizing radiation include both radioactive substances and irradiating apparatus, such as X-ray machine, with the following definitions under the legislation:

Radioactive substance – any substance which consists of or contains any radioactive chemical element whether natural or artificial and whose specific activity exceeds 75 bequerels of parent radioactive chemical element per gram of substance.

Irradiating apparatus – any apparatus which is (i) intended to produce or emit ionizing radiation; or (ii) capable of producing or emitting ionizing radiation at a dose rate exceeding 5 μSv per hour at a distance of 5 cm from any accessible point of the surface of the apparatus.

3. Responsibilities

3.1 Management of the Client: The Management of a Client whose laboratory possesses and uses ionizing radiation source(s) must:

a) Ensure that relevant and valid license(s) is/are available and all aspects of radiation safety as indicated in the legislation are complied with;
b) Delegate a responsible person with sufficient and proper training to oversee radiation safety.

3.2 Responsible Person: The Responsible Person shall:

a) Manage the procurement, licensing, delivery, storage, handling and disposal of ionizing radiation sources in accordance with legal requirements and HKSTP's guidelines;
b) Ensure that all radiation workers in the laboratory are properly trained, licensed, physically fit (passed medical examination), and provided with personal monitoring device where applicable;
c) Monitor radiation safety in the laboratory;
d) Provide safety instructions to users on specific work procedures;
e) Advise on radiation protection where necessary; and
f) Report to the management or the authority in case of any radiation incident or emergency situation.

3.3 Radiation Worker: A radiation worker shall:

a) Be licensed with the Radiation Board where applicable;
b) Be trained in radiation safety;
c) Be physically fit to carry out the radiation work by passing the annual medical examination where necessary;
d) Wear the personal monitoring device if necessary;
e) Follow all applicable radiation safety practices when working with ionizing radiation source.

4. Safety Requirements Associated with Radioactive Substances

4.1 Sealed and Unsealed Radioactive Substances – Radioactive substances can be in form of "sealed" or "unsealed" with the following definitions delineated in the Radiation (Control of Radioactive Substances) Regulations:

a) Sealed radioactive substance – a radioactive substance which is permanently enclosed in a container but in such a manner as to permit the emission of radiation. However, the substance cannot be separated from the container unless the container is damaged. Examples of commonly used sealed sources include standard solid radiation sources, analytical equipment embedded with radioactive substances such as electron capture detector, particulate analyzer, etc.

b) Unsealed radioactive substance – any radioactive which is not sealed. Liquid radiochemicals are commonly used unsealed sources in the laboratory.

While both sealed and unsealed radiation sources are regulated by law, more stringent safety control measures are imposed on the use of unsealed sources due to the higher risk of spillage and contamination. The Management of a Client should avoid or minimize the use of unsealed sources in the research works as far as possible.

4.2 Purchase – Before the purchase for any radioactive substances, the responsible person shall ensure if relevant license has been obtained from the Radiation Board. For unsealed radioactive substances, if the radioactivity of individual radionuclide to be purchased exceeds the maximum allowed radioactivity covered by existing license, amendment of the license must be completed before purchasing. Always check the existing license for details about the licensing conditions before any plan for new or modified experiment involving the use of additional radionuclides or increased radioactivity.

4.3 Personnel – All radioactive substance users must be trained in radiation safety. Users of unsealed radioactive substances and high radioactivity sealed radioactive substances must also be physically fit for the radiation work by passing a medical examination and have their radiation exposure personally monitored using the thermoluminescent dosemeters (TLDs).

