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

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

SUMMARY

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1. INTRODUCTION

In the context of the revision of the European requirements with regard to radiation protection, and in particular in anticipation of the work transposing the new EURATOM directive on basic radiation protection standards, the Ministry of Labour (Direction Générale du Travail - DGT) and the French Safety Authority (Autorité de Sûreté Nucléaire - ASN) tasked the ASN's standing groups of experts on radiation protection (GPRAD and GPMED)[1] with undertaking a forward-looking examination of delineation of and access to regulated areas.

With the aim of obtaining input for its deliberations, the "Classification of area WG"[2] needed information on the regulations and practices in other countries in the context of exposure conditions raising problems in various sectors of activity (nuclear, industrial, research, medical, transport, enhanced natural). The aim of the experts was to compare the principles of the foreign regulatory systems, in particular by identifying "two-level" systems based on regulatory legislation and on sector practices.

At ASN request, a survey has been conducted by the CEPN to identify the rules applicable to the delineation of and access to radiation protection regulated areas in seven countries: Belgium, Spain, United States, Finland, United Kingdom, Sweden and Switzerland. In addition to examination of regulatory legislation and occupational rules, the rules and practices in effect in three countries (Finland, United Kingdom and Switzerland) have been applied to a number of specific theoretical cases studies deliberately highlighting various occupational exposure situations and different sectors of activity (laboratory, medical, nuclear, etc.) [1, 2].

This report summarises the principal conclusions of the international survey conducted by the CEPN, and in particular describes the rules applied for delineation of radiation protection regulated areas, in general for all sectors and in greater detail for a few particular sectors.

2. CRITERIA FOR THE DESIGNATION OF AREA IN THE GENERAL RADIATION PROTECTION REGULATIONS

In general, the radiation protection regulations of the countries surveyed, and more particularly the regulations on area designation, are based on a single regulatory text for all sectors of activity, giving relatively few details. This basic legislation is in some cases supplemented by specific regulations or guides by sector of activity. The principal regulatory legislation and guides produced by the authorities and the other documents (plant operator procedures, for example) that were used in this survey are listed in Appendix 1.

The purpose of the designation of area is rarely stated as such in the regulations. The aim of the measures defined by the regulations is to protect workers and verify the application of the principle of optimisation of radiation protection. Areas must be classified when there is a possibility that workers risk reaching or exceeding the regulatory limit values. The main aim of designation is to identify areas necessitating special controls for access, worker monitoring, etc.

The only two countries providing some information on the purpose of the designation of areas are the United Kingdom and Switzerland. In the United Kingdom, the purpose of area designation is to "help ensure that the measures taken to avoid accidents and to implement the ALARP principle are

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

[2] Working group set up with GPRAD and GPMED members

effective". In Switzerland, the aim of the area classification is "to limit and control exposure to radiation".

Detailed area designation criteria are given in Appendix 2, and the criteria for controlled areas are summarised in Table 1. Apart from in the United States, the principal quantitative criterion for designation of a work area as a controlled or supervised area is the possibility of exceeding a fraction of the annual dose limit defined by the regulations. An hourly dose rate criterion is added in the Belgian regulations for delineating sub-areas within controlled areas. In Spain, provision is also made for different marking of areas within controlled areas according to the possibility of exceeding a dose limit over a given time period. In the United States, three types of "radiation area" are defined according to a criterion of equivalent dose received in a given time period at a given distance from the source. The United States regulations also provide for definition of an "airborne radiation area" according to the possibility of exceeding the derived air concentration. Lastly, it should be noted that in Switzerland there are no supervised areas, only controlled areas. Controlled areas are defined according to the possibility of exceeding an effective dose value or in the case of a given level of airborne or surface contamination.

Some countries (Spain, Finland, United Kingdom) also stipulate that an area should be designated as a controlled area if it is considered that specific work procedures must be applied in the area to reduce worker exposure and/or to avoid spreading contamination and/or to avoid accidental exposures.

