CENTRE D'ETUDE SUR L'EVALUATION
DE LA PROTECTION DANS LE DOMAINE NUCLEAIRE

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REPORT N°313

SURVEY OF INTERNATIONAL RULES AND PRACTICES REGARDING DELINEATION OF AND ACCESS TO REGULATED AREAS FOR RADIATION PROTECTION

- FINAL REPORT –

EXCLUDING ANNEXES

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1. INTRODUCTION

European requirements for radiological protection, especially work on transposing the new EURATOM Directive on the basic radiological protection standards, are currently being revised. The *Direction générale du travail* (DGT - General Directorate of Labour) and the *Autorité de Sûreté Nucléaire* (ASN - Nuclear Safety Authority) therefore commissioned the Radiological Protection Standing Groups of experts (GPRAD and GPMED)[1] to engage in a forward-looking debate on the delimitation of and access to regulated areas, within an *ad hoc* working group (called hereafter 'Classification of Area WG').

To fuel its debates, the 'Classification of Area WG' sought elements on international regulations and practices focusing on problem exposure situations in various areas of activity (nuclear, industrial, research, medical, transport and natural boosted). CEPN was entrusted with this study.

This report presents a summary of rules applicable in seven countries in terms of delimitation of and access to regulated radiological protection areas The countries are: Belgium, Spain, United States, Finland, United Kingdom, Sweden and Switzerland. Detailed sheets for each country can be found in the Annex.

Based on these summaries, three countries have been selected to apply their rules and practices in force to a dozen or so particular cases put together by the 'Classification of Area WG' that are representative of exposure situations. The three countries are Finland, United Kingdom and Switzerland. The case studies applied to each country are presented in the second part of this report.

[1] GPRAD : Expert group on radiation protection in the industrial and research fields – GPMED : Expert group on radiation protection in the medical field

2. METHODOLOGY ADOPTED

The regulatory texts on the radiological protection of workers and dealing with the designation of regulated radiological protection areas have been identified in each selected country through Internet research supplemented by direct contacts with representatives of the European ALARA network and the ISOE network (network of nuclear power plant operators and safety authorities). The safety authorities in some countries and/or professional companies have also published additional guides to assist in applying the regulations. Guides providing additional information on the designation of regulated areas have been identified and included in the study.

A "Country Sheet" has been put together for each country; this uses the structure of the French Order related to the designation of regulated radiological protection areas as a basis and attempts to identify the corresponding elements in the regulations or guides. Data specific to the nuclear and/or medical fields are separated from general regulatory data.

The case studies developed by the 'Classification of Area WG' have then been applied to three countries - Finland, United Kingdom and Sweden. CEPN has worked directly for this purpose with contacts in the safety authorities of the countries in question.

3. SUMMARY OF REGULATIONS PER COUNTRY

This section presents the main regulatory elements relating to the designation of regulated radiological protection areas in the countries studied. It focuses mainly on the area designation criteria. Each country sheet gives details of the access to the areas, their delimitation and posting and the regulatory quotations.

As all regulations in the countries studied refer to dose limit values for workers in their area classification criteria, Table 1 below presents the limits adopted in each country.

Table 1. Occupational dose limits in the seven countries studied

	Effective dose limit	**Equivalent dose limit**
- Belgium	20 mSv over 12 rollling months	For each organ or tissue: 500 mSv over 12 rolling months Lens: 150 mSv over 12 rolling months Skin: 500 mSv over 12 rollling months Extremities: 500 mSv over 12 rolling months
- United Kingdom **- Switzerland**	20 mSv per calendar year	Lens: 150 mSv per calendar year Skin: 500 mSv per calendar year Extremities: 500 mSv per calendar year
- Spain **- Finland** **- Sweden**	50 mSv per calendar year and 100 mSv over 5 calendar years	Lens: 150 mSv per calendar year Skin: 500 mSv per calendar year Extremities: 500 mSv per calendar year
- USA	50 mSv per calendar year	For each organ or tissue: 500 mSv per calendar year Lens: 150 mSv per calendar year Skin: 500 mSv per calendar year Extremities: 500 mSv per calendar year

3.1. Belgium

Belgian regulations on the designation of regulated areas are based on the Royal Order of 20 July 2001 covering general rules for the population, workers and the environment against the danger of ionising radiation, which involves all activity sectors.

Additional elements are provided for medical applications in two guides published by the Safety Authority (AFCN) and one published by the Upper Health Council (Conseil Supérieur d'Hygiène – CSH).

The main nuclear-related elements were provided by the Doel nuclear power plant. The Belgian Safety Authority does not publish a specific guide for operators.

3.1.1. General regulations

The aim of creating a controlled area under the Belgian regulations is to protect workers and contain the potential contamination, mainly by introducing access regulations. The only coded classification criterion appearing in the definition of areas is the possibility of exceeding the annual limit values. Dose rate values are also stated for the controlled area marking. (see Figure 1).

- **Controlled area:** Area subject to special regulations for reasons of protection against ionising radiation and containment of radioactive contamination; access is therefore regulated. A controlled area is an area where 3/10ths of annual dose limits fixed for occupationally-exposed individuals are likely to be exceeded.

- **Supervised area:** A supervised area is an area where an individual may be subject to exposure likely to result in doses above one of the dose limits fixed for members of the general public and which is not considered to be a controlled area.

The marking within the controlled area must reflect the different dose rate levels:

- Dose rate > 1 mSv/h: "Very high radiation intensity" must be posted.
- Dose rate > 0.2 mSv/h: "High radiation intensity" must be posted.
- Dose rate > 20 µSv/h: "Ionising radiation" must be posted.

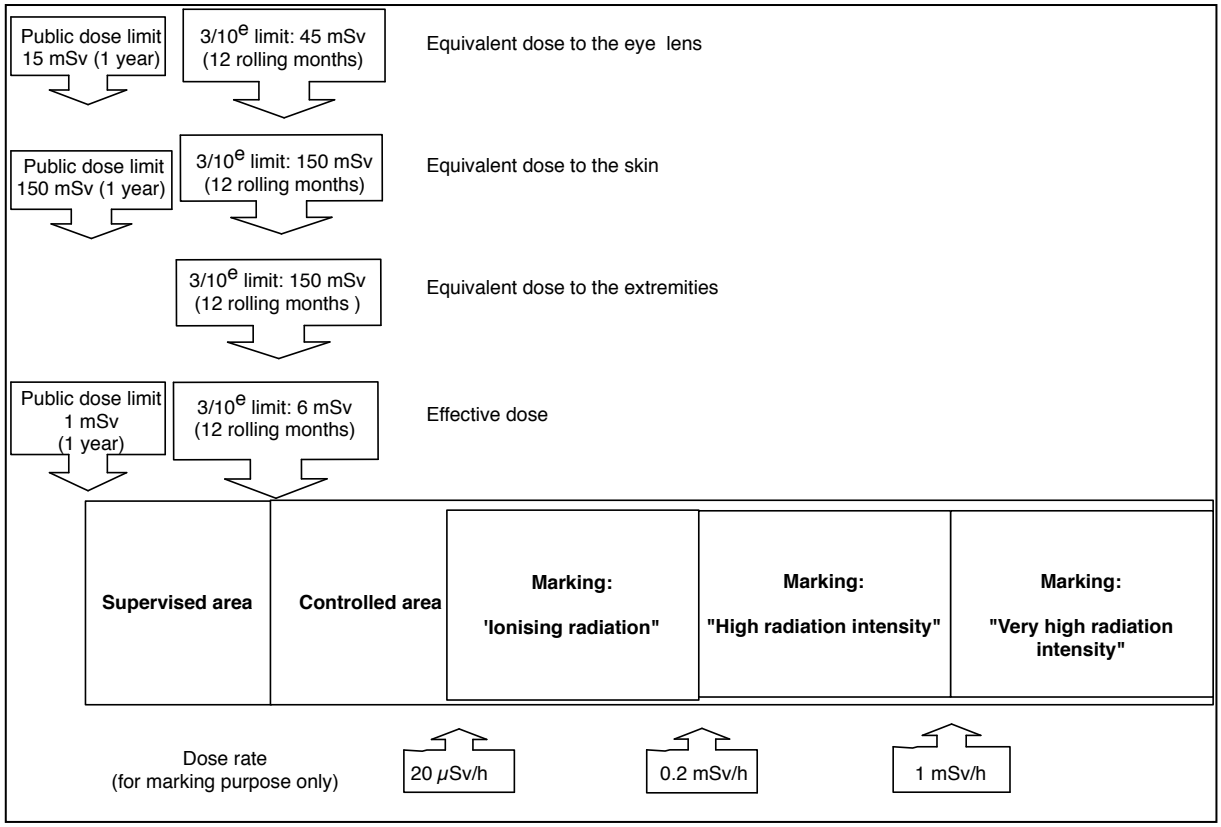


Figure 1. Criteria for the designation of supervised and controlled areas in Belgian regulations

3.1.2. Case of the Doel nuclear power plant

The Doel nuclear power plant has defined its criteria for the designation of regulated radiation areas in case of risk of external exposure on the basis of the indications given by the regulations (see Figure 2). The area colours are specific to the plant (they are not given in the regulations). Note that the lower limit of the controlled area (3 µSv/h) has been defined using a maximum presence of two thousand hours a year for a worker (compliance with the regulations gives: (3/10 x 20 mSv) / 2000 h = 0.003 mSv/h.)

Additional classification of area is created for surface contamination (see Figure 3).

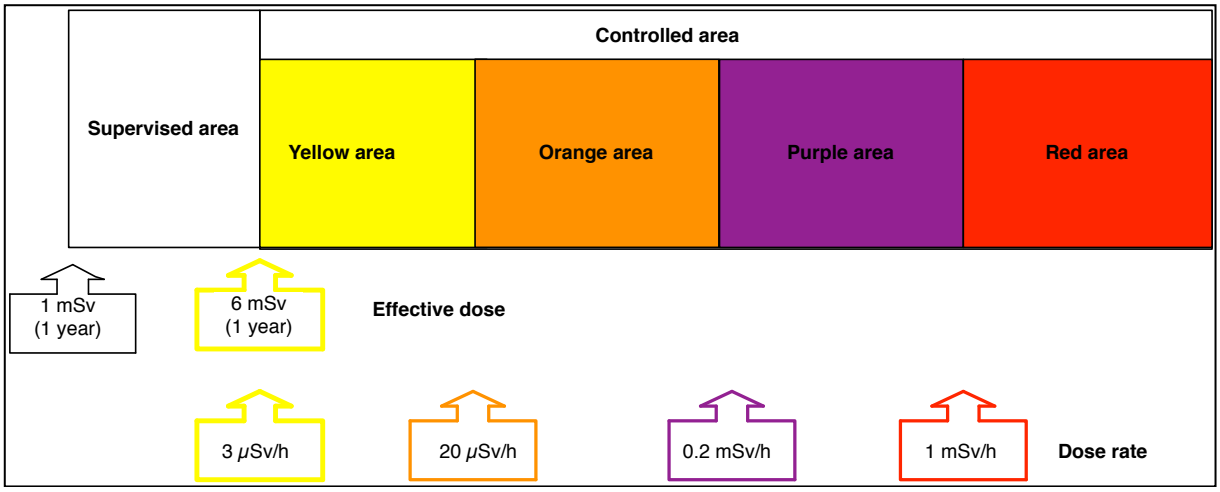


Figure 2. Criteria for the designation of supervised and controlled areas at the Doel nuclear power plant (external irradiation)

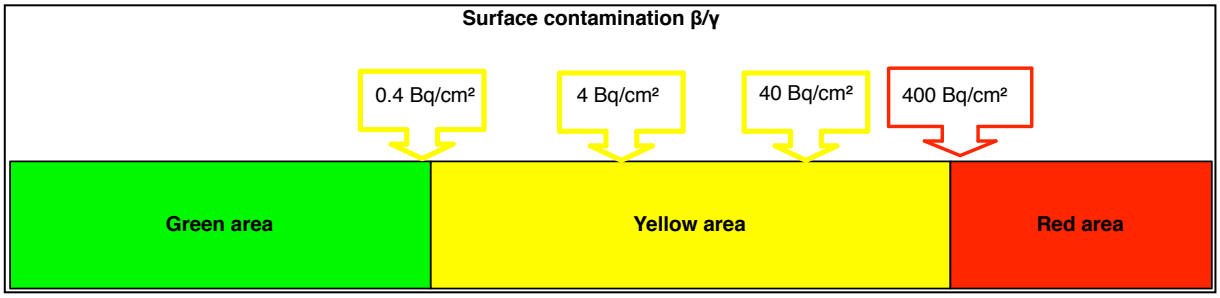


Figure 3. Criteria for the designation of controlled areas at the Doel nuclear power plant (surface contamination)

3.2. Spain

3.2.1. General regulations

Spanish regulations on classifying regulated areas fall under the Regulation on Sanitary Protection against Ionising Radiation and the Royal Application Decree 738/2001. These regulations cover all activity sectors.

Working areas have to be classified into different area types after a risk analysis, taking into account:

- the annual dose prediction,
- the contamination dispersion risk,
- the probability and amplitude of potential exposure.

The monitored and controlled area designations are based on the criterion of the dose that may be received in one year (quantified criterion) and on a more qualitative criterion of "need to follow specific work procedures to reduce exposure to radiation, avoid dispersing the contamination or avoid accidental exposure". In addition, three areas - limited stay, regulated saty or forbidden access - can be defined within the controlled area based on the potential to exceed the respective dose limits in one year, over a shorter period or in a single exposure (see Figure 4).

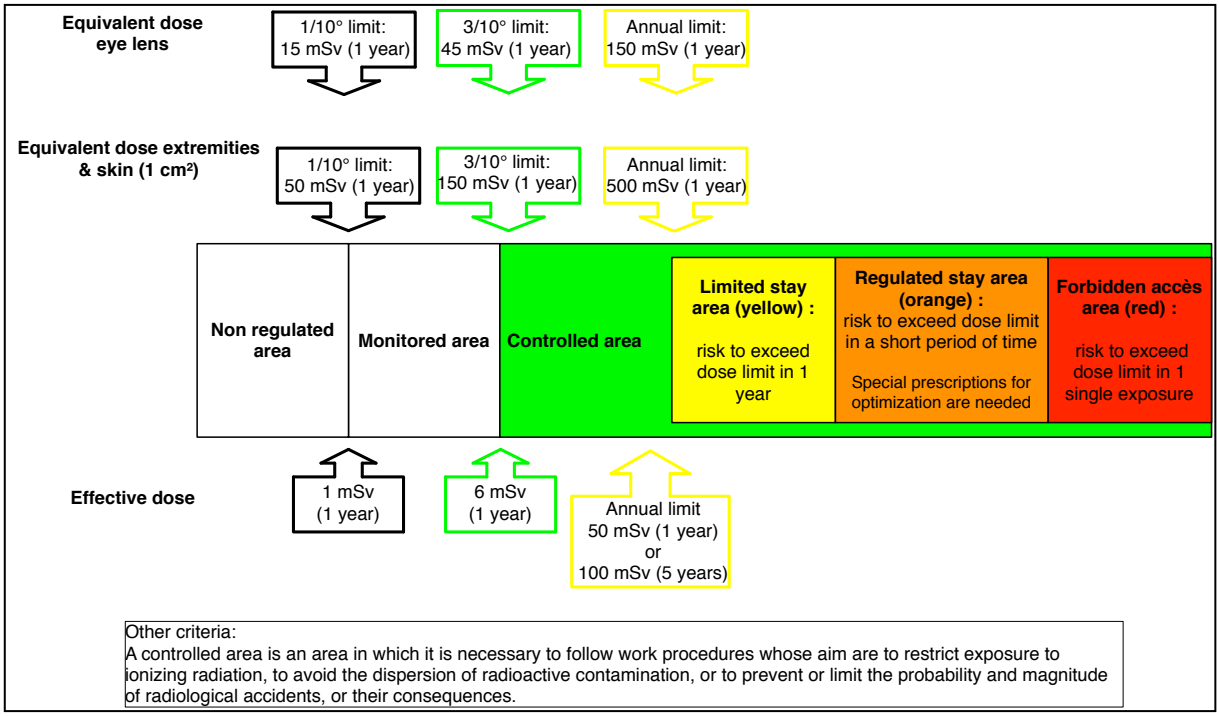


Figure 4. Criteria for the designation of monitored and controlled areas in the Spanish regulations

3.2.2. Application to the nuclear sector

In the nuclear sector, a working group initiated by CSN (Spanish Safety and Radiological Protection Authority) with operator representatives (UNESA) has put together a radiological protection guide that operators are expected to follow when preparing their own radiological protection manuals. This guide clarifies a few items on the designation of regulated radiation areas. The data have been supplemented by direct contacts with the radiological protection manager at the Almaraz power plant, who has also provided procedures from his plant.

The regulated radiation areas are designated according to the risk of external exposure, surface contamination and airborne contamination. The highest criterion defines the area. Nevertheless, where there is a joint risk (external exposure and contamination, for example), both risks are signalled.

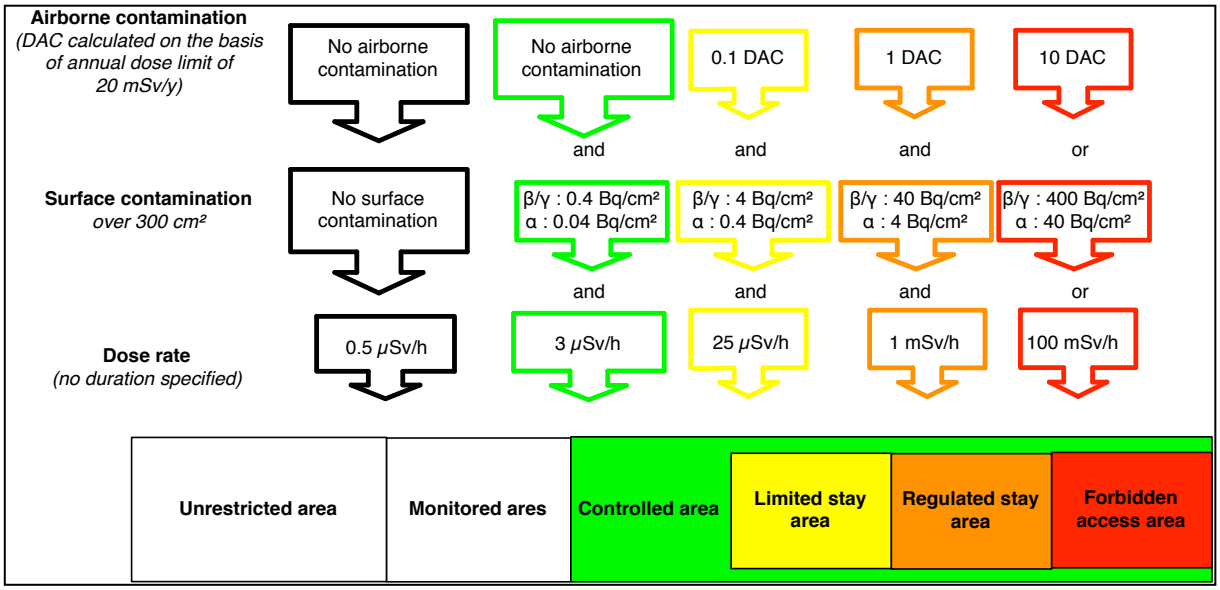


Figure 5. Criteria for the designation of monitored and controlled areas at the Almaraz nuclear power plant

3.2.3. Medical application

CSN has published a "radiological protection manual" for the medical sector that lists the rules to be applied in terms of radiological protection in health facilities. It is in fact mandatory for health facilities to draft such a manual for their installations.

