7 Organization of Radiation Protection

"My time inside there was very short compared to the amount of time it took to take on and take off this suit and to test me for how much radioactivity I have."

William Scranton
(after visiting the Three-Mile-Island reactor)

The responsibility for the correct integration of the radiation-protection rules in a company, nuclear power plant, research center, or an university lies in the hands of the radiation-protection supervisor. The radiation-protection supervisor has to appoint in a radiation-protection directive an appropriate number of radiation-protection officers for the control and surveillance of the work in question. The radiation-protection officer or, for short, the radiation officer has to be qualified for his work in the field of radiation protection. In contrast to this the radiation-protection supervisor need not be an expert in the field of radiation protection. He transfers the duty to respect the regulations of radiation protection to the radiation officer.

radiation-protection directive

Usually the handling of radioactive material requires a license from the relevant authority. It is the duty of the radiation officer to arrange the necessary licenses for the handling of radioactive material. When the radiation-protection supervisor has appointed a radiation officer, the terms and conditions of his responsibility must be well-defined in writing. If there is more than one radiation officer in a company, it must be ensured that the terms and conditions of their responsibilities do not overlap.

radiation officer

The radiation-protection supervisor must notify the competent authority of the appointment of the radiation officer and define his or their responsibility in matters of radiation protection. The notification of such an appointment is considered to be evidence of the qualification of the radiation officer in the field of radiation protection. Since the position of a radiation officer is associated with high responsibility, only persons may be appointed if no facts are known which could cast doubt on their reliability. A necessary ingredient, of course, is that they possess the required qualification for the field of radiation protection. The radiation officer is responsible for the correct handling of the radioactive material in a company, in a power plant, or a research center. He must inform the radiation-protection supervisor immediately, if there are deficiencies affecting the safety in the field of radiation protection. Conflicts may arise from the fact that the radiation officer might propose alterations in

qualification

C. Grupen, *Introduction to Radiation Protection*,
Graduate Texts in Physics, DOI 10.1007/978-3-642-02586-0_7,

the handling of the safety regulations which the radiation-protection supervisor does not agree to. However, the radiation officer must not be hindered in any way in performing his duties and he should not be put at a disadvantage due to his activities even if they do not find the full support of the radiation-protection supervisor. The radiation-protection supervisor and the radiation officer must assure that in the event of danger to life, health, or property adequate measures are taken immediately. For example, if there is a danger of the dispersion of radioactive substances this risk must be kept as low as practicable so that the danger of incorporation into the human body is kept at a reasonably low level. Also steps must be taken to assure that accidental criticality of nuclear fuel cannot occur.

radiation accidents

The regulations in the field of radiation protection require that persons who will handle radioactive material, e.g. students in a nuclear physics lab at a university, are instructed about the possible dangers of handling radioactive sources. This instruction must be done annually and has to cover a number of aspects which are:

instruction

- introduction into the local laboratory safety rules,
- introduction into the standard working procedures with radioactive sources,
- information with respect to possible dangers,
- information about radiation exposures,
- description of the safety rules and possible protection techniques,
- accurate information about the relevant radiation-protection safety rules,
- instructions about the organization of radiation protection, and the responsibility of the radiation officer. The workers perform their tasks under the guidance of the radiation officer and they are bound to follow his instructions.

The radiation officer has to ensure that radioactive materials possessed under license conform to the materials which are included in the license. Also the radioactive materials should only be handled by individuals which are authorized to do so as stated in the license. It goes without saying that all users have to carry the required monitoring equipment such as film badges or electronic dosimeters.

film badges
electronic dosimeters

An important aspect is also that the radiation officer has to ensure that all radioactive material under the license is properly secured against unauthorized removal and against theft. Special care has to be taken in the handling of unsealed radioactive sources, because there is the danger of incorporation of radioactive material. On the other hand, the radiation officer has to perform periodic leak tests of sealed sources. If an originally sealed source is found to be leaky, then it takes on the character of an unsealed source. Normally

sealed sources
unsealed sources

such a leaking source has to be stored away, because the handling of this leaky source will usually not be covered by the license.

accounting

One of the most important tasks of a radiation officer is a painstakingly correct and clear accounting. The competent authority has to be informed about the acquisition and disposal of radioactive material. It is evident that acquisition and disposal has to be well documented. It must be clear at any time which radioactive material is used or stored. For this purpose the radioactive material has to be described accurately. The list containing the used material has to contain the following items:

- radioisotope (e.g. $^{137}_{55}$Cs),
- activity and type of radiation (e.g. 10^6 Bq; β, γ),
- physical property (e.g. solid or liquid),
- sealed or unsealed source,
- date of the acquisition of the source or the radioactive material,
- address of the supplier and addressee.