Table 1. Controlled area designation criteria

	Effective dose	Equivalent dose	Hourly dose rate	Absorbed dose	Airborne contamination	Surface contamination	Specific work procedures
Belgium	✔	✔	✔				
Spain	✔	✔					✔
United States		✔		✔	✔		
Finland	✔	✔					✔
United Kingdom	✔	✔	✔				✔
Sweden	✔	✔					
Switzerland	✔				✔	✔	

The classification of areas is usually determined using an annual dose estimate based on an exposure scenario, generally conservative (taking into account the maximum dose rate, and a maximum occupancy of 250 d/year, 40 h/week, 8 h/day, etc.). A detailed job study, as recommended in France, is very rarely carried out for the designation of areas. The classification of the workspace consists usually in designating a supervised or a controlled area. This then entails the general radiation protection rules (for example regarding control means and access conditions). The detailed job study is then conducted as part of the radiation protection optimisation analysis, disconnected from the classification of the areas.

3. DESIGNATION OF AREA IN THE NUCLEAR INDUSTRY

In all the surveyed countries except Belgium, the nuclear sector is subject to specific regulations (or to specific guides published by the authorities) with regard to the classification of areas, with provisions supplementing the general regulations applicable to all sectors.

In Spain and Finland, the controlled area is defined taking three criteria into consideration simultaneously: dose rate, surface contamination and airborne contamination. The criterion with the

highest value defines the designation. In the United States, the United Kingdom, Sweden and Switzerland, the three criteria are considered separately and result in three distinct controlled areas. In Belgium, the controlled area is defined using the hourly dose rate. A designation is also applied for surface contamination (no designation linked with airborne contamination).

The dose rate and/or contamination values used to delineate zones or sectors within controlled areas are regulated in Spain (but agreed with the plant operator), Finland, the United States (but the plant operator may define stricter values) and Switzerland. These values are defined by the plant operator in Sweden and in the United Kingdom.

The main criteria for controlled area designation in the nuclear industry are given in Appendix 3. There is a remarkable lack of uniformity between the countries, whether in the designation criteria values or in the area colours and names.

Collective protection (screens, shielding) and optimisation must be implemented to reduce the number and/or size of controlled areas from the design stage in Switzerland (where criteria expressed in terms of estimated dose per week or of calculated or measured dose rate guidance values must be complied with prior to classify the areas).

Division of controlled areas into sectors is accompanied by special work and control conditions, such as:

- appropriate clothing
- presence (or not) of radiation protection personnel
- personal protective equipment, contamination monitoring
- markings and signs
- procedures and checks and access restrictions.

4. MEDICAL X-RAY SECTOR

In all the surveyed countries, the presence of an X-ray generator is the reason why a room is designated as a controlled area. This designation is either temporary, when the generator is operating (e.g. in Spain), or permanent (e.g. in Finland, Switzerland). This designation rarely changes (even with the X-ray generator locked off), except in the United Kingdom.

In Finland and in the United Kingdom, visual alarms are mandatory when the generator is switched on and during X-ray emission.

Wall shielding must be designed and room layout must be adapted in order to comply with quantitative (e.g. dose/week in Switzerland) or qualitative (United Kingdom) ALARA criteria. More restrictive criteria (dose constraint/year in Finland, effective dose/week in Switzerland) must also be complied with in adjoining rooms, in particular those where non-classified workers might stay. In general, it must be possible to designate adjacent rooms as supervised or unrestricted (non-designated) areas. The values of these constraints differ between countries, for example:

- in Belgium: 0.02 mSv/week at the outer surface of the rooms,
- in Finland: annual dose constraint 0.3 mSv/year outside the rooms, from which a weekly dose rate is derived (6 μSv/week),
- in Switzerland: two limit values have been fixed for persons non professionally exposed to radiations: a maximum dose rate 0.02 mSv/week in adjacent rooms where persons are likely to remain for long stays, and maximum dose rate 0.1 mSv/week in low-occupancy adjacent rooms.

5. UNSEALED RADIOACTIVE SOURCES

In some countries, such as Finland and Switzerland, laboratories handling unsealed sources are designated (type A, B or C) according to the activity handled and/or according to the authorisation limit (Table 2). This designation entails the application of specific design criteria and the implementation of specific rules for protective clothing or facilities (e.g. provision of change rooms). The type of dosimeter to wear (whole body or extremity) is defined according to the handled activity. In Finland, type A and B laboratories must be designated as controlled areas; type C laboratories are designated as supervised areas, unless there is a contamination risk, in which case they must be designated as controlled areas. In Switzerland, a work sector is designated as a controlled area when the authorisation limit is exceeded.