The area designation criteria quoted in the CSN medical radiological protection manual are those defined in the general regulations for supervised and controlled areas. A particular classification is also proposed:

Conventional radiology

- Monitored area: control station protected by a physical barrier
- Controlled area: inside the radiography room

Interventional radiology
- Monitored area: control station protected by a physical barrier
- Limited stay area: inside the room

The classification of X-ray generators is valid only during operation of the apparatus. Access to the room is unrestricted if the apparatus is not operating. Specific marking must be implemented for the designation of the areas according to the state of the system.

Teletherapy
During equipment operation
- Monitored area: control station
- Forbidden access area: inside the room

When the equipment is not in use
- Unrestricted access area: control station
- Controlled area: inside the room

Brachytherapy
- Controlled area: source preparation room and access to chambers
- Limited stay area: rooms occupied by patients with sources

Nuclear medicine
- Monitored area: storage of radioactive waste
- Limited stay area: chambers with patients undergoing metabolic treatment
- Controlled area: hot chamber, dose administration area, circulation and stay areas for patients who have received an injection

3.3. United States

American regulations on the classification of controlled and supervised areas are inscribed in the U.S. Nuclear Regulatory Commission (NRC) Regulations Title 10, Code of Federal Regulations – Part 20 – Standards for protection against radiations (10 CFR 20). This covers all types of facility.

The NRC publishes regulatory guides to reinforce the regulations. Regulatory Guide 8.38 is specific to the nuclear industry and lists the access conditions in the high and very high radiation areas, thereby supplementing regulations 10 CFR 20. In addition, every nuclear power plant operator has his own internal procedures: the Excelon (Braidwood power plants, etc.) and AEP (Cook power plant) procedures are described briefly in the United States country sheet.

Risk assessment before delineation of radiological areas is the responsibility of the licensee. This assessment enables activities with a risk due to ionising radiation to be carried out. Each licensee must make or cause to be made preliminary checks to:
- verify compliance with the 10 CFR 20 regulations; and
- evaluate radioactivity levels, concentrations or quantities of radioactive materials and potential radiological hazards.

3.3.1. General regulations

Regulations 10 CFR 20 define different types of area and their characteristics. Note that these types of area can only be found in the 10 CFR 20 glossary.

The following areas are those similar to the European definitions of supervised areas and controlled areas (see also Figure 6):

Restricted area
Restricted area means an area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. Restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be set apart as a restricted area.

As this area is intended to protect persons against radiation or contamination, but in a very generic way (without designation criteria), it can be considered similar to a supervised area.

Unrestricted area
Unrestricted area means area, access to which is neither limited nor controlled by the licensee.

Radiation area
Radiation area means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

High radiation area
High radiation area means an area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or 30 centimeters from any surface that the radiation penetrates.

Very high radiation area
Very high radiation area means an area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in 1 hour at 1 meter from a radiation source or 1 meter fro many surface that the radiation penetrates.

Airborne radioactivity area
Airborne radioactivity area means a room, enclosure, or area in which airborne radioactive materials composed wholly or partly of licensed materials, exist in concentrations[2]:
(1) In excess of the derived air concentrations (DACs) specified in appendix B, to §§ 20.1001 – 20.2401, or
(2) To such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours of an individual is present in a week , an intake of 0.6 percent of the annual limit on intake (ALI) or 12 DAC-hours.

These three "radiation areas" and the "airborne radioactivity area" are similar to various types of controlled areas found in other countries.

[2] In practice, in the Unite-States, DAC and ALI are calculated based on an annual dose limit of 50 mSv

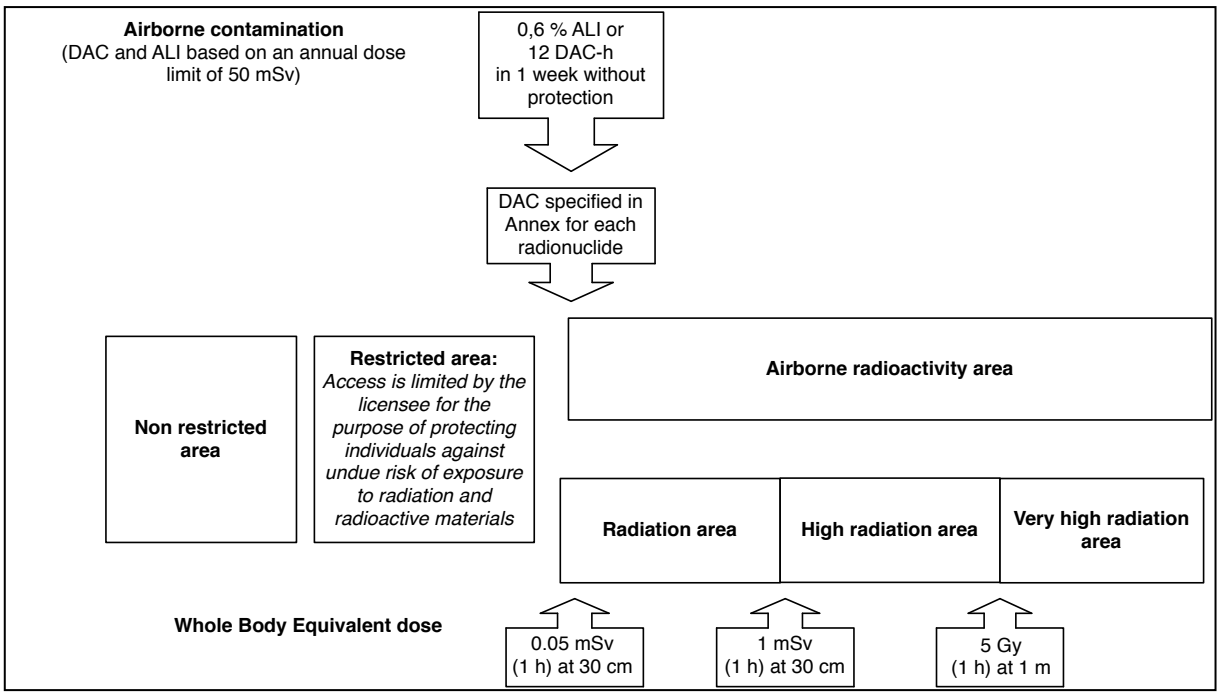


Figure 6. Criteria for the designation of regulated radiation and contamination areas in United States regulations

The licensee shall ensure that each entrance or access point to a high radiation area has one or more of the following features:

- A control device that, upon entry into the area, causes the level of radiation to be reduced below that level at which an individual might receive a deep-dose equivalent of 1 mSv in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

- A control device that energizes a conspicuous visible or audible alarm signal so that the individual entering the high radiation area and the supervisor of the activity are made aware of the entry; or

- Entryways that are locked, except during periods when access to the areas is required, with positive control over each individual entry.

For the very high radiation areas, in addition to the requirements for high radiation areas quoted previously, the licensee must introduce additional measures to ensure that an individual cannot access without permission or inadvertently areas with radiation levels potentially higher than or equal to 5 Gy/h at one metre from a radiation source or any other surface through which the radiation penetrates.

3.3.2. Radiation areas designation at the Cook nuclear power plant

The Cook nuclear power plant has defined the following areas (see Figure 7 to Figure 9)

Restricted area
This area covers:

- all areas in which radioactive materials are stored, handled or processed or areas in which the dose rates are greater than or equal to 15 μSv/h.
- all areas to which access is controlled in order to protect individuals against the risks of exposure to radiation and/or radioactive materials.

Radioactive material area (RMA)

Radiation area
All areas where the dose rate is greater than or equal to 45 μsv/h at 30 cm and less than 0.9 mSv/h at 30 cm.

High radiation area
All areas where the dose rate is greater than or equal to 0.9 msv/h at 30 cm and less than 9 mSv/h at 30 cm.

Locked High Radiation Area (LHRA)
All areas where the dose rate is greater than or equal to 9 msv/h at 30 cm and less than 5 Gy/h at one metre.

Locked Very High Radiation Area (LVHRA)
All areas where the dose rate is greater than or equal to 5 Gy/h at one metre.

Neutron Exposure Area (NEA)
All areas where the dose rate from neutron radiation is greater than or equal to 20 mSv/h.

Contaminated Area (CA)
All areas in which loose surface contamination exceeds either of the following limits:

- greater than or equal to 1000 dpm[3]/100 cm^2 (16.7 Bq/100 cm^2) and less than 100,000 dpm/100 cm^2 (1.6 kBq/100 cm^2) of beta/gamma activity, or
- greater than or equal to 20 dpm/100 cm^2 (0.3 Bq/100 cm^2) of alpha radioactivity.

Airborne radioactivity area
All areas for which either of the following conditions is met:

- the sum of particulate, iodine and tritium airborne radioactivity concentration are greater than or equal to 0.3 DAC, or
- the sum of particulate, iodine, tritium and noble gases concentrations, as applicable, are greater than or equal to 1.0 DAC.

High Contamination Area (HCA)
All areas where the average loose surface contamination levels are greater than or equal to 100,000 dpm/100 cm^2 (1.6 kBq/100 cm^2) of beta/gamma activity.

Hot Spot

[3] Disintegrations per minute

A location is designated as a hot spot when normally accessible components have dose rates greater than or equal to 1 mSv/h on contact and five times greater than the area dose rate at 30 cm.

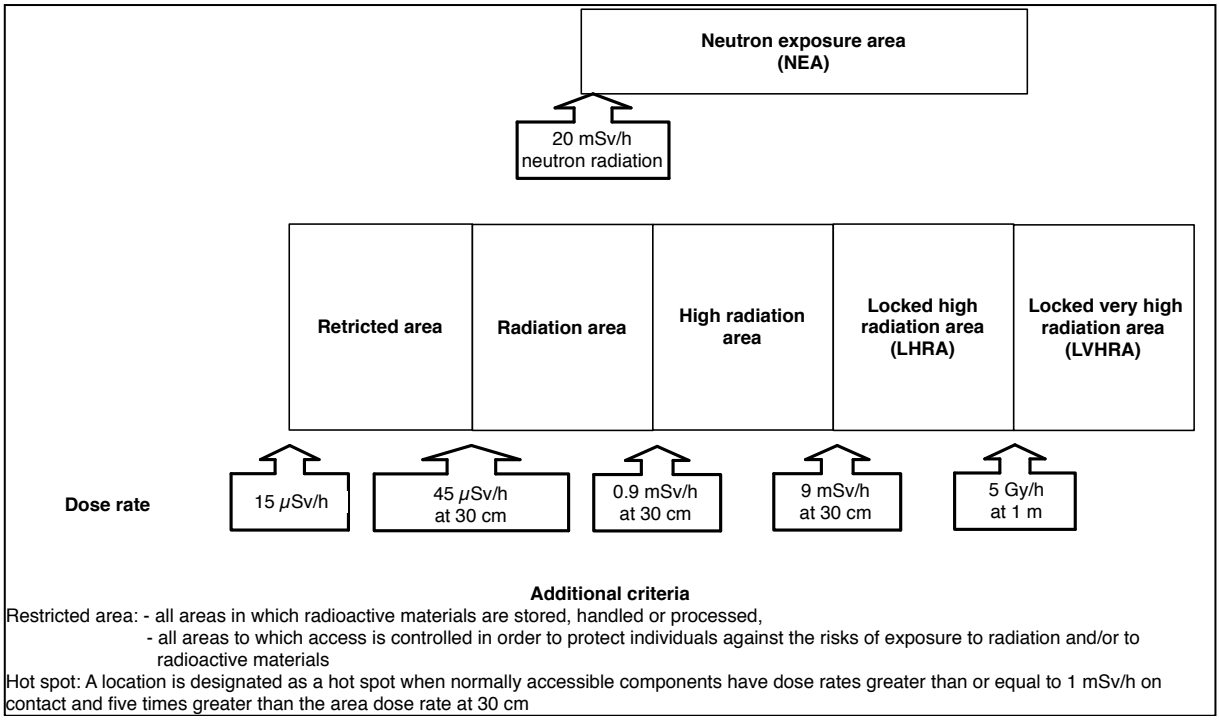


Figure 7. Criteria for the designation of regulated radiation areas at the Cook nuclear power plant (external exposure)

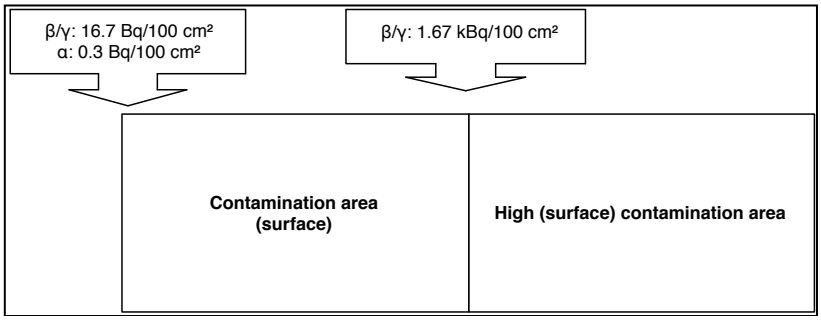


Figure 8. Criteria for the designation of regulated contamination areas at the Cook nuclear power plant (surface contamination)

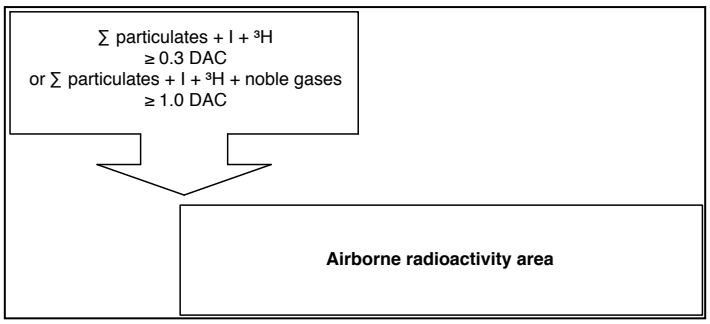


Figure 9. Criteria for the designation of regulated contamination areas at the Cook nuclear power plant (airborne contamination)

Each entrance to a LHRA or a VHRA shall be controlled by a lock and key unique to that access point. The locking mechanism for these access points may consist of:

- The installed lock core in the door/gate, provided the electronic lock control system has been disabled for that door/gate
- An external locking mechanism (chain & padlock, hasp & lock, bar & lock) or other mechanisms approved by an RP Supervisor

The electronic lock control system shall not be used as the sole lock control mechanism on LHRA or VHRA access points.

If access to a LHRA cannot be closed physically by a key-operated locking system, it must be marked as follows:

- delineation of the area (physical barrier or rope)
- conspicuous signs on all accessible sides
- installation of a flashing light system or posting of a security guard continuously at the access to the area.

3.4. Finland

Finnish regulations on designating regulated areas are found in the Radiation Act. This covers the use of all radiation (whether or not ionising) and the other practices that cause or can cause exposure to radiation that is hazardous for human health. These general regulations are not very prescriptive: they are supplemented by two regulatory guides that detail the management of supervised and controlled areas and the marking to be used - guide ST 1.3 Warning signs for radiation sources and guide ST 1.6 Operational Radiation Safety.

The authorities (STUK) have published guides to boost and clarify the implementation of the regulations in various sectors. They are based on guides ST 1.3 and ST 1.6 but give specific details of the sector covered. Note especially the following guides:

- ST 2.2 Radiation safety of radiotherapy equipment and treatment rooms
- ST 3.6 Radiation safety in X-ray facilities
- ST 5.6 Radiation safety in industrial radiography
- ST 6.1 Radiation safety when using unsealed sources

The authorities have published a specific guide for the nuclear industry: YVL 7.9 Radiation protection of workers at nuclear facilities.

3.4.1. General regulations

The classification (of areas) shall take into account:
- the nature of the use of radiation sources,
- the estimated annual doses caused by the practice,
- the hazard of contamination, and
- the potential exposure.

In addition, attention shall be paid to the possibility of an abnormal event, which might result in radiation exposure high in comparison with the exposure caused by normal operations

The supervised and controlled area designations are based on the criterion of the dose that may be received in one year (quantified criterion) and on a more qualitative criterion of the need to introduce safety rules and special procedures given the risks of external exposure or contamination (see Figure 10).