4.4 Laboratory Area – Radioactive substances must only be used or stored at designated laboratory areas covered by the corresponding licenses. A copy of each license shall be displayed or available at convenient location in the laboratory. A radiation hazard warning sign shall be posted at the entrance of the laboratory. The area should also be accessible to authorized users only. Other laboratory requirements regarding sealed and unsealed radioactive substances are listed separately below.

a) Areas with Sealed radioactive substances:

i. The sealed sources shall be kept in suitable containers with sufficient shielding;
ii. The area should be ventilated efficiently if gases radioactive substances may be generated due to decay of the radioactive sources;
iii. Proper personal protective equipment, if necessary, should be available for use.

b) Areas with Unsealed radioactive substances:

i. The floor should be covered with monolithic materials such as seamless vinyl or epoxy;

ii. The walls should be coved to the floor for ease of cleaning;
iii. The bench surfaces should also be impervious and easy to clean;
iv. The lighting fixtures should be flush with the ceiling to eliminate dust collection;
v. There should be independent laboratory ventilation system;
vi. Special radioisotope fume hood should be available for use if radioactive aerosols are likely to be generated during radiation work;
vii. Sufficient and appropriate shielding materials should be provided;
viii. Wash basin, preferably made of stainless steel and equipped with hands free faucet, should be available;
ix. Emergency shower and eyewash unit should be available in the vicinity;
x. Necessary personal protective equipment such as gloves, lab coats, eye protectors should be provided;
xi. A calibrated radiation survey meter should be available;
xii. Sufficient and appropriate radioactive waste containers should be available; and
xiii. Spill control kit for radioactive substances should be available.

4.5 Handling and Operation – Local rules for the radiation laboratory and standard operating procedures (SOP) for specific radiation work should be established and displayed at a conspicuous area in the laboratory for all users to follow. These rules and procedures should also be revised whenever necessary. For laboratories where unsealed radioactive substances are used, relevant safety information such as Nuclide Safety Data Sheets (NSDS) should also be available for reference.

a) Precautions for handling sealed radioactive substances:

i. No eating, drinking, smoking, application of cosmetics, or storage of foods or drinks should occur in the laboratory;
ii. Wear protective equipment such as gloves, protective clothing, eye protectors, etc. whenever necessary;
iii. Use appropriate shielding, forceps or tongs to handle sealed radioactive substances whenever necessary.

b) Precautions for handling unsealed radioactive substances:

i. No eating, drinking, smoking, application of cosmetics, or storage of foods or drinks should occur in the laboratory;
ii. No mouth pipetting;
iii. Wear personal protective equipment consisting of at least a laboratory coat, appropriate gloves and eye protectors;
iv. Wear personal monitoring device, i.e. TLD badge, during work for monitoring personal exposure to radiation;

v. All works should be conducted in secondary containment facilities such as a spill tray lined with absorbent materials;
vi. Suitable shielding materials should be used in all experimental situations and when storing radioactive substances or wastes;
vii. All radioactive substances should be stored in a suitable cabinet, container or refrigerator according to the storage requirements as given by the manufacturer;
viii. All operations that may produce a vapor, gas, spray or dust should be carried out in the radioisotope fume hood;
ix. Each radioactive preparation should be properly clearly marked with details of the chemical compound, radionuclide, activity, date and name of user;
x. Use of any radioactive substances should be properly recorded;
xi. A calibrated radiation survey meter should be available and used throughout all radiation works;
xii. Equipment to be used in active working areas should be retained only for that purpose and be labelled accordingly;
xiii. Possibly contaminated gloves, absorbent materials, cleaning equipment and disposable laboratory equipment should be disposed of as radioactive waste in suitable, adequately labelled containers;
xiv. Clean-up of the active working area and checking for any contamination should be conducted after each experiment and at the end of each day.
xv. Radiation working areas should be cleaned by laboratory staff. Cleaning staff should not service these areas;
xvi. Before leaving the laboratory, wash hands thoroughly. Monitor hands, clothing and shoes to ensure no contamination is present.