Table 2. Laboratory classification examples

Laboratory type (Finland)/Work sector (Switzerland)	Finland	Switzerland
	Maximum activity handled at any one time	**Activity handled per operation or per day**
Type C	10 x exemption limit	1 to 100 x authorisation limit
Type B	10^4 x exemption limit	1 to 10^4 x authorisation limit
Type A	> 10^4 x exemption limit	1 x authorisation limit to the upper limit defined in the authorisation

6. OPEN SITE INDUSTRIAL RADIOGRAPHY

Criteria to be complied with for controlled area boundary marking in open site industrial radiography vary between countries (dose or dose rate) (examples in Appendix 4). The calculation parameters (time over which the dose rate is averaged, for example) for these criteria are not always very explicit, either in the general regulations or in the practical implementation guides. Except in Finland, there is no provision for delineating a supervised area outside the controlled area.

The surveyed countries make no provision for waiving the established criteria, which must be complied with even if they entail the delineation of very large controlled areas (evacuation over several hundred metres if necessary). “Temporary” or “mobile” controlled areas (e.g. for radiography of pipes or pipelines) is possible, as well as temporary modification in the designation of an area (in particular in nuclear facilities). In all such cases the marking is modified in consequence.

7. AREA ACCESS CONDITIONS

In all the countries, the general regulations stipulate that only authorised persons can have access to regulated areas. Workers accessing these areas must be classified in category A or B and must be monitored by individual dosimetry. It should be noted that active dosimetry is not required in controlled areas in all cases. All workers accessing regulated areas must have been trained on the fundamentals of radiation protection and on the risks to which they are exposed at their workplace. Suitable protective clothing is necessary, particularly in the case of contamination.

In addition, in the nuclear sector, the regulations or guides stipulate that a “radiation work permit” must be issued for any entry into a controlled area. Radiation protection support is required according to the risk level, as well as a pre-job briefing. Insofar as possible, red areas must be locked.

To the best of our knowledge, the regulations of the surveyed countries do not define any access restrictions for temporary workers.

8. CONCLUSIONS

The general regulations on the designation of regulated areas in the surveyed countries are in general not very prescriptive. They are supplemented by orders or guides published by the authorities, specific to the various sectors of activity. Other than in the nuclear sector, division of a controlled area into sub-areas, according to the dose rate, for example, is not required.

The main purpose of the classification of areas is to "identify" areas that necessitate special controls for worker access and monitoring. It is not directly associated with the level of the radiological risk at the workplace. Mandatory additional job studies are used as the basis for determining the specific protection measures for the actual exposure conditions.

Large differences in regulations and practices between the various countries are observed, in particular with regard to:
- names, types and numbers of areas or sub-areas;
- area delineation criteria (dose rate, contamination level, etc.);
- values of these criteria;
- marking.

This situation may raise problems for cross-border workers who are confronted with very different practices. It is therefore particularly important to make sure that such workers receive appropriate training when starting work in another country. Moreover, it would no doubt be useful consider moving towards greater harmonisation, at least at European level.

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APPENDIX 1 – LIST OF REGULATORY LEGISLATION AND GUIDES RELATING TO AREA DESIGNATION

	Acts/decrees	Authority/Ministry guides	Other documents used
Belgium	Royal Order of 20 July 2001 [3]	AFCN: - Guide to medical use of X-rays [4] - Guide to good practice in the use of X-rays in veterinary medicine [5] Conseil Supérieur d'Hygiène: - Report on radiation protection quality assurance in nuclear medicine [6]	Nuclear operator procedures [7, 8]
Spain	Royal Decree implementing the regulations on health protection against ionising radiation [9]	CSN: - General radiation protection manual (medical sector) [10] - Guide for industrial gammagraphy facilities [11] CSN and UNESA: - General radiation protection manual (nuclear sector) [12]	Madrid Hospital radiation protection manual [13] Nuclear operator procedures [14 to 16]
United States	Federal Code (10CFR20) [17] New York State Sanitary Code [18]	NRC: - Guide to control of access to high and very high radiation areas (nuclear) [19]	Nuclear operator procedures [20 to 22]
Finland	Act on ionising radiation [23]	STUK: - Guide Zoning all sectors [24] - Guide RP and nuclear zoning [25] - Guides for other sectors [26 to 32]	Nuclear operator procedures [33]
United Kingdom	Ionising radiations regulations (IRR 99) [34]	HSE: - Code of Practice and guidance for application of IRR99 [35] - Guides for nuclear inspectors [36, 37]	Nuclear operator procedures [38]
Sweden	Basic rules for radiation protection of workers and the public [39] Regulations for radiation protection of workers in nuclear power plants [40]	-	Nuclear operator procedures [41]
Switzerland	Radiation protection act (Federal Assembly) [42] Radiation protection order (Federal Council) [43] Sector technical orders (Federal Interior Department) [44 to 48] Sector technical directives (OFSP or IFSN) [49 to 51]	-	Nuclear operator procedures [52]