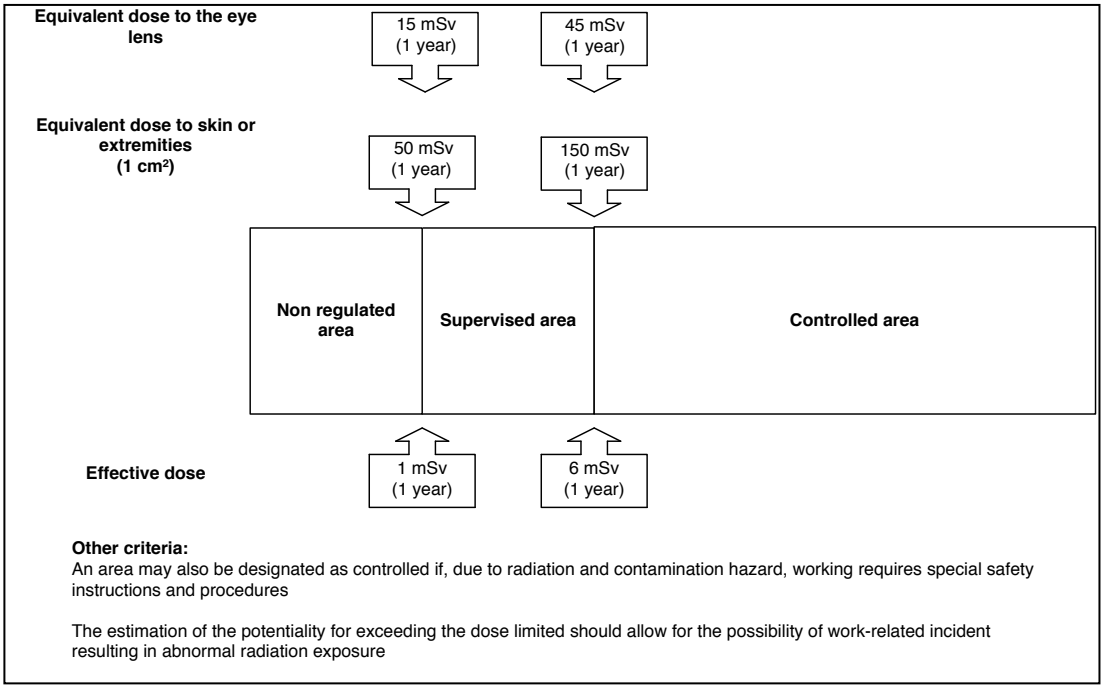


Figure 10. Criteria for the designation of supervised and controlled areas in the Finnish regulations

3.4.2. Rules in the nuclear industry

Additional criteria are defined in guide YVL 7.9 covering the supervised and controlled areas in nuclear facilities. Supervised and controlled areas must be delineated after systematic measurements of the dose rate, surface contamination and airborne contamination (see Figure 11).

The external dose rate, the surface contamination or the airborne radioactivity concentration may locally exceed the designation limit if the zone in question is separated by access barriers and is marked with signs indicating the radiological condition, the potential time limits on workers in the zone and the protection equipment required.

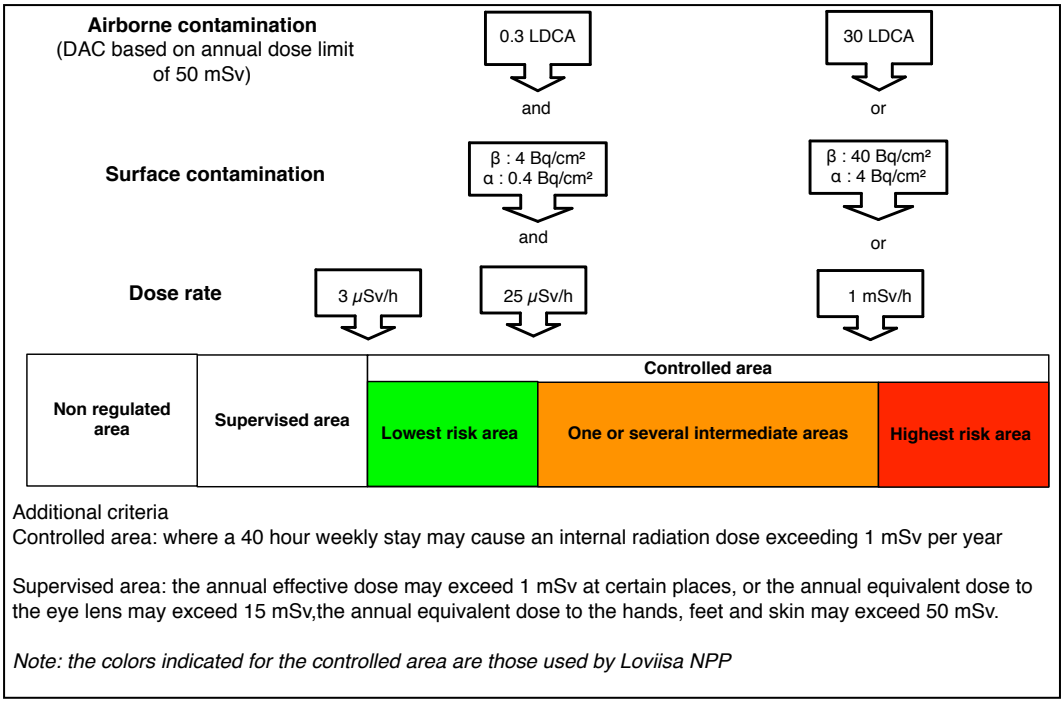


Figure 11. Criteria for the designation of supervised and controlled areas for nuclear power plants in Finland

3.4.3. Rules in the medical sector

The rules in general guide ST 1.6 also apply to the medical sector. This guide gives especially area classification examples (see Finland country sheet in the report annex). Good examples include:

- Fixed X-ray equipment: The controlled area in a room in which fixed x-ray equipment is used shall consist of that area next to the patient which, during irradiation, is exposed to primary radiation or radiation scattered directly from the patient. The rest of the use area may be classified as supervised, and the control room may be unclassified. If the control room is only partly shielded or open at the top or sides, it may be classified as supervised

- Fixed fluoroscopy equipment: A room in which fluoroscopy equipment is used shall be classified as a controlled area during irradiation. In interventional radiography, for example, the control room shall also be classified as a controlled area if the control devices are located in a partly shielded space or in a space which is open at the top or sides.

The specific radiotherapy guide states that the treatment rooms must be classified as a controlled area. The rooms adjacent to the treatment room where regular work is carried out must normally be classified as a supervised area. The shielding surrounding rooms must be designed so that dose limits are complied with. The following dose constraints must be observed to apply the principle of optimisation:

- 6 mSv over one year in rooms adjacent to the treatment rooms designated as supervised areas,
- 0.3 mSv over one year for the adjacent rooms, not designated as supervised areas, to which unauthorised persons have unrestricted access

Planning limits based on a weekly dose, derived from the dose constraint, are normally used during the design and construction of treatment rooms. These planning limits are:

- for supervised areas: 120 µSv/week,
- for the other areas: 6 µSv/week.

These rooms must also be designed so that the instantaneous dose rate in the rooms adjacent to the treatment room does not exceed 20 µSv /h in areas where individuals are present or work regularly.

Note that regulatory guide ST 3.2 covering to the use of mammography equipment uses a criterion relating to the number of examinations to classify the room: where more than four thousand examinations are conducted per year with mammography equipment, its immediate surroundings must be classified as a supervised area. Such classification is not necessary when fewer examinations take place over a year.

3.4.4. Rules in industrial radiography

Where the radiography equipment is placed in a shielded enclosure and operated from outside this enclosure, the shielded enclosure is a controlled area. The dose rate at one metre from the walls of the enclosure must be less than 7.5 µSv/h when the X-ray equipment is used to the maximum of its parameters or when the maximum activity available is used by the gamma radiography equipment.

When using portable X-ray equipment, the areas surrounding the object being X-rayed where the dose rate exceeds 60 µSv/h must be "isolated" as controlled areas. In addition, a supervised area must be set up in the areas where the dose rate exceeds 7.5 µSv/h.

3.5. United Kingdom

In the United Kingdom, the specific requirements for protection of workers and the population against ionising radiation are given in the Ionising Radiations Regulations 1999 (IRR99) [1]. To facilitate practical implementation of IRR99, the Health and Safety Executive (HSE), the British authority responsible for radiation protection, has published an application guide, the Approved Code of Practice (ACOP) and guidance, which provides a detailed analysis and explanation of each of the IRR99 regulations. The regulations are satisfied by applying the Code of Practice. Guidance is also given, but carries less weight than the Code of Practice.

For the nuclear industry, HSE has published nuclear facility Safety Assessment Principles (SAPs) for nuclear installation inspectors to provide them with guidance in their inspection work [3]. The SAPs describe the good practices to be implemented from the point of view of the Nuclear Installations Inspectorate (NII), part of the HSE. To support the SAPs, HSE has also published several Technical Assessment Guides (TAG) providing more operational details of the various principles, while remaining fairly general. The principal TAG giving instructions for the designation of areas is TAG38, covering radiological protection.

The description in this document of practical application in the nuclear sector is based on the British Energy radiological safety rules, which put into effect the undertakings given by this operator to the authority on the practical implementation of the radiation protection regulations.

In the medical sector, a guide to good practice in radiation protection in the clinical environment for the medical and dental sectors [6] was produced jointly by the Institute of Physics and Engineering in Medicine, the National Radiological Protection Board[4] and the Health and Safety Executive in 2002. It clarifies the IRR99 regulations, including area delineation criteria and delineation characteristics,

[4] The National Radiological Protection Board (NRPB) became a Division of Health Protection Agency (HPA) in 20005 and subsequently part of Public Health England (PHE) in 2013.

conditions of access to these specific areas, and the specific aspects for mobile systems (radiography equipment).

3.5.1. General regulations

The British regulations state that the aim of the IRR99 and the associated Approved Code of Practice (ACoP) is to provide a framework for ensuring that occupational exposure to ionising radiation is kept as low as reasonably practicable (ALARP) and that the stipulated dose limits are not exceeded.

The Code of Practice adds that the main objective in designating controlled areas is to help ensure that the measures taken to avoid accidents and implement the ALARP principle are effective. Controlled areas allow verification of who can enter or work in these areas and of which special procedures are to be followed.The supervised areas are designated mainly in areas where a potential risk of a change in radiological conditions could upgrade them to controlled areas.

Any new activity involving work with radiation must undergo prior risk assessment to identify the measures to be taken to limit exposures. In addition, the code of practice states that the risk assessment for designation of controlled areas must take account of the following factors:
- which people are likely to need access to the area;
- the level of supervision required;
- the nature of the radiation sources in use and the extent of the work in the area;
- the likely external dose rates to which anyone can be exposed;
- the likely periods of exposure to external radiation;
- the physical control methods already in place, such as permanent shielding and ventilated enclosures;
- the importance of following a procedure closely in order to avoid receiving significant exposure;
- the likelihood of contamination arising and being spread unless strict procedures are closely followed;
- the need to wear personal protective equipment in that area; and
- maximum doses estimated for work in the area.

In terms of quantitative criteria, the IRR99 is based solely on the annual dose limit values for workers to designate a supervised or controlled area. The Code of Practice give stipulates criteria in terms of external and hand-related dose rate. (see Figure 12).

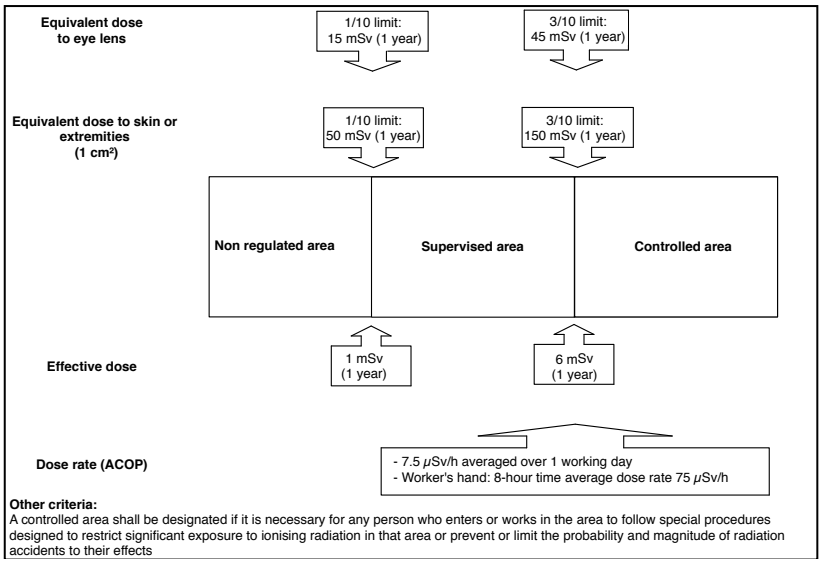


Figure 12. Criteria for the designation of supervised and controlled areas in the United Kingdom regulations

Note that the dose rate value of 7.5 µSv/h to designate a controlled area was calculated when the regulations still stipulated an annual dose limit of 50 mSv/year and considering the controlled area start criterion of 3/10ths the annual dose limit, i.e. 15 mSv/year.

An average figure of 7.5 µSv/h is obtained when taking two thousand working hours a year. This criterion has been maintained in the Code of Practice. The Code nevertheless underlines the recommendation to consider classifying as a controlled area any area where the external dose rate is routinely more than 3 µSv/h and where workers spend about two thousand hours a year. They would then be likely to exceed the 6 mSv/year.

Where the periods during which work under radiation takes place are clearly defined or are intermittent, the employer has the option of declassifying provisionally the area designated initially as controlled. This provisional declassification is possible if effective measures are applied to eliminate the reasons why the area in question was classified initially as controlled (for example, justified by the temporary removal of radioactive sources in the area or by disabling an X-ray generator).

3.5.2. Rules in the nuclear industry

In addition to the IRR99 rules, the Safety Assessment Principles (SAP) for nuclear facility inspectors and the technical radiological protection guide [TAG38] state that supervised or controlled areas must, if necessary, be sub-divided. The sub-division must be based on the irradiation, contamination and aerosol levels. The sub-divisions must be supported by appropriate controls, especially with respect to the access to the area, its occupancy rate and the use of personal protection equipment. Where a significant fraction of one of the dose limits can be received in a few minutes, access must be restricted by physical means, for example padlocks or alarms. The SAP do not, however, give quantitative data. TAG38 states that these areas must be clearly categorised and measurement and protection means suitable for each one must be defined. In addition, area classification must be an indication of the control means to be implemented and adapted according to areas C1, C2, C3, etc. and areas R1, R2, R3, etc., which correspond respectively to increasing levels of contamination and irradiation.

Rules adopted by British Energy

British Energy defines two types of radiation areas: those for the risk of external exposure (areas R1 to R4) and those for the risk of surface or airborne contamination (areas C2 and C3). The British Energy rules are explained in a document written by an inter-industry radiological protection coordination group (BNFL, British Energy and Nuclear Electric) in 2002. This document describes the rationality in defining the limits between the supervised areas and the different controlled areas. (Extracts can be found in the United Kingdom country sheet in the annex report).

Radiation controlled areas are classified based on the dose rate (see Figure 13). If, due to a localised source, an area should be designated as R3 according to the dose rate criteria, but the area would be restricted to a radius of 500 mm around the source, then the area may be designated as R2. The existence of a high local dose rate must be indicated locally by a sign. The same rule applies to an R3 area in which there is a source that should require designation of the area as R4.

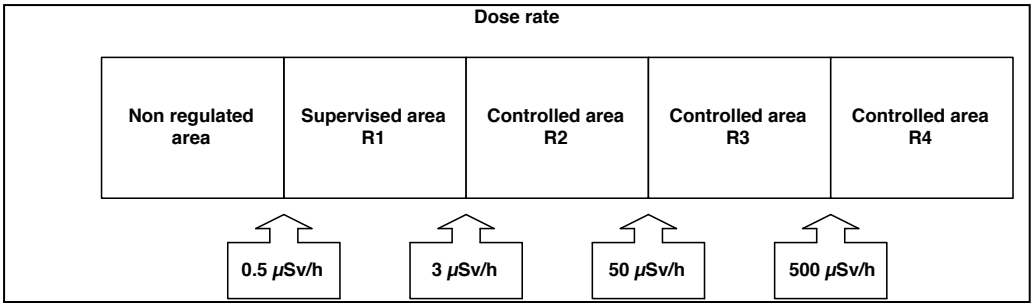


Figure 13. Criteria for the designation of supervised and controlled areas at the Sizewell nuclear power plant (external exposure)

The controlled area designation criteria for surface contamination (C2 areas) is the level of loose contamination averaged over an area not exceeding 1000 cm^2 on the floor, walls or ceiling or 300 cm^2 in all other cases. (see Figure 14).

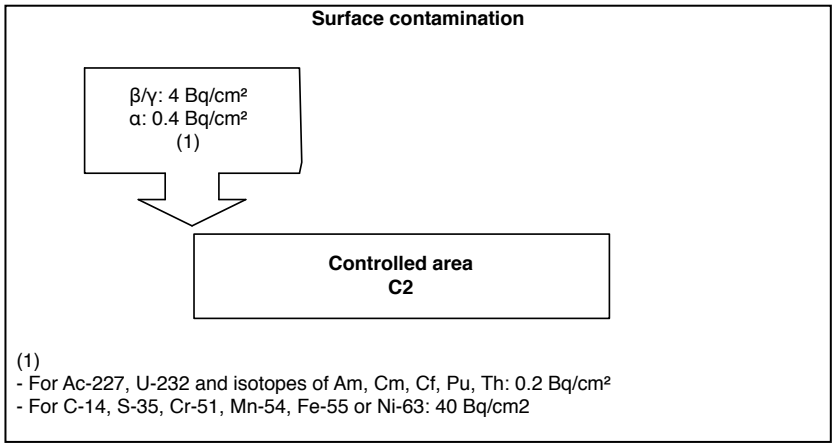


Figure 14. Criteria for the designation of controlled areas at the Sizewell nuclear power plant (surface contamination)

An area is designated as a contamination controlled area C3 when the air activity, averaged over a working period not exceeding 8 hours, exceeds or may exceed the activity values indicated either in radionuclides or general beta or alpha (see Figure 15).

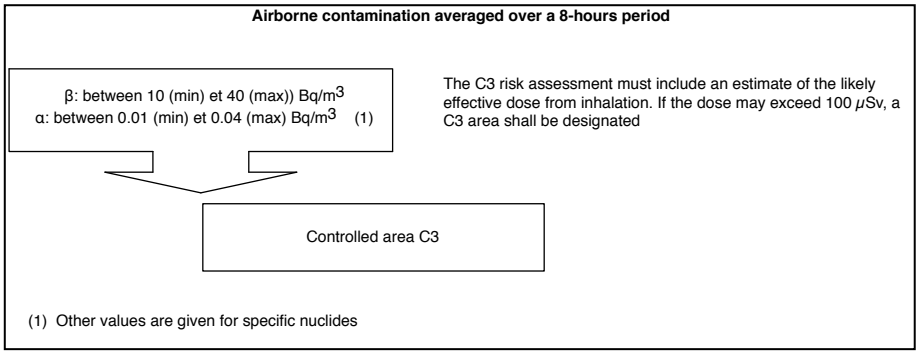


Figure 15. Criteria for the designation of controlled areas at the Sizewell nuclear power plant (airborne contamination)

Areas R2, R3 and R4 must be clearly delineated. Permanent controlled areas R4 must, where practicable, be separated from other areas by doors kept locked to prevent unauthorised entry. An area may be classified R4 temporarily in some circumstances. This new R4 area must, where reasonably practicable, be segregated by locked doors. If this is not possible, barriers must be used to segregate the area. Access to areas with dose rates greater than 1 Sv/h at 0.5 m must be controlled by a double-key system.