Figure 7.1
Design-approved radioactive sources for demonstration experiments (QSA Global GmbH)

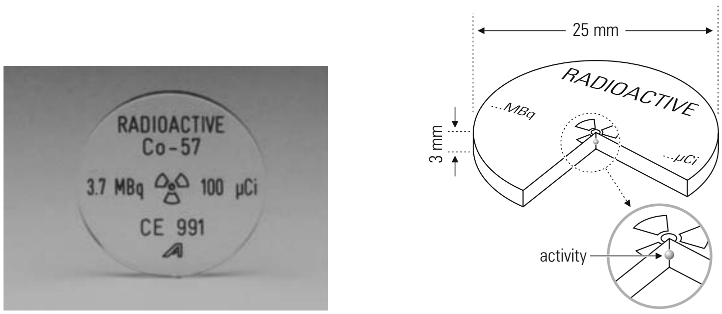


Figure 7.2
Pointlike emitter, in this case 3.7 MBq ^{57}Co, for use in the field of radiography (type 25/3, AEA Technology QSA GmbH)

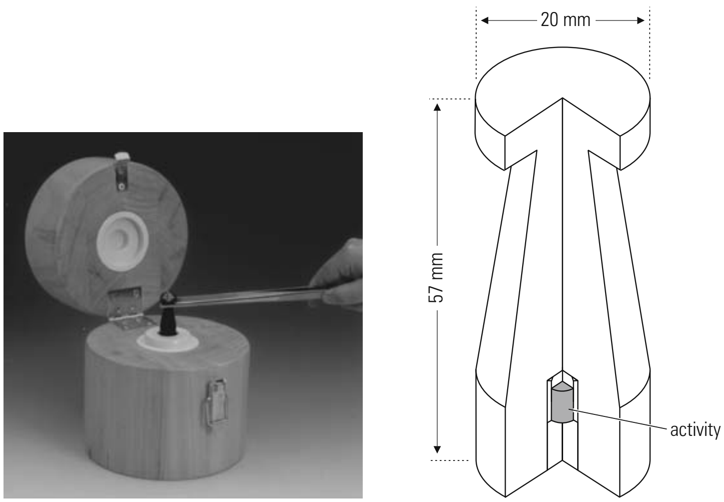


Figure 7.3
^{137}Cs calibration source for function control of detectors for activity measurements (type CDRB 1548, 3.7 MBq, AEA Technology QSA GmbH)

documentation

The written documentation about special instructions, area monitoring, body doses, contamination measurements, possession, and disposal of radioactive material have to be stored over a long period of time. Body doses have to be kept up to the age of 75 of the monitored person, but at least 30 years.

radiation passport

Radiation doses have to be documented in a radiation passport for the radiation workers. The purpose of this is to prevent to exceed the dose limits, in particular, if radiation workers are active in different companies and places. The radiation passport shows whether the owner of the passport fulfills the conditions for the envisaged activity, e.g. in an exclusion area or radiation-controlled area. The radiation officer of a plant is supposed to allow only activities for those people not belonging to the company, if they can provide an uninterrupted, complete radiation passport. This radiation passport should contain the following information:

- personal data and employer;
- information about external and internal radiation exposures;
- body doses, possibly exceeding the annual limits;
- result of the medical checkup;
- possible respiratory protection instruction and training;
- accounting of radiation exposures in the occupational life.

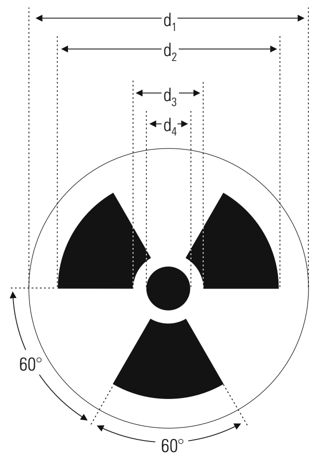
Radioactive materials, containers, and rooms, in which radioactive material is being used or stored, just as instruments for the production of ionizing radiation and devices with design qualification approval have to be properly labeled. Also the different radiation areas (exclusion areas, controlled areas, surveyed areas) and contaminated areas have to be marked as such.

Workers have to be alerted of possible dangers. The characterization or warning of relevant radiation areas must be done with the official warning labels (see Fig. 7.4) with the following indications

- ATTENTION – RADIATION,
- RADIOACTIVE,
- NUCLEAR FUEL,
- EXCLUSION AREA – NO ADMITTANCE,
- CONTROLLED AREA,
- CONTAMINATION.

In addition, the labeling must contain information about the radioisotope, its activity, and the responsible radiation officer. Labels which are no longer valid ***have to be removed***.