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APPENDIX 2 – AREA DESIGNATION CRITERIA (ALL SECTORS)

	Controlled area	Supervised area
Belgium	3/10ths of the annual dose limits for workers exceeded Within controlled areas, "ionising radiation", "high radiation intensity" or "very high radiation intensity" signs according to the hourly dose rate (20 µSv/h, 0.2 mSv/h and 1 mSv/h, respectively)	Any of the annual dose limits for the public exceeded
Spain	3/10ths of the annual dose limits for workers exceeded Within controlled areas, definition of "limited stay" (yellow), "regulated stay" (orange) or "forbidden access" (red) zones according to the risk of exceeding annual limits over one year, over a shorter period or in a single exposure, respectively	Effective dose > 1 mSv Equivalent dose > 1/10th of the annual dose limits for workers
United States	Three types of area: "radiation area" or "high radiation area" according to the equivalent dose received in 1 hour at 30 cm and "very high radiation area" according to the absorbed dose received in 1 hour at 1 metre from the source "Airborne radioactivity area" if 0.6% of the ALI or 12 DAC-h exceeded in 1 week without respiratory protection	No supervised areas
Finland	3/10ths of the annual dose limits for workers exceeded	Effective dose > 1 mSv Equivalent dose > 1/10th of the annual dose limits for workers
United Kingdom	3/10ths of the annual dose limits for workers exceeded External dose rate > 7.5 µSv/h averaged over a working day Hand exposure: average dose rate > 75 µSv/h over 8 hours	Effective dose > 1 mSv Equivalent dose > 1/10th of the annual dose limits for workers
Sweden	3/10ths of the annual dose limits for workers exceeded	No quantitative delineation criteria
Switzerland	Effective dose > 1 mSv Airborne contamination > 1/20th of the limit for each radionuclide present Surface contamination > radionuclide limit for each radionuclide present	No supervised areas

APPENDIX 3 – CONTROLLED AREA DESIGNATION CRITERIA (NUCLEAR INDUSTRY)

<table>
<tr><td>Belgium

(Doel nuclear power plant)</td><td>White area: d < 3 µSv/h
Yellow area: 3 µSv/h ≤ d < 20 µSv/h
Orange area: 0.02 mSv/h ≤ d < 0.2 mSv/h
Purple area: 0.2 mSv/h ≤ d < 1 mSv/h
Red area: d ≥ 1 mSv/h</td><td>Contaminated area
Green area: SC β/γ < 0.4 Bq/cm^2
Yellow area: 0.4 Bq/cm^2 ≤ SC β/γ < 400 Bq/cm^2
Three zones in the yellow area:
0.4 – 4 Bq/cm^2 β/γ
4 – 40 Bq/cm^2 β/γ
40 – 400 Bq/cm^2 β/γ
Red area: SC β/γ ≥ 400 Bq/cm^2</td></tr>
<tr><td>Spain

(Almaraz nuclear power plant)</td><td colspan="2">Green controlled area:
- 3 µSv/h ≤ d < 25 µSv/h, and
- SC β/γ < 4 Bq/cm^2 averaged over 300 cm^2
- SC α < 0.4 Bq/cm^2 averaged over 300 cm^2, and
- AC < 0.1 DAC

Yellow limited stay area:
- 25 µSv/h ≤ d < 1 mSv/h, and
- SC β/γ < 40 Bq/cm^2 averaged over 300 cm^2
- SC α < 4 Bq/cm^2 averaged over 300 cm^2, and
- AC < 1 DAC

Orange regulated stay area:
- 1 mSv/h ≤ d < 100 mSv/h, and
- SC β/γ < 400 Bq/cm^2 averaged over 300 cm^2
- SC α < 40 Bq/cm^2 averaged over 300 cm^2, and
- AC < 10 DAC