3.5.3. Rules in the medical sector

The procedures for the designation of regulated radiation areas in the medical sector are based on the requirements of IRR99 and the associated ACOP. The details given here are those recommended by the joint working group of the Institute of Physics and Engineering in Medicine, the National Radiological Protection Board and the Health and Safety Executive in 2002.

Overall, the guide states that the following areas should be classified as controlled areas:

- areas concerned by radiopharmacy activities,
- areas containing sealed sources for radiotherapy,
- departments or rooms used for patients undergoing radiotherapy or brachytherapy,
- areas containing fixed X-ray generating equipment,
- areas where there is a significant risk of radiological contamination outside the working area.

Where the radiation sources no longer exist (e.g. X-ray generator shut down, sources withdrawn, etc.), the controlled area may be declassified temporarily. The guide notes that it can, however, be more practical to designate the area as controlled permanently and only allow access following written rules.

To delimit the controlled areas more precisely, the guide recommends using the following dose rate criteria as a basis:

Dose rate in µSv/h used area delineation

Criterion	Controlled areas	Supervised areas	Unsupervised public areas
IDR	> 2000 µSv/h	> 7.5 µSv/h	< 7.5 µSv/h
TADR	> 7.5 µSv/h	> 2.5 µSv/h	< 2.5 µSv/h
TADR 2000	> 3 µSv/h	> 0.5 µSv/h	< 0.15 µSv/h*

* 0.15 µSv/h is three-tenths of 0.5 µSv/h or 300 µSv/year – which is an appropriate dose constraint for an office worker assuming an occupancy of 2000 h per year.

IDR: instantaneous dose rate: instantaneous dose rate averaged over 1 minute

TADR: Time-averaged Dose Rate: estimated over eight hours taking account of the use and volume of work for a typical scenario on the worst day (occupancy factor equal to 1)

TADR 2000: Time-averaged Dose Rate 2000: estimated over two thousand hours taking account of the occupancy in addition to the use and volume of work

The guide proposes flow charts for use in determining the classification of areas depending on the different dose rate values (see United Kingdom country sheet). The IDR is used as a departure point for the designation process, for it is easily measurable and does not depend on the working hours. The TADR is used next (workload and use) and lastly the TADR 2000 (occupancy time over the year).

3.6. Sweden

The general principles of radiation protection in Sweden are laid down by the radiation protection act (1988:220). The designation of regulated areas in Sweden is defined in the regulations established by the Swedish authorities (SSM) covering the "Basic provisions for the protection of workers and the general public in practices involving ionising radiation" (SSMFS 2008:51).

With regard to the nuclear industry, there are specific regulations covering workers in nuclear power plants (SSI FS 2000:10). Additional elements for the Ringhals nuclear power plant come from feedback from the benchmarking visit and the Ringhals safety rules, with extra information provided directly by the Ringhals Radiological Protection Manager.

3.6.1. General regulations

The criteria for the designation of regulated radiation areas in the Swedish regulations are specified solely in terms of annual dose (see Figure 16) and only cover the controlled area. The so-called supervised areas are areas subject to the regulations but that are not controlled areas.

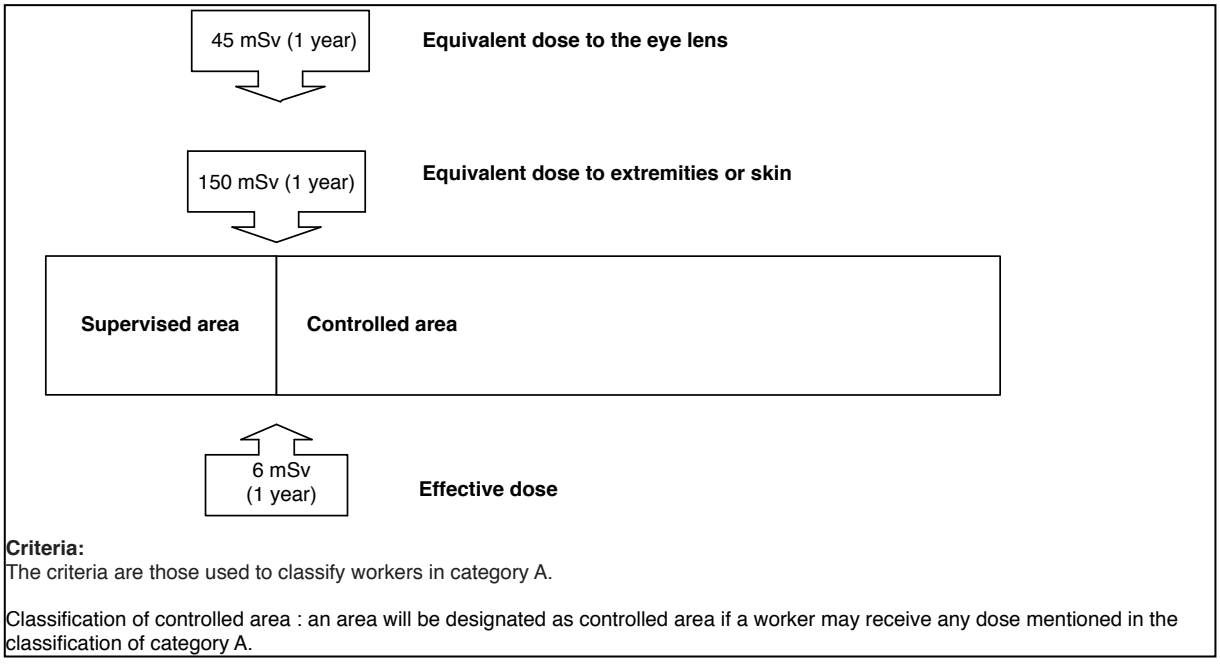


Figure 16. Criteria for the designation of supervised and controlled areas in the Swedish regulations

3.6.2. Rules in the nuclear industry

The Ringhals nuclear power plant defines both the controlled areas for external irradiation based on a dose rate criterion and the controlled areas for airborne (based on the DAC[5]) and surface contamination (with distinction made between beta/gamma and alpha emitters). (see Figure 17 to Figure 19).

[5] The DAC is calculated based on 20 mSv/year and two thousand working hours a year.

An area with a dose rate greater than 3 mSv/h is considered as a "high dose rate area". In addition, a hot spot can be defined when the dose rate near a component or circuit is higher than normal.

The upper value of the blue area has been defined as not to exceed the limit of 50 mSv/year (two thousand working hours at 25 µSv/hour)

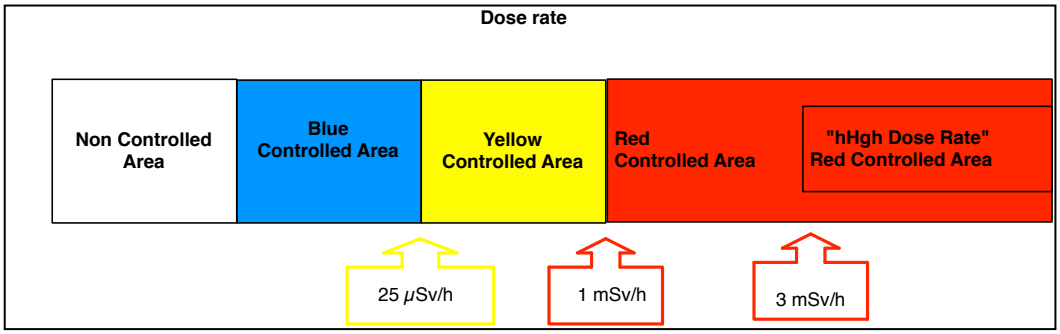


Figure 17. Criteria for the designation of controlled areas at the Ringhals nuclear power plant (external exposure)

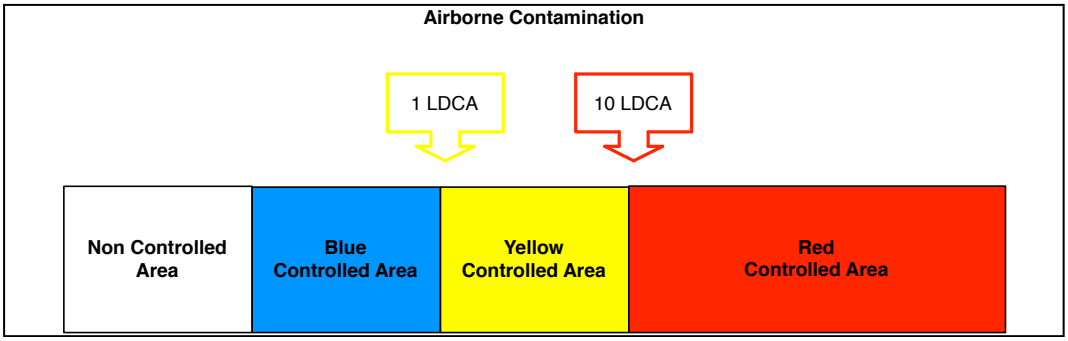


Figure 18. Criteria for the designation of controlled areas at the Ringhals nuclear power plant (airborne contamination)

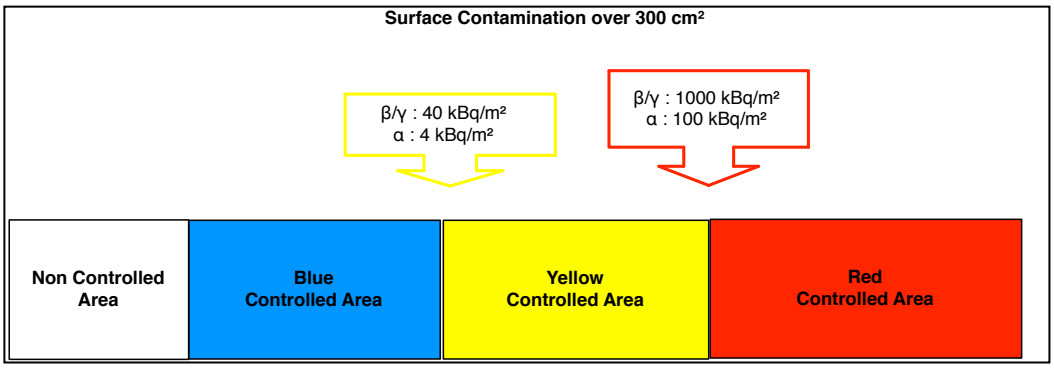


Figure 19. Criteria for the designation of controlled areas at the Ringhals nuclear power plant (surface contamination)

Areas with different radiological ambiences are delimited using barriers, ropes or chains. The physical barrier can be a wall or a closed door. This barrier can only be crossed once the stipulated protection actions have been carried out. These barriers must be combined with sign panels.

The recommended equipment in the event of surface or airborne contamination is detailed in the Sweden country sheet.

3.7. Switzerland

In Switzerland, the requirements applied to the protection of workers and the general public against ionising radiation are specified in the Radiological Protection Act (RPA) of March 1991 and its application rules specified in the Radiological Protection Ordinance (RPO) of 22 June 1994. The RPA applies to all activities and facilities. The classification principles for controlled areas are given in the RPO.

For nuclear facilities, and more specifically nuclear power plants, the management of exposures at levels as low as reasonably practicable is governed by the principle of optimisation of radiation protection; the designation of regulated areas is presented as a much less important measure than prior assessment of individual doses. Directive IFSN-G15/f for Swiss nuclear facilities refers only to controlled areas for which “the licensee shall take the necessary measures to ensure effective planning of radiation protection”, but does not give any criteria for the delineation, access rules and working conditions to be applied in such areas. Area designation and criteria are given only in a directive (in German) *Richtilinie für den überwachten Bereich der Kernanlagen und des Paul Scherrer Institutes HSK-R-07* of June 1995. To define the practices that can be observed in the Swiss nuclear power plants, data from a radiation protection benchmarking visit made by the CEPN to the Beznau nuclear power plant in 2006 are also used.

Three ordinances define the criteria for the designation of regulated radiation areas in the medical sector: they cover accelerators used for medical purposes, the medical use of sealed radioactive sources and radiological facilities for medical purposes. Directive R-06-03 on dosimetric monitoring in hospitals from the Federal Office of Public Health also gives a few, not very detailed, elements on access conditions in controlled areas.

A specific ordinances states the area classification elements in non-medical ionising radiation production facilities: it applies mainly to industrial radiography or radioscopy work (fixed or mobile). The controlled area designation criteria are not defined, but information on delineation and on marking specific to controlled areas is given.

Lastly, another ordinance indicates a few elements in the field of non-sealed sources, including delineation of areas and their access conditions, especially when transporting sources.

3.7.1. General regulations

The aim of the designation of regulated radiation areas is to "restrict and control the exposure to radiation". The main text of the RPO only mentions the need to designate controlled areas (Art. 58). Additional elements given in Annex 1 to the RPO give criteria based on the effective dose and the surface and airborne contamination (see Figure 20). Swiss regulations give no indication of possible sub-areas in the controlled area.

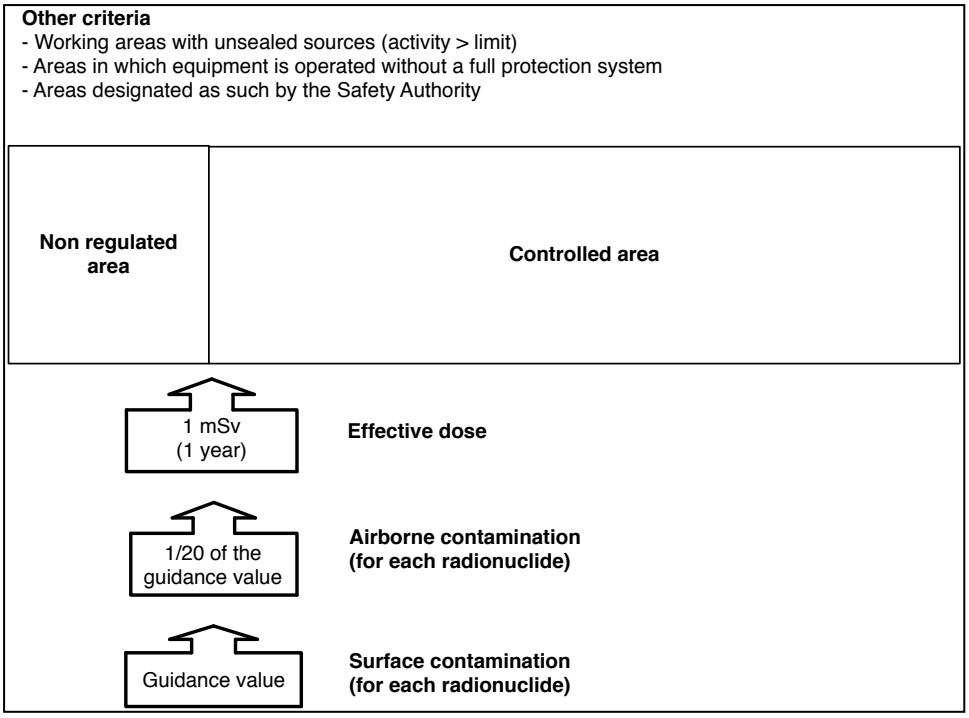


Figure 20. Criteria for the designation of controlled areas in the Swiss regulations

The RPO gives no indication of possible sub-areas in the controlled area.

Additional information on permissible doses outside controlled areas is given in the article covering shielding facilities (Art. 59 of RPO):

1. The room or area in which stationary radiation generators or radioactive sources are operated or stored shall be designed and shielded in such a way that, taking into account the frequency of use:
   a. in places situated within the premises but outside controlled areas, where non-occupationally exposed persons may be present, the local dose does not exceed 0.02 mSv per week; in places where people are not continuously present, this value may be exceeded by up to a factor of five;
   b. in places outside the premises, the off-site limits specified in Article 102 are not exceeded[6].

2. With the agreement of the supervisory authority, in rarely occupied places outside controlled areas within continuously monitored premises, where exceeding the dose limit specified in Article 37 (1 mSv/year) is prevented by appropriate measures, the ambient dose rate may be up to 0.0025 mSv per hour.

[6] *Art. 102 – Off-site limits :*
1. The yearly average concentration of airborne radioactive substances off-site shall not exceed a three-hundredth of the guidance value specified in Annex 3 Column 11
2. The weekly average concentration of radioactive substances in publicly accessible waters shall not exceed a fiftieth of the exemption limit for specific activity specified in Annex 3 Column 9
3. Direct radiation off-site must not lead to ambient doses exceeding 1 mSv per year in premises where people live, spend time or work, or 5 mSv per year in other areas.

3.7.2. Rules in the nuclear industry

The directive specific to the nuclear industry defines supervised areas and states that all controlled areas must be located within a supervised area.

In addition, controlled areas must be defined in closed rooms. The controlled areas are classified according to the level of surface and/or airborne contamination (areas I and IV). Sectors inside controlled areas are determined according to the external exposure (sectors V to Z). (see Figure 21 to Figure 23).

The surface (CS) and airborne (CA) contamination criteria relate to the guideline values defined in the annex to the RPO for each radionuclide.