4.6 Waste Disposal – Radioactive substances and materials contaminated with radioactive substances must be disposed of as radioactive waste.

a) Waste with sealed radioactive substances:

Unwanted sealed radioactive substances are usually collected and shipped back to the manufacturers for final disposal.

b) Waste with unsealed radioactive substances:

i. Radioactive waste should be segregated and stored according to different radionuclides and properties of chemicals in suitable and adequately labelled containers;
ii. The storage area should be provided with proper and sufficient shielding;
iii. Follow the respective licensing conditions for final disposal of the radioactive waste.

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5. Safety Requirements Associated with Irradiating Apparatus

5.1 Types of irradiating apparatus – The most commonly used irradiating apparatus at the Science Park is X-ray machine. Other irradiating apparatus include any high voltage (20 kV or above) vacuum devices that may have potential for generating X-ray. X-ray machines can be further categorized into the following three types according to the design and purpose of use:

a) Closed-beam X-ray machine (e.g. X-ray diffractometer, etc.)

b) Open-beam X-ray machine for purposes affecting the human body (e.g. diagnostic X-ray devices)

c) Open-beam X-ray machine for purposes other than x-raying human bodies (e.g. industrial X-ray machines for non-destructive testing)

A closed-beam X-ray machine has the X-ray beam, the target materials and the detector enclosed in an interlocked cabinet while an open-beam X-ray machine does not have a cabinet or enclosure and therefore requires more safety control measures.

5.2 Purchase and installation – The possession and use of any type of irradiating apparatus requires a valid license from the Radiation Board. The owner of an irradiating apparatus must apply for such license before purchasing to facilitate the import, delivery and installation of the apparatus. Upon completion of installation, the Radiation Board should be notified in order to obtain the valid license for operation.

5.3 Personnel – All irradiating apparatus users must be trained in radiation safety. Users of open-beam X-ray machines or other irradiating apparatus as required by the Radiation Board must obtain valid user licenses for operating the apparatus. They must also be physically fit by passing a medical examination and have their radiation exposure personally monitored using the thermoluminescent dosemeters (TLDs).

5.4 Laboratory Area – Irradiating apparatus must only be installed and used at designated location specified by the corresponding license. The entrance to this area shall be posted with a radiation hazard sign and a copy of the irradiating apparatus license shall be displayed in the vicinity of that particular apparatus. The area shall also be restricted to authorized users only.

Moreover, the laboratory area where open-beam X-ray machines or other irradiating apparatus specified by the Radiation Board shall have additional safety features as follows:

a) It shall be designated only for operation of the specified open-beam X-ray machine or other irradiating apparatus;

b) It shall be built-in with sufficient shielding for protection against the radiation meeting Radiation Board's requirements; and

c) A warning light shall be installed at the entrance in such a way that it must be turned on whenever the irradiating apparatus is energized.

5.5 Operation – Local rules for the laboratory and Standard Operating Procedures (SOP) for the irradiating apparatus must be established and displayed at a conspicuous area in the laboratory for all users to follow. SOP should include basic requirements for users, normal operating procedures, safety precautions and emergency response in particular to that apparatus. It should be revised whenever there are any modifications to the apparatus or any changes in its application.

a) Precautions for operating closed-beam X-ray machines:

i. Only authorized and trained personnel are allowed to operate the machines.
ii. Flammable chemicals should not be kept in the vicinity of the machines.
iii. No alternation should be made to the machine unless the X-ray tube is de-energized.
iv. Alignments or adjustments shall not be carried out visually while the X-ray tube is energized, unless a viewing system is used to avoid direct exposure to the radiation. Proper protective equipment should also be used whenever necessary to protect the body parts which might be exposed to the radiation.
v. Safety devices (such as enclosure interlocks) of the machines must be regularly checked for normal functions.
vi. Repair and maintenance of the machines shall be carried out by qualified personnel on a regular basis.

b) Precautions for operating open-beam X-ray machines:

i. Only authorized personnel who are trained, physically fit and licensed are allowed to operate the machines. They must also wear their TLDs for personal monitoring during operation.

ii. Useful X-ray beam must be directed away from room entrance or adjacent occupied areas.