The radiation officer has to perform a number of measurements in those areas for which he is responsible. These measurements serve the purpose of radiation-protection monitoring and control. These measurements include the following items:



$d_1 = 80$ mm $d_3 = 20$ mm
$d_2 = 63$ mm $d_4 = 12.5$ mm

Figure 7.4
Radiation warning label. For different sizes of this label the values d_2, d_3, and d_4 have to be properly scaled for the allowed set of parameters d_1 (20, 40, 80, 160, 250 mm). The black areas are imaged on a yellow background. In most cases this label is framed by a black triangle the apex of which points to the top (see Fig. 7.5)

- measurement of dose values,
- monitoring of the amount of activity,
- admission control,
- control of correct storage,
- leak tests,
- checkup on the safety measures,
- monitoring of unusual radiation exposures,
- check on the dose limits for radiation-exposed workers and non-radiation-exposed persons,
- measurement of incorporations,
- measurement of contaminations,
- monitoring of the environmental radiation,
- monitoring of possible contaminations of air, water, and ground.

monitoring

The radiation officer can hire staff to help him to fulfill his duties. Their field of activity must be clearly defined in writing in the form of a radiation-protection directive.

Occasionally there will certainly be incidents in the practical work of radiation protection where it is the duty of the radiation officer to inform the competent authority about these incidents, e.g.

exceeding dose limits

loss of radioactive sources

finding of radioactive substances and acquisition of actual control

- exceeding the allowed dose limits,
- loss and acquisition of radioactive material,
- deficiencies and problems with safety systems.

In case of accidents in radiation-protection areas the following priority always has to be respected, namely, rescue – alert – secure – inform the competent authority.

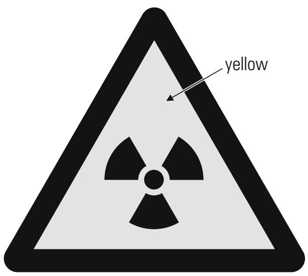


Figure 7.5
Frequently used form of the radiation warning label

medical examination

The aim of the medical examination which is compulsory for radiation workers of category A is not primarily to diagnose radiation damages but rather the purpose of these examinations is to check the state of health of the worker before he starts his activity and while he is working in these radiation areas. For persons which become active in a controlled area a medical examination is compulsory before they start to work in the controlled area. For persons of category A in Europe the medical examination has to be repeated annually.

limitation of activities

restricted activities

In case of health risks as diagnosed in a medical examination the activities of the worker can be limited (e.g., if there is a problem with carrying respiratory equipment, only the handling of sealed radioactive sources may be allowed). It is even possible to exclude certain workers from working in a radiation-exposed area, e.g. pregnant women. The restriction or reduction of tasks for persons in controlled areas can also be the consequence of exceeding the allowed annual whole-body dose. The purpose of these restrictive procedures is to limit further radiation exposures so that the dose over a period of several years stays within the allowed dose limits.

An important aspect in the field of practical radiation protection is the handling of incidents and accidents. One has to distinguish between minor incidents, accidents, large serious accidents, and emergency situations. In such cases the permitted dose for radiation workers may be exceeded. A situation is already called an accident, if the continuation of a plant has to be interrupted for safety reasons. When designing an installation or plant, one has to take care that accidental doses may not exceed the values given in the respective radiation-protection regulations. For the European Union this accidental dose is 50 mSv/yr which must not be exceeded.

radiation accidents
emergency situations

Radiation accidents and emergency situations are quite rare. But also minor radiation incidents below the threshold for emergency situations just as accidents or severe accidents have to be handled with great care to ensure a maximum of safety for the radiation workers.

minor radiation incidents

The handling of radiation accidents requires to consider the following items:

- provision for accidents (e.g. first aid, adequate training),
- activate the procedure for an emergency situation (limit or reduce the amount of the damage, prepare the fire fighting, medical treatment of persons involved in the accident),
- report to the radiation-protection supervisor, radiation officer, and information of relatives of persons involved in the radiation accident,
- analysis and reconstruction of the accident,
- duty of disclosure of the accident at the competent authority.

alarm planning

duty of disclosure

The radiation-protection regulation classifies three categories of accidents, if fires are involved. These different categories are related to the amount of activity concerned in the various parts of the installation or plant. Depending on the amount of radioactive material these areas have to be properly labeled as an information for the fire brigade.