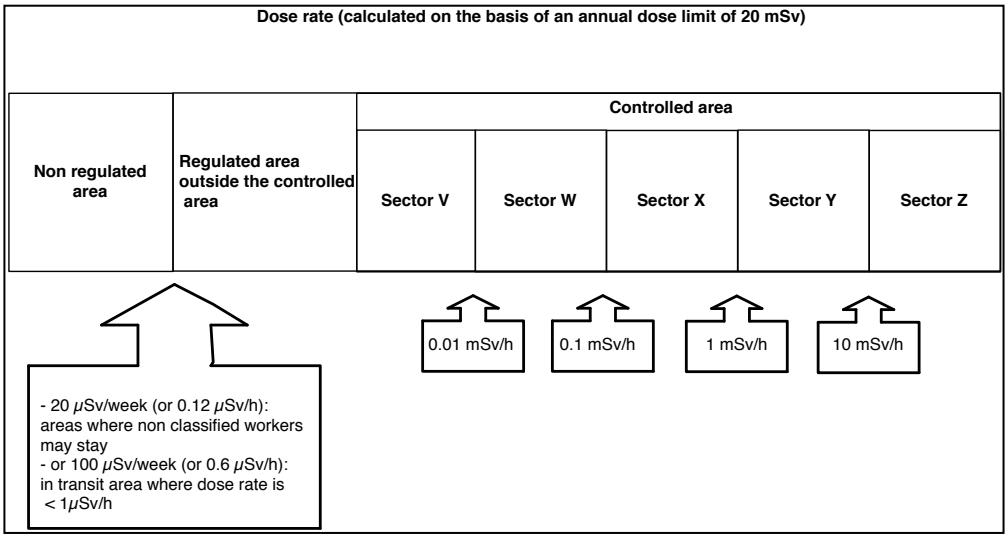


Figure 21. Criteria for the designation of controlled areas in the Swiss regulations for nuclear facilities (external exposure)

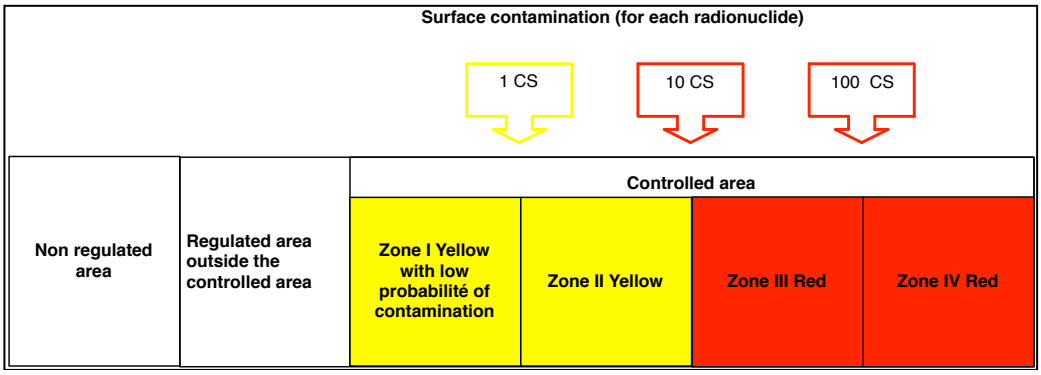


Figure 22. Criteria for the designation of regulated radiation areas in the Swiss regulations for nuclear facilities (surface contamination)

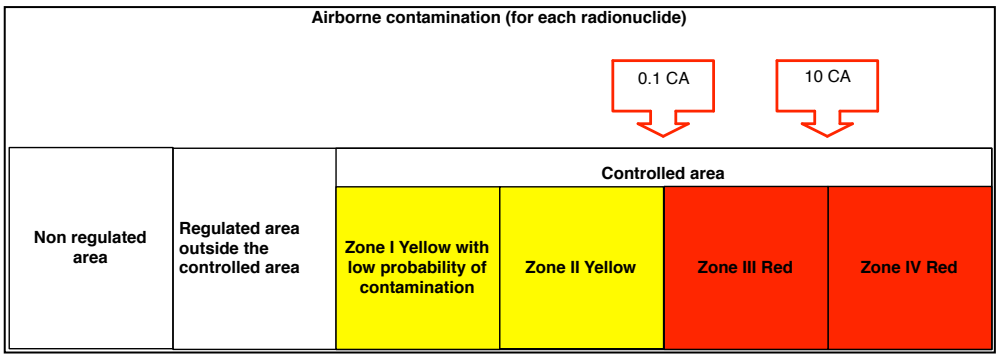


Figure 23. Criteria for the designation of controlled areas in the Swiss regulations for nuclear facilities (airborne contamination)

The following access conditions are stated in the directive:

Personnel entering a controlled area must have received training and information on the risks to which they are exposed. A suitable change room must be provided. The access doors must be subject to appropriate control. Accesses to emergency exits leading to non-controlled areas must be marked so as to prevent unauthorised entry into controlled areas. The pressure in the controlled area must be lower than the pressure in the adjacent non-controlled area.

Protective clothing regulations

- Area 0: no regulation
- Area I: coat, area-specific overshoes or shoes
- Area II: coverall, area-specific overshoes, gloves
- Area III: coverall with red marking, area-specific clothing under the coverall, area-specific overshoes, protective hood, gloves, dust mask available
- Area IV: coverall with red marking, area-specific clothing under the coverall, protective hood, gloves, protective boots, protective mask with absolute filter.

Area access conditions and stay times

- Areas 0, I, II: no additional access restrictions, and time complying with the ALARA concept
- Area III: access after authorisation given in accordance with the operating rules, possibly under the control of the RP department, stay time may be limited by airborne contamination
- Area IV: access after authorisation given in accordance with the operating rules and only under strict control by the RP department, stay time limited according to occupational health considerations.

Access conditions according to dose rate, wearing an electronic dosimeter

- Sector V: no access restriction, and time complying with the ALARA concept
- Sector W, X: access only for personnel authorised according to the internal rules, and limited stay time
- Sector Y: access only for personnel authorised according to the internal rules under control by the RP department or a representative, and very limited stay time
- Sector Z: access restricted to personnel authorised according to the internal rules and under strict control by the RP department, after production of a work plan, and very strictly limited stay time.

The Beznau nuclear power plant applies the directive and has three types of radiation areas based respectively on the dose rate, surface contamination and airborne contamination criteria

3.7.3. Rules in the medical sector

Electron accelerators
Accelerators must be operated in an irradiation room. The control system must be located outside the irradiation room. The irradiation room must be considered as a controlled area.
In sectors contiguous with the irradiation room, the following ambient doses must not be exceeded:
- 0.02 mSv per week at any location outside the controlled area,
- 0.1 mSv per week at any location inside the controlled area.

At locations outside the controlled area where a long stay is not planned and where no work station is installed, an ambient dose five times greater than the dose given above is permitted.

Sealed radioactive sources
Irradiation units must be operated in an irradiation room. The control system must be located outside the irradiation room. The irradiation room must be considered as a controlled area.

In the rooms of patients undergoing radiotherapy, movable shielding should be installed, in addition to adequate room perimeter shielding. Stationary shielding at least 110 cm high should be installed along the patient's bed. It must be designed to ensure that the ambient dose rate outside the shielding does not exceed 25 µSv/h.

In sectors contiguous with rooms where medical radioactive sources are used or stored, the following ambient doses must not be exceeded at any location:

a. 0.02 mSv per week at locations where individuals not occupationally exposed to radiation may stay for long periods or at locations where the stay is not under the control of the licensee;
b. 0.1 mSv per week at locations accessible only by individuals occupationally exposed to radiation or which are not intended for a long stay.

Radiological facilities for medical use
The design of rooms where radiological facilities are used must comply with the same criteria as quoted previously for the radioactive sources in the medical sector.

4. CASE STUDIES

Three countries - Finland, United Kingdom and Switzerland - have been selected for a comparison of area classification regulations and noted practices. Eight case studies covering some fifteen exposure situations have been prepared by the 'Classification of Area WG' and submitted to CEPN for analysis with the collaboration of radiological protection experts and inspectors from STUK (Finland), HSE (United Kingdom) and OFSP (Switzerland).

4.1. Case 1: Room containing a glove box

4.1.1. Presentation of scenario

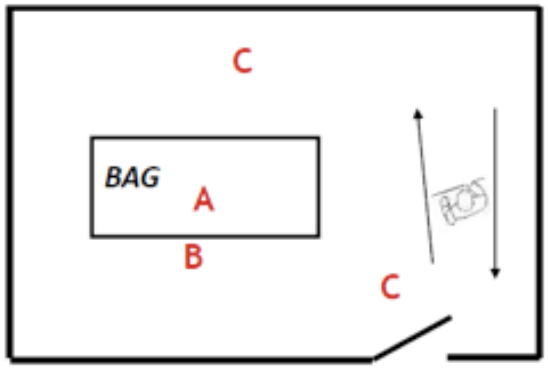
Context:

- Room with glove box (BAG)
- No surface contamination in the room.
- The worker only enters the room when no operation is to be carried out in the glove box.

Radiological hypotheses:

- Dose rate [H*(10)] inside the room is less than 10 µSv.h^{-1} [γ] under 300 mg.cm^{-2} at **C.**
- Dose rate [H'(0.07)] in the glove box (under 7 mg.cm^{-2}) is 0,8 mSv.h^{-1} [γβ].
- Measurement of dose rate [H'(0.07)] on contact with panel (under 7 mg.cm^{-2}) is 0.1 mSv.h^{-1} [γβ].

Situation a): No work in the glove box



Contamination:
No contamination in the room

Irradiation:

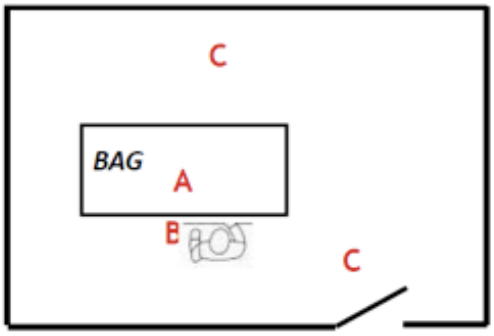
H'(0.07) measures (with Babyline) on contact (under 7 mg.cm^{-2})
A : Dose rate in the glove box (Ramda) : 0.8 mSv.h^{-1} [γβ]

B : Dose rate on contact with panel : 0.1 mSv.h^{-1}

H(10) measure (with Babyline) of ambient dose rate (300 mg.cm^{-2})*

C : Ambient dose rate: < 10 µSv.h^{-1} [γ]

Situation b): Work in the glove box



Contamination:
No contamination in the room

Irradiation:

H'(0.07) measures (with Babyline) on contact (under 7 mg.cm^{-2})
A : Dose rate in the glove box (Ramda) : 0.8 mSv.h^{-1} [γβ]

B : Dose rate on contact with panel : 0.1 mSv.h^{-1}

H(10) measure (with Babyline) of ambient dose rate (300 mg.cm^{-2})*

C : Ambient dose rate: < 10 µSv.h^{-1} [γ]

4.1.2. Designation of areas in Finland

The designation of areas takes place without considering whether or not a worker is present in the room. It is applied to the entire room; the glove box walls or the various work stations are not subject to a different type of classification.

The room is classified according to rules stipulated in guides ST 1.6 (operational radiological protection) and 6.1 (non-sealed sources). The classification is based on an assessment of the annual dose (estimated by a work station assessment or based on feedback from identical laboratories) or, and this is particularly true for laboratories in the medical sector, on the activity handled at any one time (i.e. based on the maximum activity of radioactive sources that may be in the glove box when a handler is present).

The case study cannot be dealt with properly as this information (handled activity) is lacking. A type B laboratory (i.e. where the activity handled is greater than 10^4 times an exemption value in guide ST 6.1), and certainly a type A, would be classified as a controlled area; a type C laboratory (i.e. where the activity handled is greater than ten times an exemption value in guide ST 6.1) would be classified in the same way if there is a risk of contamination, otherwise it would be classified as a supervised area.

The effective annual dose of 6 mSv/year, a criterion used as a basis for classifying an area as controlled areas, would be achieved for a room occupancy rate of six hundred hours (with an ambient dose rate of 10 µSv/h). It is therefore likely that this room is classified as a controlled area.

In terms of marking, a radiation hazard warning sign will be displayed at the entrance to the room, but with no mention of controlled or supervised area.

4.1.3. Designation of areas in the United Kingdom

Situation a: no work in the glove box

IRR99 stipulates the use of an effective annual dose criterion for the classification of this type of room: supervised area from 1 mSv/year, controlled area from 6 mSv/year. The maximum effective dose rate (measured or estimated) in the room would be used (100 µSv/h) rather than the ambient rate

(10 µSv/h). Thus, the room would be classified as a supervised area if a worker could stay in it more than ten hours/year or a controlled area if he could stay more than sixty hours/year. Downgrading the classification level at points C (transit area around the glove box) can, however, be envisaged, provided that the glove box can be separated from the transit area - physically if possible - or a biological shielding is installed around the glove box (the HSE would recommended this solution by virtue of the application of the ALARP optimisation principle). Thus, if the maximum effective dose rate could be been brought below 0.5 µSv/h, the room (or the part of the room separate from the glove box) could be classified as a non-regulated area: (2000 h/year x 0.5 µSv/h = 1 mSv/an).

However, the room will remain a supervised area due to the risk of contamination outside the glove box (potential incident situation), unless the operator can demonstrate that the glove box containment cannot be ruptured.

The ACoP (Approved Code of Practice) also suggests using an effective dose rate criterion. However, even after separating the glove box from the transit area, if 7.5 µSv/h* < equivalent dose rate$_{\text{max pts C}}$ < 10 µSv/h (averaged over one working day), points C should be classified as a controlled area.

Despite this potential ACoP option, the annual effective dose criterion normally prevails: thus, if the operator can demonstrate that the room is rarely used (effective dose < 1 mSv/year), then the room can theoretically be classified as a supervised area, even with an effective dose rate higher than 7.5 µSv/h*. However, if the dose rate criterion alone was used to determine the classification of area, then the operator will be obliged to measure the dose rates regularly.

* This criterion of 7.5 µSv/h comes from the previous limit of 50 mSv/year:
  - 3/10 x 50 mSv/2000 h = 7.5 µSv/h.

It has not been altered since the regulatory dose limit changed to 20 mSv/year.
An equivalent criterion is still sometimes used to fix the supervised area limit:
  - 1/10 x 50 mSv/2000 h = 2.5 µSv/h (value not mentioned in the ACoP)

The area marking is always displayed at the separation between distinctive classification areas (i.e. in principle, not on the glove box itself).

Situation b. Work in the glove box

The IRR99 stipulates an equivalent annual dose criterion (at the extremities) for the work in the glove box:
  - supervised area from 50 mSv/year
  - controlled area from 150 mSv/year

With $H_p(0.07)$ = 800 µSv/h, the equivalent dose of 150 mSv/year (glove box classified as controlled area) could be achieved with hands being exposed in a glove box for 45 min/day (averaged over 250 days/year). A supervised area classification is recommended for hands exposed in a glove box for some 15 min/day (averaged over 250 d/year). This is the maximum exposure time that has to be actually demonstrated by the operator.

The glove box classification cannot be downgraded into a non-regulated area whatever the annual use time, even very low (due to the risk of incidental contamination).

Nuclear sector

British Energy has set its own rules for the designation of radiation areas its facilities (see annexed United Kingdom country sheet). The operator classifies areas of a "hot laboratory" in a nuclear facility based on measured dose rates and the risk of contamination (surface or airborne) assessed from

activity measurements. The criteria used for the designation based on the risk of contamination depend on the radionuclides present. It is therefore difficult to determine the classification of a laboratory from the only data made available. Note however that:

• If the dose rate is < 3 μSv/h, the traffic area in the room can then be classified R1, or R2 if the dose rate is > 3 μSv/h, provided that physical barriers can be installed between point B (glove box work station) and points C (traffic area). Otherwise it is classified as at point B in area R3.

The marking at the entrance to the room indicates both types of risk - contamination and irradiation - (e.g. controlled area R3 - C3).

4.1.4. Designation of areas in Switzerland

Situation a: no work in the glove box

In this type of room, the "working area" is classified based on the activity handled (by operation or by day). With respect to the dose rate inside the glove box, the sector is at least type A and therefore classified as a controlled area (supervised areas do not exist in Switzerland). In addition, given the fire resistance requirements for the working area, the whole room will be classified as a controlled area, not just the glove box (with *ad hoc* displays at the entrance door).

It must be demonstrated that an effective dose of 1 mSv/year is not exceeded to avoid such a room being considered a controlled area (based on a conservative occupancy hypothesis of two thousand hours, in the ambient dose rate: the actual exposure time is not considered). This cannot be demonstrated in this case as the ambient rate is 10 μSv/h.

Situation b. Work in the glove box

The annual activity handled sets the type of dosimetry (entire body, extremities) and medical supervision required (not the type of area) in Switzerland (see Directive L.06-01):

Dosimetry for the use of non scelled radioactive sources

Type of nuclide	**Whole body dosimetry**		**Extremity dosimetry**		**Control of incorporation**
	Activity when working	Annual handleld activity	Activity when working	Annual handleld activity	Annual handleld activity
General					
γ emitters	> 1 LA			> 200 LA	> 200 LA > 20 LA in volatile form
β emitters with E_{β}^{max} < 1 MeV	-		-		> 200 LA > 20 LA in volatile form
β emitters with E_{β}^{max} > 1 MeV	> 100 LA (working area B)	> 200 LA	> 100 LA (working area B)	> 200 LA	> 200 LA > 20 LA in volatile form

4.2. Case 2: Large hall with "hot spots" and adjacent corridor

4.2.1. Presentation of scenario

Situation a: Work at ground level

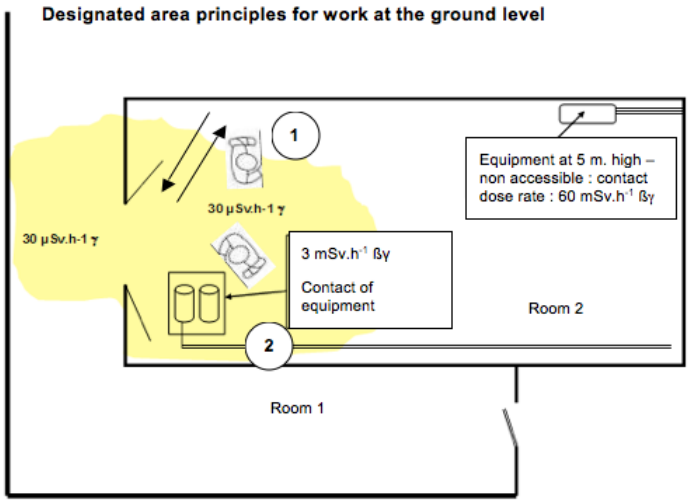
1. Context:

This is a typical case of a maintenance intervention in a nuclear facility:

- Floor-mounted equipments (e.g. pumps) in room 2 has a "contact[7]" equivalent dose rate of 3 $mSv.h^{-1}$.
- These equipment generate an equivalent ambient dose rate of 30 $\mu Sv.h^{-1}$ in an adjoining corridor (room 1), in an area marked yellow on the diagram below.
- Another, inaccessible, item of equipment located 5 m above the ground has an equivalent contact dose rate of 60 $mSv.h^{-1}$.
- No surface contamination in rooms 1 or 2.

Distinction will be made between operations on equipment (i.e. at point 2) and the "transit" passage in room 2 (e.g. at point 1) or in the corridor.