iii. Flammable chemicals must not be kept in the room where the machine is installed and used. Ignitable gas or vapor must be free from this area.

iv. When the machine is used inside a demarcated area, all persons should be excluded from the area during irradiation.

v. Where it is necessary for any person to enter or remain in demarcated area while the machine is irradiating, the shielding and operating conditions should be such that the radiation doses received by such persons are not in excess of the dose limits.

vi. Arrangements must be made (e.g. emergency stop in the vicinity) to ensure that the persons within the demarcated area can switch off quickly all sources of ionizing radiation from within the area, can leave the area without delay and can, if necessary, obtain immediate help from outside the area.

vii. No alternation should be made to the machine unless the X-ray tube is de-energized.

viii. Alignments or adjustments shall not be carried out visually while the X-ray tube is energized, unless a viewing system is used to avoid direct exposure to the radiation. Proper protective equipment should also be used whenever necessary to protect the body parts which might be exposed to the radiation.

ix. Safety devices (such as room door interlock, if there is any) of the machines must be regularly checked for normal functions.

x. Repair and maintenance of the machines shall be carried out by qualified personnel on a regular basis.

5.6 Disposal – The licensee of an irradiating apparatus must notify the Radiation Board and follow the Board's recommendations for disposal of the irradiating apparatus and cancellation of the license.

6. Accidents / Incidents and Emergency Responses

6.1 Leakage of radiation – In case radiation leakage is detected from an operating irradiating apparatus, the apparatus must be switched off immediately. The user should report the incident to the Responsible Person, who should in turn seek assistance from the manufacturer's request servicing personnel for checking and maintenance.

6.2 Accidental exposure to radiation – If any person is suspected to have been accidentally exposed to high energy radiation, S/he must report the case to the Responsible Person and seek medical assistance as soon as possible.

6.3 Spillage and decontamination – In an incident involving spillage of radioactive substances, an assessment should be made so that suitable measures can be taken for minor and major spillage accordingly.

a) Minor spillage which may involve only a low radioactivity level (< 4 MBq or 0.1 mCi):

i. Report the incident to the Responsible Person and notify HKSTP by telephone following HKSTP's general laboratory emergency procedures;
ii. Demarcate the contaminated area with a warning notice;
iii. Wear gloves, protective clothing, shoe covers and respirator where appropriate;
iv. Drop appropriate absorbent around the spill to avoid its spreading;
v. Cover the spill with absorbent and allow it to absorb the radioactive substances;
vi. Starting decontamination by moving the surrounding absorbents slowly towards the spill;
vii. Clean the area with water or appropriate detergent;
viii. Monitor the decontamination process continuously with a proper radiation survey meter;
ix. All materials used in the decontamination process (including protective clothing, gloves, shoe covers, absorbent materials, etc.) must be treated and disposed of as radioactive waste.

b) Major spillage which may involve a higher radioactivity level (≧ 4 MBq or 0.1 mCi):

i. Alert other nearby personnel and evacuate the laboratory immediately;
ii. Under safe condition, shut off the laboratory ventilation system and close the laboratory door;
iii. Stay in a nearby safe area. Report the incident to the Responsible Person and notify HKSTP by telephone following HKSTP's general laboratory emergency procedures;
iv. Call the local emergency hotline (999) and wait for assistance;
v. Warn other persons to keep clear of the contaminated area;
vi. Injured or possibly contaminated persons should not proceed far away from the contaminated area until they have been monitored;
vii. When emergency personnel arrive, provide them with necessary information about the incident;
viii. Emergency personnel will treat any injured first, then minimize the spread of contamination from the spill and start decontamination procedures.

6.4 Reporting of accidents / incidents to the Authority – All accident and incident cases involving major spillage of radioactive substances, personal exposure to high

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energy radiation, and loss of ionizing radiation sources, etc. shall be reported to the Radiation Board as soon as possible within 48 hours.