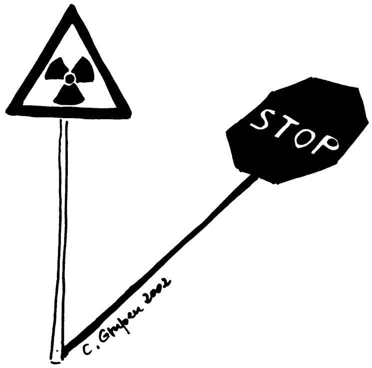
information
for the fire brigade

Procedures to dispose of radioactive waste are defined in the radiation-protection regulations. The following requirements have to be considered for the adequate disposal of radioactive waste:

- correct labeling of the radioactive waste (e.g. identification of the radioisotope, recycled material);
- labeling of the waste container with detailed information on the amount of radioactive waste, total activity, dose rate at a distance of 1 m, date of storage, . . . ;
- possibility of preliminary storage of radioactive waste.

It is important to note that it is not permitted to subdivide the radioactive waste into quantities which fall below the exemption limits

forbidden dispersal
of radioactive waste



or clearance levels. Also the dilution and dispersal of radioactive waste or radioactive materials into the environment is forbidden.

7.1 Supplementary Information

Example 1

radium mineral springs

radon inhalations

In so-called radium mineral springs concentrations of radon including the decay products in the decay chain of 4000 Bq/l can occur. Radon is produced in radium decays. The radium concentration, however, in the water is relatively low, in most cases with levels of about 1 Bq/l. One frequently talks about radium springs and radium baths, even though the correct denomination would have been radon springs and radon baths.[1] In earlier times these kinds of treatment were prescribed. It is known now that swimming in these mineral springs or drinking the radium water can lead to considerable radiation exposures.[2] A famous victim of such a radium treatment was the American golfer Eben Byers, who died 1932, because he had drunken every day twelve bottles of radium water to relieve the pain after an arm injury.

Similar considerations also hold for radon inhalations. According to the recommendation of the ICRP, radon concentrations in houses should not exceed 200 Bq/m^3. Typical values in most apartments and houses are on the order of 30 Bq/m^3. Record values for radon concentrations in houses were found in the small city St. Joachimstal in Bohemia. This town was famous for uranium mining with the consequence that in some places radon concentrations up to

[1] I thank Prof. Dr. H. von Philipsborn for pointing this out to me.

[2] The spas actually advertize these treatments by indicating that the α rays emitted form the radium effectively massage the cell membranes, thereby improving the patient's health!

10^6 Bq/m^3 inside houses were measured. The basement of some of the houses essentially consisted of uranium-containing waste from the uranium mines. In the decay chain of uranium also the radioactive noble gas radon occurs and by leaking through the basement radon can reach the living rooms of the houses.

Example 2

The maximum permitted surface contaminations for working areas are different for α emitters on the one side and β and γ emitters on the other side. Typically, because of the high radiation weighting factor for α emitters, the limits are different by a factor of 10 for α-ray emitters on the one hand and β and γ emitters on the other hand.

α rays are connected with a very high biological effectiveness. This is the reason why the exemption limits for α-radiating isotopes, or dose limits for possible contaminations, are much more stringent compared to β and γ emitters. The external radiation with α rays does not present a problem because in most cases α rays are already absorbed in air (a typical range is about 4 cm) and in any case even if α rays reach humans these α rays will be absorbed in the surface layers of the tissue or in the clothing. In contrast to that α-emitting radioisotopes become extremely dangerous, if they are incorporated, because in that case the full effect of the high relative biological effectiveness comes into play.

effect of α rays

Summary

The radiation-protection supervisor of an installation or a nuclear power plant defines in the radiation-protection directive the area of competence for the radiation officers. For this particular area only the radiation officer is responsible. The radiation officer has to be qualified in the field of radiation protection and he has to fulfill the duties as they are laid down in the radiation-protection directive. The radiation officer's qualification in the field of radiation protection has to be updated in regular intervals by attending relevant courses on radiation protection.

7.2 Problems

Problem 1

The dose rate at a work place is assumed to be 4 μSv/h. For a person who works on a regular basis 40 hours per week over the whole year in this area, this room must be associated with a radiation area. Will this room be a radiation-controlled zone or just a radiation-surveyed area according to the European regulations?

Problem 2

In a container surrounding the reactor in a nuclear power plant (volume $V_1 = 4000\,\mathrm{m}^3$) a tritium concentration of $100\,\mathrm{Bq/m}^3$ is measured. This tritium originated from a containment area in the inner reactor core of a volume of $500\,\mathrm{m}^3$. Work out the original tritium concentration. What was the total activity?

Problem 3

inhalations

In a working area a ^{60}Co concentration in the air of $1\,\mathrm{Bq/m}^3$ is found. For an annual breathing volume of $8000\,\mathrm{m}^3$ one will incorporate about 8000 Bq. Work out the amount of ^{60}Co corresponding to this activity ($T_{1/2}(^{60}\mathrm{Co}) = 5.24$ yrs, mass of a ^{60}Co nucleus $m_{\mathrm{Co}} = 1 \times 10^{-22}$ g)!