2. Radiological hypotheses:



[7] *The "contact" dose rate must be understood as being the dose rate measured as close as possible to the outside surface of an item of equipment or a material with an appropriate measuring instrument. (This comment also applies to other cases where this expression is used).*

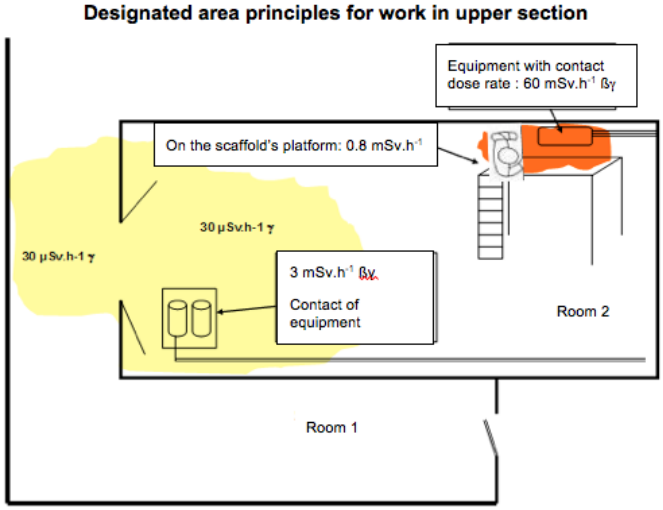
Situation b: Work in upper section

1. Context:

The situation is identical to the previous one, but in addition:

- an item of equipment (located high up) is accessible via scaffolding. It has an equivalent contact dose rate of 60 $mSv.h^{-1}$ and induces an equivalent ambient dose rate of 0.8 $mSv.h^{-1}$ on the scaffod's platform.

2. Radiological hypotheses:



4.2.2. Designation of areas in Finland

The case is studied for the industry (non-nuclear) as well as based on the rules applicable in the nuclear industry by virtue of the specific guide YVL 7.9 (see Finland country sheet).

Situation a: Work at ground level

In the (non-nuclear) industry, the annual dose is the basis for the designation of regulated radiation areas. This is calculated from working times and actual dose rates (i.e. measured, calculated or estimated realistically).

The transit areas (rooms 1 and 2) are classified as supervised areas (it is believed that workers do not spend enough time in these areas to receive an annual dose of 6 mSv; the floor-mounted equipment is only there temporarily, for the time required for a maintenance operation). Regular dose rate measurements are mandatory to check that they are still at the expected levels.

Signs will be posted as close as possible to the installed equipment indicating the measured dose rate (at 1 metre) and a warning not to come any closer: "*Staying closer than 1 metre to the equipment is prohibited*"

For the maintenance work itself (point 2), the marking will not be modified if it is a single job (only category A workers are accredited for the maintenance operation).

In the nuclear industry, both rooms 1 and 2 are classified as a controlled area (with the colour code orange, as the dose rates are higher than 25 µSv/h). Special signs and physical barriers (e.g. marking tape) are installed around equipment (with mention of the measured dose rate)

Situation b: Work in upper section

For work in the upper section, in the (non-nuclear) industry, as previously (situation (a)), the annual dose is the basis for the designation of areas. This is calculated from actual working times and dose rates (i.e. measured, calculated or estimated realistically). It is therefore likely that the designation determined for situation (a) will be maintained in rooms 1 and 2. Only the scaffolding platform will be classified as a controlled area, as the dose received could, at least in theory, reach 6 mSv/year (from 750 hours in the ambient dose rate of 0.8 mSv/h). Special signs will be installed at the bottom of the scaffolding stating that access is prohibited to unauthorised personnel: "*Access by unauthorised persons prohibited*".

In the nuclear industry, as previously, both rooms 1 and 2 will be classified as a controlled area (with the colour code orange, as the dose rates are higher than 25 µSv/h). The scaffolding platform (0.8 mSv/h) does not have sufficient dose rate to be classified as a controlled area with the colour code red (from 1 mSv/h). However, depending on how realistic the estimation and measuring uncertainties are thought to be, it could be classified as a red controlled area as a conservative measure. Special marking will be installed at the bottom of the scaffolding stating that access is prohibited to unauthorised personnel: "*Access by unauthorised persons prohibited*".

4.2.3. Designation of areas in the United Kingdom

Situation a: Work at ground level

The IRR99, which has to be applied in all sectors of activity, classifies both rooms as a controlled area.

Under British Energy's own rules, both rooms will be classified as controlled area type R2 (as soon as the ambient dose rate is lower than 50 µSv/h below the hot spot source or around the installed pumps). A sub-area R3 will be marked where possible at the work stations, i.e. on the pumps installed on the floor and on the scaffolding, even R4 if access to these various sources cannot be protected better or barred physically. In the latter case, the room should be locked.

An inspector with the British authority (HSE) takes the view that the case as described represents a situation that would be deemed unacceptable in terms of efforts made to optimise radiological protection (ALARP principle in the United Kingdom), as room 1 is a passage area (corridor); should it become accessible to unclassified personnel, the recommendation would be to install biological shielding around the installed sources, thereby reducing the dose rate to less than 2.5 µSv/h (operational criterion of a non-regulated area). In any case, HSE would insist on "shielding" around installed pumps or on their being moved to a location with no impact on the ambient dose rate in the adjoining room 1.

Situation b: Work in upper section

British Energy would install R4 marking around the scaffolding with a reminder on the platform (an additional sign indicating the presence of a hot spot).

4.2.4. Designation of areas in Switzerland

Situation a: Work at ground level

In this situation, rooms 1 and 2 are controlled areas when the RPO is applied strictly.

The more precise regulations applicable to designation of radiation areas in nuclear power plants breaks the controlled area down into sub-areas based on the dose rate:

Thus, where the worker only passes through the two rooms, this would be a sector W as the maximum rate is 30 µSv/h. Point 2, with 3 mSv/h on contact, would be a sector Y which, as such, must be delimited by physical barriers.

Specific radiological protection measures must be implemented for maintenance operations on floor-mounted equipment, as they take place in a sector Y: delimitation of the area with a yellow, "radioactive" paper strip, indications of dose rate measurements on contact and at 1 metre or at the edge of the area, ban on entering without supervision by a radiological protection engineer, limited stay period.

An inspector from the Swiss authority (OFSP) takes the view that the dose rate in the corridor at the exit from room 2 is not acceptable as is. Swiss regulations state that the dose rate in a corridor in a controlled area must be below 25 µSv/h. The authority would therefore require the walls and doors to be shielded (better) and if possible kept closed, or that the pumps be installed elsewhere.

Situation b: Work in upper section

The controlled area designation rules applicable to the nuclear power plants would classify the upper part of the scaffolding as a sector Z. In addition to the radiological protection rules applicable to the sectors Y, a sector Z must (if possible) be locked (only the radiological protection engineers hold a key). Access is then reserved exclusively for authorised agents according to the in-house rules under the control of the radiological protection department after drawing up a work plan (dose forecast) and very severely limited period of presence. The marking is installed at the entrance to the sector, therefore in this instance on the area delimitation barriers, at the foot of the scaffolding.

4.3. Case 3: Temporary storage parking area (spent fuel packaging)

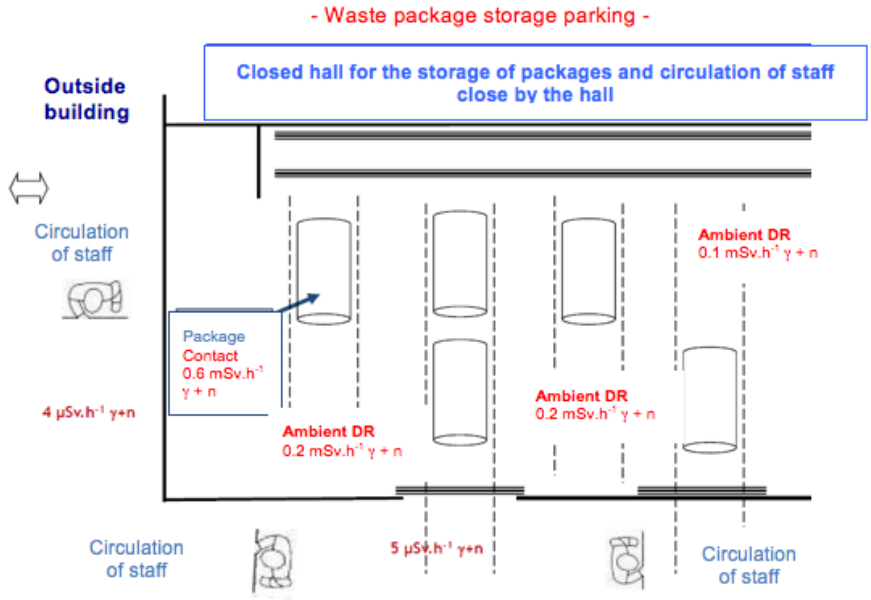
4.3.1. Presentation of scenario

1. Context:

- Spent fuel packages are stored temporarily in an enclosed parking area with possible access through a door. This enclosure is surrounded by a passage for the circulation of staff.

2. Radiological hypotheses:

- The ambient dose rate (gamma + neutrons) in the parking area is between 0.1 and 0.2 $mSv.h^{-1}$. (Note that each package has an equivalent dose rate on contact of 0.6 $mSv.h^{-1}$)
- The passage for the circulation of staff around the parking area has equivalent ambient dose rate comprise between 4 and 5 $\mu Sv.h^{-1}$ (see diagram below).



4.3.2. Designation of areas in Finland

The areas designation rules in nuclear facilities apply: the transit areas - with dose rates between 3 and 25 µSv/h - will be classified as green controlled areas. Inside, the interim storage parking area - with doses rates between 25 µSv/h and 1 mSv/h - will be classified as an orange controlled area. Hot spot signs will be placed on each package (indicating the dose rate measurement on contact and/or at 1 metre).

4.3.3. Designation of areas in the United Kingdom

The IRR99 allows the transit area to be classified as a supervised area under certain conditions, mainly where it can be demonstrated that the annual dose of 6 mSv cannot be reached (i.e. from 1200 hours of presence per year in the traffic area). The supervision and inspections where appropriate will focus on this last point (i.e. checking for no fixed work station, table, workshop, etc.). The inside of the interim storage hall will be classified as a controlled area.

In the British Energy facilities, the transit areas outside the hall will be classified as a controlled area type R2 (ambient dose rates between 3 and 50 µSv/h); the inside of the hall will be a controlled area type R3 (ambient dose rates of between 50 and 500 µSv/h).

As packages have a contact dose rate higher than 500 µSv/h, a restricted-size, type R4 area can be designated inside the type R3 area. In this case, signs will be installed about 50 cm from packages with a poster indicating that this is a high dose rate area (and stating the dose rate value measured at 50 cm).

4.3.4. Designation of areas in Switzerland

The RPO indicates that outside controlled areas, and where individuals may stay who are exposed to radiation under circumstances not linked to their professional capacity, the ambient dose must not exceed 0.02 mSv per week. Swiss regulations also provide a set of guideline values (expressed in dose rates) which can compensate for this rule: where the guideline value is observed, it can then be considered that the general rule is observed.

Location	Location where persons stay	Guidance value (µSv/h)
Outside a controlled area		
Within the company boundary	- Locations not intended for long stays, such as toilets, waiting rooms, change rooms, archiving and storage rooms without work place, counters, corridors, staircases, lift shafts and other accessible spaces	< 2.5 *(20 µSv / (40 h / 5))*

Thus, the dose rate would have to be less than 2.5 µSv/h to declassify the personnel passage area into a non-controlled area. However, even in these circumstances, it is important to make sure that there is no fixed work station (table, chair, workshop, etc.). In which case, the dose rate must drop below 0.5 µSv/h (use of additional biological shielding).

Location	Location where persons stay	Guidance value (µSv/h)
Outside a controlled area		
Within the company boundary	- Fixed work place	< 0.5 *(20 µSv / 40 h)*

As these values are not observed in this case, the personnel circulation area would be classified as a controlled area. The inside of the interim storage hall will also be classified as a controlled area (as a dose of more than 1 mSv/year could be achieved with a conservative hypothesis of two thousand working hours/year).

The rules applicable to the nuclear power plants state the designation of these two controlled areas, the result being special radiological protection rules that are then implemented (see Switzerland country sheet): the transit area would be classified as controlled area sector V (as the dose rates are below 10 µSv/h) and the hall as controlled area sector X everywhere, even in contact with the packages (as the dose rates are between 0.1 and 1 mSv/h).

4.4. Case 4: Intermittent use of an X-ray generator

4.4.1. Presentation of scenario

An operator takes an X-ray using an X-ray generator (examining a patient or inspecting a metal part). Based on the type of X-ray taken, the beam can be directed vertically and towards the ground or horizontally towards adjoining room B.

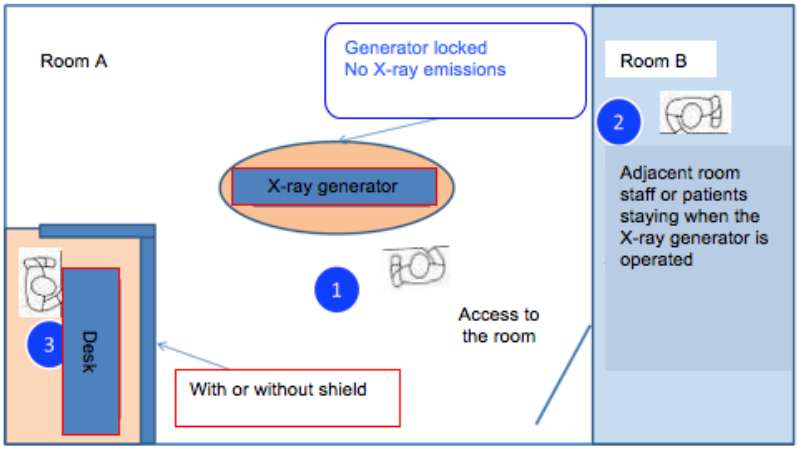
The following three situations are considered in practice:

- Situation a: when positioning the patient or the part to be X-rayed, the electric generator is switched on but does not emit X-rays;
- Situation b: as soon as the patient or part is positioned correctly, the operator launches the emission of X-rays from the console;
- Situation c: once exposure has been completed, the operator locks the X-ray generator, thereby preventing it from being switched on.

Radiological hypotheses in situation b

- the exposure level at position 1 is assessed at 180 µSv for six hours a day;
- in the adjoining room, the effective dose integrated during working hours is assessed at 60 µSv/month (position 2);

- at the console (position 3), the exposure for six hours a day is assessed respectively at 24 µSv (behind the screen) and 48 µSv (with no protective screen).



4.4.2. Designation of areas in Finland

Guides ST 1.6 (general rules) and ST 3.6 (specific rules for X-ray facilities and the examples in Annex B of this same document) must be consulted to deal with this case.

Theoretically, the controlled area is the area around the patient who during the irradiation is exposed to the primary beam and the beam diffused by the patient's body. The rest of the room where the generator is installed can normally be considered as a supervised area. The control room (console area) can be a non-regulated area.

However, the case study shows high dose rates which, even with the proposed shielding, can result in an annual effective dose of 6 mSv (in two thousand hours of exposure) being exceeded. The entire room A (including the console area) would therefore be classified as a controlled area. In addition, according to guide ST 3.6, the shielding between rooms A and B must be reinforced so that the dose constraint of 0.3 mSv/year can be observed in room B (the annual provisional dose in the case study is far too high - 0.72 mSv/year).

Guide ST 3.6 also indicates the marking rules for the radiological risk in X-ray facilities. The risk must be signalled on the doors of these facilities (with a radiation hazard warning sign at the very least even if access to the premises by outsiders is barred or sufficiently controlled). Where a warning light is the only method of indicating the hazards of accessing the irradiation room, it must comply with the following specific features:

- A yellow or white light indicating when the X-ray generator is switched on and ready for the examination. It is recommended that this light bears the text “DEVICE OPERATIONAL” (in Finnish).
- a red light during irradiation. It is recommended that this light bears the text “NO ENTRY” (in Finnish).

In addition, signs (banning an extending stay) must also be fixed to the doors of rooms adjoining the irradiation room if the shielding has been designed for an occupancy rate of these rooms of less than one (i.e. less than two thousand hours/year); this can cover equipment store rooms or cloakrooms, for example.

4.4.3. Designation of areas in the United Kingdom

Point 1 - Examination room

The irradiation room in the medical sector is classified as a controlled area from the patient positioning stage; a warning light with the text CONTROLLED AREA is recommended. During the emission of X-rays, it is recommended that the additional text X-RAY ON is displayed. When the generator is switched off and locked, the warning lights are extinguished and the room is no longer designated as a controlled area.

In the industrial sector, the instructions are similar with dual control between the warning and the generator: the equipment cannot be switched on if the warning light is faulty and the generator is switched off if the light fails during the X-ray emission or when it is switched on.

Comment: The dose rates are not limited in the controlled area (including in the beam).

Point 3 - Control console

There is no special advantage in making the console area a supervised area in this room configuration (with a door giving access to the X-ray emission area). If, on the other hand, access to the console area is through another door (i.e. with no direct access to the patient area), the question could indeed be asked about special designation of area for this space.

But, as is, the situation is unsatisfactory, as the dose received in 250 days (at a rate of six hours/day) is potentially 12 mSv/year (without shielding) and 6 mSv/year (with shielding), the limit value for a controlled area in the United Kingdom. The console area would then be maintained as a controlled area and it is more than likely that an inspector from the radiological protection authorities would ask for the console area shielding to be reinforced.

Point 2 (corridor adjacent to the room, inaccessible to the general public but accessible to the staff)

On the express understanding that the area is inaccessible to the general public (which would appear to be the case as there is no door), room B could be a non-regulated area as the maximum calculated dose (60 µSv/month x 12 months = 720 µSv/year) is less than 1 mSv/year, provided more frequent occupancy of the room is really impossible, in which case it would be classified as a supervised area.

HSE would also recommend improved shielding between rooms 1 and 2 or moving the X-ray generator (application of the optimisation principle - ALARP) despite the clear compliance with the design limit (< 20 µSv/week).

4.4.4. Designation of areas in Switzerland

In the medical sector, the Ordinance on radiological facilities for medical use (Ordinance on X-rays) applies when dealing with this case.

Specific criteria have to be observed in Switzerland from the facility design phase: the necessary shielding is calculated using the frequency of use of the equipment and dose rates in the direct and diffused beams, so that the dose rates sought outside or inside the controlled area are observed. These target values figure in the Ordinance:

- 0.02 mSv per week in adjacent rooms where individuals not occupationally exposed may stay for long periods

- 0.1 mSv per week in adjacent rooms where individuals not occupationally exposed do not stay for long periods (waiting rooms, cloakrooms, etc.)
- 0.1 mSv per week at any place in adjoining rooms occupied by occupationally-exposed individuals only

The console area will normally be a controlled area as firstly, considerable investment must be made in shielding to declassify the area and secondly, because the person going from the console to the examination or treatment room is in any case a classified worker (with access to a controlled area).

In the proposed case, room A is classified as a controlled area as it houses an X-ray emission machine: no distinction is made as to whether it is operating or shut down.

In the adjacent room B, the integrated monthly dose (60 µSv) "averaged" at 15 µSv per week complies with the design criterion of 20 µSv/week. This room is not necessarily classified as a controlled area when the user of the equipment can guarantee compliance with this criterion at all points in the room, including just behind the wall between rooms A and B (a fixed work station backing onto the wall is in fact a possibility). Compliance with this criterion is unlikely if the generator beam is directed towards this wall. The establishment will then be obliged to install additional shielding to be able to declassify room B or it will be advised to relocate the generator. In addition, the installation of an access door to room B (separate from the access via room A) will be necessary to allow access of non-classified personnel to room B.

At point 1, the provisional dose is 180 µSv for six hours a day (i.e. potentially 45 mSv over 250 working days): this dose (higher than the Swiss regulatory limit) is clearly unacceptable without more precise knowledge of the use time of the room.

At point 3 (console area), the exposure (six hours a day) is assessed at 24 µSv behind shielding and 48 µSv where there is no shielding (i.e. respectively 120 µSv and 240 µSv for a five-day week). As is, the situation would also be unacceptable as it does not comply with the mandatory criterion of 100 µSv/week for the adjoining rooms where occupationally-exposed individuals stay. The authorities would therefore insist on extra shielding between the X-ray generator room and the console area.

This case was not investigated for industry in Switzerland.

4.5. Case 5: Use of an intense radiation beam

4.5.1. Presentation of scenario

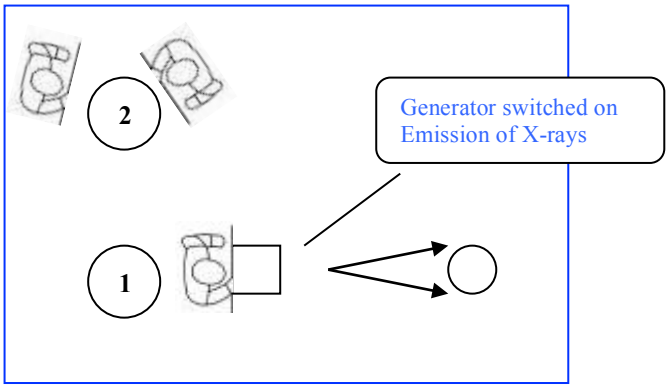
Situation a: Operating phase

1. Context

A technician (or doctor), operator A (position 1), carries out an operation very close to a beam (unprotected) from an X-ray generator, for which the dose rate is 1 Gy/min at the level of the hand if the operator places it directly in the beam.

The direct beam is used no more than two minutes per operation.

Two more operators (B and C) (position 2) are working nearby but they only risk external exposure by diffused radiation.



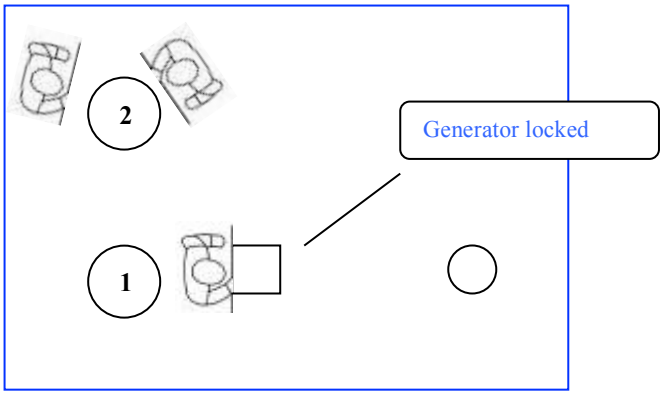
2. Radiological hypotheses

When the beam is operating, the equivalent dose rate is 2.5 mSv/h at 50 cm (position 1), moving to 10 µSv/h at 7 m (position 2).

The equivalent dose rate at the entrance to the room is 5 µSv/h.

Situation b: Shutdown phase (X-ray generator locked)

1. Context



2. Radiological hypotheses

- the X-ray generator is no longer switched on and is locked (no radiation emission).

4.5.2. Designation of areas in Finland

This case is very similar to the previous one and the same guides (ST 1.6 and ST 3.6) should be used. The room is always a controlled area if the X-ray generator is permanently installed, otherwise it maintains this status during its use, regardless of the situation (i.e. whether or not it is switched off and locked).

The dose constraint (0.3 mSv/year) for the use of X-ray equipment applies and therefore rooms and equipment must be designed in terms of shielding, voltage, etc. so that they comply in all aspects (with conservative hypotheses for personnel presence and examinations in a year).

Given the high dose rates expected during the emission of X-rays, the personnel should have personal protection equipment available.

Outside the room, the same warning lights should be installed as recommended for case 4.

4.5.3. Designation of areas in the United Kingdom

This case was only investigated for interventional radiography. The same rules apply as for case 4. The entire room would be classified as a controlled area.

4.5.4. Designation of areas in Switzerland

The same rules apply as for case 4. The entire room would be classified as a controlled area (generator operating or shut down).

There is no limit to the instantaneous dose rate (it cannot really be measured as it can vary considerably). The wearing of dosimeters, gloves or a lead apron at the work station will be stipulated.

Outside the room, the shielding should be designed for compliance with the criteria presented in case 4 and in the Switzerland country sheet.

4.6. Case 6: Workshop being dismantled

4.6.1. Presentation of scenario

1. Context:

The operators are working in a workshop to cut up parts contaminated by ^{239}Pu. The interventions take place using self-contained breathing apparatus for two shifts of two hours a day.

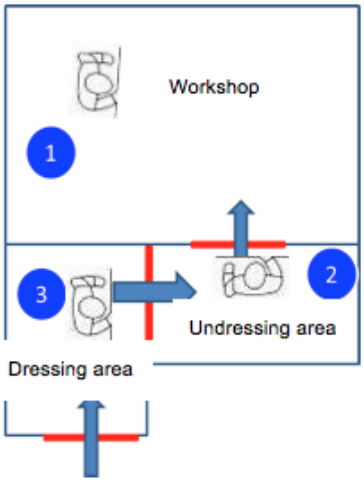
The contamination level recorded in the workshop is 2000 Bq/m^3 (point 1)

In the clothing removal airlock (point 2), the contamination level recorded is 0.5 Bq/m^3 and the operators wear a protective mask.

There is no airborne contamination in the clothing removal airlock (point 3).

2. Radiological hypotheses:

- an operator who remains one hour with no personal protection in the presence of an activity concentration of 0.44 Bq/m^3 of ^{239}Pu receives a committed effective dose of 25 µSv;
- the external exposure is negligible.



4.6.2. Designation of areas in Finland

The workshop (room 1) will be classified as a controlled area as special protection measures and procedures (for example, ventilation, breathing apparatus, depressurised airlock, assisted clothing/clothing removal, etc.) must be implemented: this is a sufficiently qualitative criterion to classify a work space as a controlled area. If the equipment or procedures are faulty, the individual dose for a workshop worker would be very high (> 100 mSv/h) according to guide ST 7.3, which gives the derived air concentration limits - DAC - and the annual limit on intake - ALI - for all the radionuclides: all possible measures must be taken to reduce the airborne concentration of ^{239}Pu in the workshop.

This comment applies also for the clothing removal airlock where the concentration is such that it is possible (based on the annual use period) to exceed 6 mSv/year, especially in an incident situation. As in the previous case, this airlock will in any case be classified as a controlled area given the protection arrangements and specific procedures to be implemented.

The clothing airlock, which has no airborne contamination, could be kept as a supervised area (metrological monitoring of the airborne dispersion would nevertheless be recommended). In the nuclear power generating industry, both airlocks and the workshop would be classified as controlled areas (note that the airborne contamination levels are sub-area criteria for the controlled area in Finnish nuclear power plants: orange area from 0.3 DAC and red area from 30 DAC. These derived limits, compared with the old effective annual dose limit of 50 mSv, are given in the annex to guide ST 7.3).

4.6.3. Designation of areas in the United Kingdom

According to IRR99, any work space where special procedures (e.g. wearing PPE) are necessary should be classified as a controlled area, which is clearly the case of the workshop (2000 Bq_{Pu239}/m^3) and the clothing removal airlock (0.44 Bq_{Pu239}/m^3). In the nuclear industry (e.g. British Energy) a work area is considered at risk from internal contamination by inhalation if the concentration in the air is such that it can generate a dose of 1 mSv/year without PPE; it is then designated C3 (this value is 0.013 Bq/m^3 for Pu-239). Both the workshop and the clothing removal airlock would then be classified controlled area C3 and probably also C2 (risk of surface contamination): HSE considers the situation unacceptable as the airborne contamination in the clothing removal airlock is deemed too high.

The clothing area (where there is no airborne contamination) would nevertheless be classified as a supervised area as it adjoins a contaminated controlled area: a warning on the potential airborne (and surface) contamination would probably be displayed at the entrance along with mandatory air sampling measures.

4.6.4. Designation of areas in Switzerland

Even before its dismantling, the workshop should be considered as a controlled area with respect to the activity present.

As in Finland and the United Kingdom, the Swiss nuclear industry (e.g. Beznau nuclear power plant) also uses guide values for air (CA) or surface (CS) concentration. These provide the basis for creating specific designation of areas for the risk of internal exposure (see Annex 3 to the RPO for these guide values for each radionuclide and §9.12. in the RPO for how they are calculated). The AC (compared with a dose of 20 mSv per year) of the ^{239}Pu is 0.3 Bq/m^3. The rules for the designation of areas for the airborne contamination are explained in the Switzerland country sheet in this report.

The workshop (2000 Bq/m^3 at point 1) would be classified as a controlled area, red area IV (> 10 CA)
The clothing removal workshop (0.5 Bq/m^3 at point 2) would be classified as a controlled area, red area III (> 0.1 CA)
This type of area defines directly the type of personal protection to be worn and the access conditions:

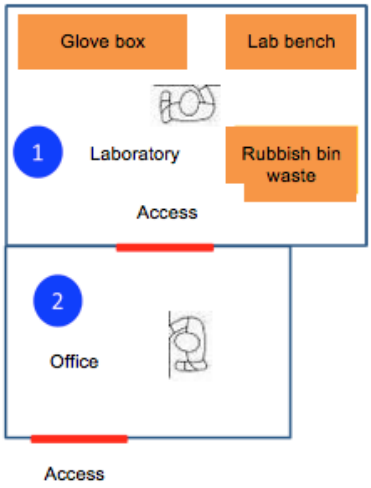
- Area III: complete coverall with red markings, area-specific clothing under the coverall,area-specific overshoes, protective hood, gloves, dust masks available. Access after authorisation given in accordance with the operating rules, possibly under the control of the RP department, stay time may be limited by airborne contamination
- Area IV: coverall with red marking, area-specific clothing under the coverall, protective hood, gloves, protective boots, protective mask with absolute filter. Access after authorisation given in accordance with the operating rules and only under strict control by the RP department, stay time limited according to occupational health considerations.

4.7. Case 7: Laboratory where radioactive iodine-131 is handled

4.7.1. Presentation of scenario

Figure 24. Context:

The operators prepare injectable solutions of iodine-131 every day in the glove box at the laboratory depicted below. All operations relating to this activity cause airborne contamination of the laboratory.



2. Radiological hypotheses:

- The exposure of an operator with no personal protection for one hour in the presence of an activity concentration of 1900 Bq/m^3 of iodine-131 induces a committed effective dose of 25 µSv.
- the glove box contains a flask of a iodine-131 solution permanently, generating an equivalent dose rate of 40 mSv/h in contact with the flask and 15 µSv/h at the glove box work station located 1 m away from the flask. The estimated activity concentration in the glove box is 60,000 Bq/m^3;
- the surface contamination of the premises is negligible;
- the external exposure at point 2 is negligible;

The airborne contamination level recorded every day for one month by sampling the ambient air is equal to:

- 1000 Bq/m^3 at point 1;
- 20 Bq/m^3 in the office at point 2.

4.7.2. Designation of areas in Finland

A laboratory's classification (A, B or C) depends on the amount of activity handled (see case 1). The decisive criterion is an exemption level expressed in Bq. A laboratory is type C if the activity handled "at any one time" is less than ten times this exemption level, type A if it is more than ten thousand times this level and type B if it is between the two (Guide ST 6.1 Radiation safety when using unsealed sources).

The exemption level for I-131 is 1 MBq (see Guide ST 1.5): it is therefore a type C laboratory. Type A and B laboratories are systematically classified as a controlled area and type C laboratories as a

supervised area (Guide ST 1.6). Where non-classified workers can enter the laboratory room, a dose constraint of 0.3 mSv/year is applied to them (thus, the office is considered to be part of the laboratory if this constraint is not met).

In the proposed example, by applying a simple rule of three (20/1900 x 25 µSv/h x 8 h x 250 d), the dose in the office could reach 0.6 mSv/year: it is an integral part of the laboratory and takes the same classification of supervised area. Only classified workers therefore have the right of access.

4.7.3. Designation of areas in the United Kingdom

Laboratory

Under the IRR99, the glove box and work station would obviously be a controlled area given the dose rates. The conservative calculation of maximum exposure means that the annual regulatory limit is exceeded: 15 µSv/h (at 1 m from the flask) x 8 hours x 250 days = 30 mSv/year.

The operate must therefore demonstrate a far lower occupancy rate for the glove box. However, even when using the glove box for less than one hour a day (i.e. dose < 4 mSv/year, less than 6 mSv though), the laboratory would remain a controlled area (due to uncertainties over the long-term validity of a dose averaged over a month and the potential lengthier exposure of the handler). The marking at the laboratory entrance would only state airborne contamination even when it is likely that a risk of surface contamination also exists.

Additional protections (glove box shielding) will probably be required (ALARP).

Office

According to the IRR99, the office is a non-regulated area as the estimated annual dose inside it is less than 1 mSv/year using the following calculation: 20/1900 x 25 µSv/h x 8 hours x 250 days = ~600 µSv/year
However, an increase in the laboratory occupancy rate could raise the airborne contamination and therefore the dose received in the office, which could therefore be kept as a supervised area (as a precaution) without improving the ventilation.

4.7.4. Designation of area in Switzerland

Medical sector

Normally there should be no activity in the air in room 1 in a type C laboratory as work is carried out in a glove box or under an “arch”. Even with no airborne contamination, the whole of room 1 would be classified as a controlled area (“type unknown”) as the start activity is not known.

If airborne contamination is deemed too high in the glove box and for routine (everyday) work, a hermetically-sealed hot cell would be preferred, with depressurisation to prevent the airborne contamination of the laboratory. The classification of the inside of the glove box is not different from the laboratory. The entire room is classified rather than the glove box alone. In addition, given the dose rate at the work station (15 µSv/h) in the laboratory, it would in any case be classified as a controlled area (potential of more than 1 mSv/year over two thousand working hours).

Based on the single criterion of airborne contamination, the office is less than 1/20th CA (20/800 [8]= 0.025) and could therefore theoretically be a non-regulated area (less than 1 mSv/year). But knowing the dose rates in the office would also be important (especially without the area adjoining the laboratory) to decide whether or not it is acceptable not to classify it as a controlled area.

Comment: Where the activity is very high, a cloakroom to enter the laboratory would be necessary (from type B laboratories upwards).

Nuclear sector (guide HSK-R-07)

The classification of a hot laboratory in a nuclear facility – this is probably not the laboratory proposed in the case study – would follow the rules already laid down in case 4.
The CA value for the iodine-131 is 800 Bq/m^3.
The laboratory (1000 Bq/m^3) would therefore be classified as a controlled area – red area III (between 0.1 and 10 CA) and sector W for the risk of external exposure (dose rate of between 10 and 100 µSv/h).
There is no specific classification for the exposure at the extremities (hands).

As already stated, there is 0.025 CA at point 2 (office). But the office would not for all that be classified as yellow area II (< 0.1 CA) as the RPO also applies: as it is below one twentieth of the CA, the internal dose is less than 1 mSv/year; as the external dose is negligible, the office could not be a controlled area but in this case a cloakroom should be installed between the office and the laboratory.

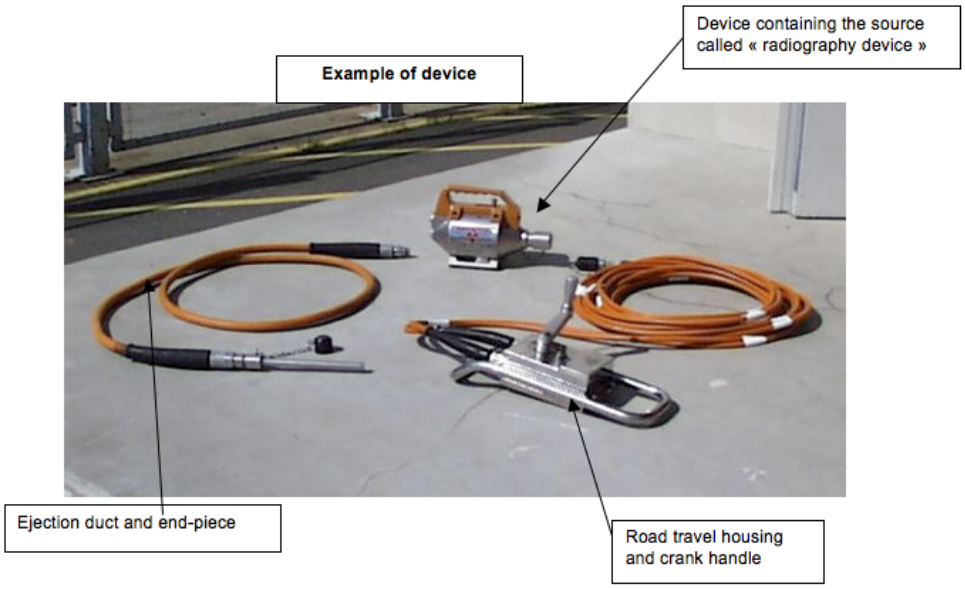
Comment: as there is air contamination, there is also potential surface contamination that should be looked at.

The protective clothing and access conditions (to an area III) are specified in guide HSK-R-07. They have already been listed under case 6.

[8] 800 Bq/m^3 is the guide value for iodine-131 (CA) which generates a dose of 20 mSv in one year of exposure (2400 m^3/year inhaled).

4.8. Case 8: Use of portable industrial radiography apparatus

4.8.1. Presentation of scenario



We are considering three situations:

- situation a: an inspection on the public highway (example: X-raying welds in gas, water systems etc. in an urban environment);
- situation b: a weld inspection in an industrial establishment outside a regulated area;
- situation c: a weld inspection inside an industrial establishment in a regulated area (supervised and/or controlled).

Additional questions for situation c:

1. Context:

For the special case of an X-ray examination of a weld in steel piping in a regulated area of an industrial establishment, the applicable rules will be illustrated in the following case:

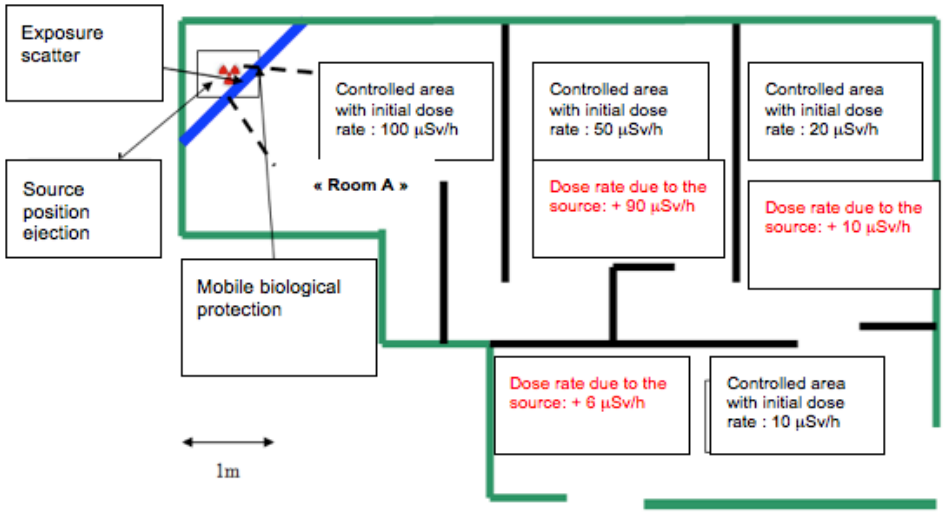
The radiography takes place in a building with initial dose rates (initial equivalent dose rate) that are assumed homogeneous per room (no airborne contamination: exclusively external exposure areas).

The premises can only be accessed by classified employees (individuals likely to be exposed to an effective dose of more than 6 mSv over one year or twelve rolling months according to the applicable legislation).

The need for operating continuity of various items of equipment in the rooms means that access cannot be totally prohibited during the inspection by radiography and marking must therefore be as comprehensive as possible.

2. Radiological hypotheses:

The gamma radiography apparatus contains a source of iridium-192 (^{192}Ir) with 1.73 TBq activity. This creates an equivalent dose rate at one metre from the protected source in the order of 30 mSv/h given the biological protections installed [redacted] (233 mSv/h at one metre from the naked source). The existence of a collimator, given the direction of the exposure (exposure scatter) provides little if any attenuation for the rooms in question.



Comment: Below the rooms will be named room A (where the exposure takes place), west room (where the equivalent dose rate goes from 50 to 140 µSv/h during the exposure), east room (where the equivalent dose rate goes from 20 to 30 µSv/h during the exposure) and south room (where the equivalent dose rate goes from 10 to 16 µSv/h during the exposure).

The internal walls [redacted] provide an attenuation of an average factor of five to ten given diffusions but without leak lines. The additional equivalent dose rates provided by the source in the ejected position in each room are shown in red above. To simplify, all these equivalent dose rates are also assumed homogenous in each room except for the room marked A that contains the source. The initial equivalent dose rate for this room is assumed homogenous, whereas the equivalent dose rate provided by the source varies roughly according to the inverse square of the distance from the protected source. It is also convention to assume that the external walls attenuate the equivalent dose rate fully.

4.8.2. Designation of areas in Finland

The specific guide (ST 5.6 – Radiation safety in industrial radiography) applies to situations a and b. The controlled area is delimited at the points where the dose rate can reach 60 µSv/h[9] (instantaneous dose rate, when the source is ejected, in inspection position). The supervised area is not shown (delimited) at 7.5 µSv/h but its extent is controlled by regular measurements.

In practice, the STUK frequently makes it mandatory to delimit the controlled area at a value less than 60 µSv/h (e.g. 20 µSv/h): the supervised area is then replaced by a more extensive controlled area. The size or surface area of the controlled area is not deemed an acceptable obstacle by the Finnish authority. Where necessary (public area), it should be evacuated prior to exposure.

There is traditional marking: radiation hazard warning sign, access and intrusion control and warning lights connected to the apparatus.

Guide YVL 7.9 applies to situation c (radiographic inspections inside a controlled area): during the exposure, the changes in area classification (in this instance the east room which goes from green to orange) must be indicated. The exposure room is made a red area. The west and south rooms remain orange and green respectively during the exposure.

The regulations only make it mandatory to lock (or control strictly) red-areas rooms but in practice, during exposure, access is restricted or even forbidden over as large a surface area as possible when this does not impact other essential work. The radiography therefore takes place preferably at night for this reason.

4.8.3. Designation of areas in the United Kingdom

Virtually the same rules apply to all three situations.

The IRR99 recommend that at the edge of the controlled area, the effective dose rate must be less than 7.5 µSv/h (this is the “instantaneous” dose rate, averaged in fact over one minute, with the source in the collimator or its position required for the examination; the source ejection phase is considered to be so short that it would in any case generate a minimum dose at the edge of the controlled area). There is no supervised area beyond the controlled area.

The ACoP states that it is mandatory for industrial radiography to comply with this value of 7.5 µSv/h at the edge of the controlled area, outside room/enclosure.

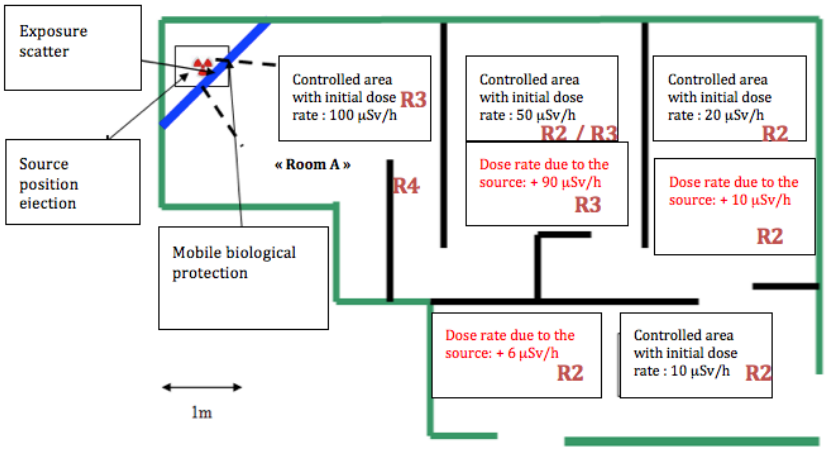
As in Finland, no exemption is possible to reduce the size of the controlled area: it can be several hundred metres when the exposure takes place outside (in the public space and it may therefore be necessary to evacuate the population: only radiographic operators can enter the controlled area). When inspecting large objects (eg. pipelines), the radiography will be halted and the edges of the controlled area changed as and when necessary (it will, however, be preferable, if possible, to delimit from the start any area likely to be a controlled area at a given moment).

[9] This value comes from a 1970s guide that is still prevalent in some Scandinavian countries (Flag Books - Nordic cooperation in the nuclear energy field).

Industrial radiographic exposure is combined with a series of warning measures, mainly:

- a warning light – theoretically – controlled by the switching on of the apparatus (but in practice running as soon as the controlled area is installed)
- an audible alarm set off with each exposure
- the installation of *ad hoc* marking at all possible entrances to the controlled area (stairs, scaffolding, doors, etc.), including via the upper or lower floors (the National Radiological Protection Board has published a specific brochure on the procedures to be followed and alarms to be installed during industrial radiography exposure)

In principle, it is recommended for situation c (radiographic examinations inside a controlled area) that the variation in dose rate during the exposure does not force a change in category for working areas adjoining the exposure area. The proposed example complies with this rule, as the east, west and south rooms remain R3, R2 and R2 respectively before and during the exposure. Room A is classified as R4 (instead of R3) during the examination. Access to it is therefore prohibited (locked or physical barrier with crossing alarm).



4.8.4. Designation of areas in Switzerland

The Order on facilities in the non-medical sector applies to situations a and b. The criteria to be observed are expressed in dose/week:

- 0.02 mSv per week in rooms outside the controlled area, where individuals not occupationally exposed may stay for long periods
- 0.1 mSv per week on rooms outside the controlled area where individuals not occupationally exposed do not stay for long periods
- 0.1 mSv per week at any place in the controlled area occupied by occupationally-exposed individuals only. The maximum dose rate permitted at the accessible places must not exceed 100 µSv/h (but no dose rate limitation where no one may enter during exposure)

The criterion of 0.1 mSv/week would therefore apply if the inspection took place on the public highway (a pavement or a street are not considered as a place for an extended stay).

The 0.02 mSv/week must be observed in a professional area (permanent presence possible in rooms adjoining the exposure area).

The frequency and actual use time of the machine along with the maximum dose rate during the exposure must be checked for compliance with these criteria (ejected source, in examination position). The table in Annex 2 to the Order on unsealed sources can also be used (that also applies): it gives hourly guide dose rates that, if observed, suggest that the criterion of dose per week will also be observed for continuous use of the apparatus, based on different attendance times for exposed individuals (round the clock, 40 h/week or 8 h/week). It is therefore possible to take account of the actual use time of the machine to deduce the maximum dose rate outside the controlled area.

Regarding situation c (radiographic examinations inside a controlled area), before operating the exposure, room A is a controlled area sector X and the other rooms are classified sector W. During the exposure, room A becomes a sector Z (access reserved only for authorised agents under internal regulations and under strict control of the radiological protection engineers department after drawing up a work plan and very severely limited access time), the west room becomes a sector X (no ban on access, but a change of marking and restricted period of presence) and the other two rooms remain as sector W.

5. OVERVIEW

The radiological protection regulations in the various countries studied, more especially in relation to the classification of areas, are generally based on a single regulatory text for all activity sectors and give little detail. Regulations or specific guides for each activity sector supplement the basic text.

The purpose of designating regulated radiation or contamination areas is rarely explained as such. The aim of measures taken by the regulations is to protect the workers and check the application of principle of optimisation of radiological protection. Areas must be classified when workers risk reaching or exceeded the regulatory limit values. The main aim is to "identify" the areas requiring special controls for access, monitoring of workers, etc. Protection measures must be adapted based on "work station assessments".

The United Kingdom and Switzerland are the only two countries to explain briefly the purpose of designating areas. Area classification in the United Kingdom aims to "help ensure that the measures taken to avoid accidents and implement the ALARP principle are effective". The aim of area designation in Switzerland is to "restrict and control the exposure to radiation".

Criteria for the designation of regulated areas

An area is classified as controlled area by evaluating the annual dose according to an exposure scenario that is normally conservative (and which takes into account the maximum dose rate and a maximum occupancy rate of 250 d/year, 40 h/week, 8 h/d, etc.). A detailed work station assessment, as recommended in France, is only rarely performed to establish the classification of areas. The designation of regulated areas often simply classifies the work space as a supervised or controlled area. The general radiological protection rules are then adapted to the type of area (mainly on the control means and access conditions). The detailed work station assessment is normally part of the radiological protection optimisation analysis and therefore has nothing to do with the designation of areas.

Other criteria are considered to establish the designation of regulated areas – above all in the nuclear industry – but they vary from one country to the next and also in how they are taken into account:

- Dose rate (effective or equivalent)
- Airborne or surface contamination (the limits and guide values for the concentration in the air or surface contamination do not abide by the same annual dose limits nor the same reference exposure scenarios).
- Total activity handled (laboratories, unsealed sources)

All-sector regulations do not provide for sub-areas in the controlled area except in Belgium, Spain and the United States.

Designation of regulated radiation areas in the nuclear industry

The sub-areas are required in the nuclear sector only, not the others (apart from Spain where a sub-area is introduced in the medical sector). The dose rate and/or contamination values delimiting the sub-areas for the nuclear sector are regulatory in Spain (but come from an agreement with the operator), Finland, the United States (but the operator can fix other, more restrictive values) and Switzerland. These values are fixed by the operator in Sweden and the United Kingdom.

Operators/countries do not seem to harmonise on the values, graduation, signage, access conditions or control resources in the controlled area or sub-areas. Figure 24 illustrates the differences in values adopted for the dose rate criterion in the nuclear sector.

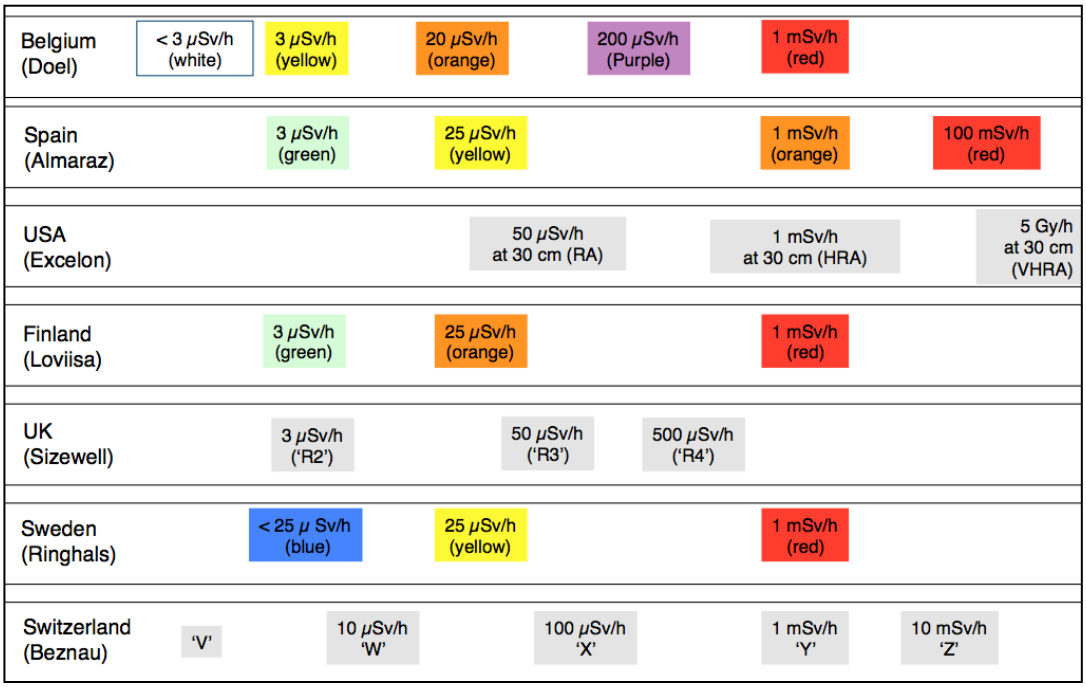


Figure 24. Dose rate criterion values for the designation of controlled areas the nuclear sector

Classifying a transit area (temporary presence) as a controlled area is not (normally) considered as an acceptable situation in fact.

Collective protection (screens, shielding) and optimisation must be implemented to reduce the controlled areas in number and/or size from the design phase in Switzerland (where criteria expressed in dose per week – evaluated – or dose rate guideline values – calculated or measured – must be observed before the areas' classification takes place).

There is not normally a subdivision in non-regulated area/supervised area/controlled area inside a same room.

The controlled area classification also entails special intervention and control conditions, such as:

- *Ad hoc* clothing
- Whether or not RP personnel are present
- PPE, contamination meter
- Marking out and signage
- Access procedures, controls and restrictions

X-ray medical sector

In all circumstances, the presence of an X-ray generator means that the room is classified as a controlled area. This classification can be temporary when the generator is running (e.g. Spain) or permanent (e.g. Finland and Switzerland). This classification of area rarely changes (same X-ray generator switched off and locked) except in the United Kingdom.

Warning lights are mandatory when the generator is switched on and during X-ray emissions (Finland and United Kingdom).

Wall shielding must be designed and the geometry of the premises adapted to comply with the quantitative (e.g. dose/week in Switzerland) or qualitative (United Kingdom) ALARA criteria. Even more restrictive criteria (dose constraint/year in Finland, effective dose/week in Switzerland) must also be observed in adjoining rooms, especially those where non-classified workers may spend time. Adjacent rooms must normally be classified as supervised or unrestricted areas. These constraints differ in value from one country to the next. For example:

- In Finland, an annual dose constraint of 0.3 mSv/year outside rooms must be observed. This constraint is derived from the weekly dose rate (6 μSv/week).
- In Switzerland, compliance with a maximum dose rate of 0.02 mSv/week is required in adjacent rooms where individuals intend to stay for a long time and a maximum dose rate of 0.1 mSv/week in adjacent rooms that are little used.

Unsealed radioactive sources

Laboratories in some countries which handle unsealed sources are classified (type A, B or C) based on the activity handled and/or the authorised limit. This is the case in Finland and Switzerland. This classification therefore results in specific design criteria being applied and specific rules being introduced for protection clothing or equipment. The type of dosimeter to be worn (full body or extremity) is defined according to the activity handled.

In Finland, areas are classified according to the type of laboratory. Thus class A or B laboratories (handling activity greater than or equal to 10^4 x exemption value) must be classified as a controlled area. Type C laboratories (handling activity less than 10^4 x exemption value) are classified as a supervised area, except where there is a contamination risk when they must be classified as a controlled area.

Industrial radiography

A supervised area is not normally established beyond the controlled area. There is a variety of criteria to be observed at the edge of the controlled area markings (dose or dose rate). The calculation parameters (for example, the time over which the dose rate is averaged) for these criteria are not always very explicit in either the general regulations or in the practical implementation guides:

- Dose/week in Switzerland (according to conservative evaluation or a detailed work station assessment)
- Dose rate (/h calculated during the exposure time, source ejected in control position) in the United Kingdom
- Dose rate (/h during the control period) in Finland

The countries studied do not deviate from the established criteria that must be observed even if this means delimiting huge controlled areas (evacuation over several hundred metres if necessary). A "Provisional" or "movable" designation of area (e.g. for radiography of pipework or pipelines) is possible in the same way as a temporary reclassification of an area (especially in nuclear facilities). The marking is modified as a result in all these circumstances.

Access conditions to the areas

The regulations in all countries state that only authorised individuals may enter the regulated areas. Workers entering these areas must be classified as category A or B and wear a personal dosimeter. Note that active dosimetry is not systematically required in a controlled area. All workers entering regulated areas must have been trained in the bases of radiological protection and the risks run at their work station. Adequate protective clothing is necessary, especially in the case of contamination.

In addition, in the nuclear sector, the regulations or guides state that a "radiological work permit" must be issued for any access into a controlled area. Radiological protection support is required to be present based on the risk level and a pre-job briefing must be carried out. Red areas must be locked wherever possible.

To our knowledge, the regulations in the countries studied make no mention of access restrictions for temporary staff.