Red forbidden access area:
- d > 100 mSv/h, or
- SC β/γ > 400 Bq/cm^2 averaged over 300 cm^2
- SC α > 40 Bq/cm^2 averaged over 300 cm^2, or
- AC > 10 DAC</td></tr>
<tr><td rowspan="2">United States

(Cook nuclear power plant)</td><td rowspan="2">Radiation area
45 µSv/h at 30 cm ≤ d < 0.9 mSv/h at 30 cm
High radiation area
0.9 mSv/h at 30 cm ≤ d < 9 mSv/h at 30 cm
Locked high radiation area
9 mSv/h at 30 cm ≤ d < 5 Gy/h at 1 metre
Locked very high radiation area
d ≥ 5 Gy/h at 1 metre
Neutron exposure area
$d_{neutron}$ ≥ 20 mSv/h</td><td>Contaminated area
- 16.7 Bq/100 cm^2 ≤ SC β/γ < 1.6 kBq/100 cm^2, or
- SC α ≥ 0.3 Bq/100 cm^2
High contamination area
- SC β/γ ≥ 1.6 kBq/100 cm^2</td></tr>
<tr><td>Airborne radioactivity area
- ∑ particles, iodine and tritium ≥ 0.3 DAC, or
- ∑ particles, iodine, tritium and noble gases ≥ 1.0 DAC</td></tr>
</table>

d: dose rate
SC: surface contamination
AC: airborne contamination

Finland **(Loviisa nuclear power plant)**	Green area - $d \leq 25$ µSv/h, or - SC $\beta/\gamma \leq 4$ Bq/cm^2 - SC $\alpha \leq 0.4$ Bq/cm^2, or - AC ≤ 0.3 DAC Red area - $d \geq 1$ mSv/h, or - SC $\beta/\gamma \geq 40$ Bq/cm^2 - SC $\alpha \geq 4$ Bq/cm^2 - AC ≥ 30 DAC	Orange area - 25 µSv/h < d < 1 mSv/h, or - 4 Bq/cm^2 < SC β/γ < 40 Bq/cm^2 - 0.4 Bq/cm^2 < SC α < 4 Bq/cm^2 - 0.3 DAC < AC < 30 DAC
United Kingdom **(Sizewell B nuclear power plant)**	Area R2 3 µSv/h < d < 50 µSv/h Area R3 50 µSv/h < d < 500 µSv/h Area R4 d > 500 µSv/h	Surface contamination controlled area C2 - SC > 4 Bq/cm^2 β/γ - SC > 0.4 Bq/cm^2 α - *Other values for specific radionuclides* Airborne contamination controlled area C3 - AC > 10 Bq/m^3 β/γ - AC > 0.01 Bq/m^3 α - *Other values for specific radionuclides*
Sweden **(Ringhals nuclear power plant)**	Blue area d < 25 µSv/h Yellow area 25 µSv/h < d < 1 mSv/h Red area d > 1 mSv/h	Surface contamination controlled area Blue area - SC < 40 kBq/m^2 β/γ - SC > 4 kBq/m^2 α Yellow area - 40 kBq/m^2 < CS β/γ < 1000 kBq/m^2 - 4 kBq/m^2 < CS α < 100 kBq/m^2 Red area - SC β/γ > 1000 kBq/m^2 - SC α > 100 kBq/m^2 Airborne contamination controlled area Blue area: AC > 1 DAC Yellow area: 1 < AC < 10 DAC Red area: AC > 10 DAC

d: dose rate
SC*: surface contamination*
AC: airborne contamination

Switzerland **(Beznau nuclear power plant)**	Sector V: d < 0.01 mSv/h Sector W: 0.01 mSv/h < d< 0.1 mSv/h Sector X: 0.1 mSv/h < d < 1 mSv/h Sector Y: 1 mSv/h < d < 10 mSv/h Sector Z: d > 10 mSv/h	Surface contamination controlled area *for each radionuclide* Yellow area I with low probability of contamination - SC < 1 limit value Yellow area II 1 limit value < SC < 10 limit value Red area III - 10 limit value < SC < 100 limit value Red area IV - SC > 100 limit value
		Airborne contamination controlled area *for each radionuclide* Yellow area I with low probability of contamination - AC < 0.1 limit value Yellow area II - AC < 0.1 limit value Red area III - 0.1 limit value < AC < 10 limit value Red area IV - AC > 10 limit value

d: dose rate
SC: surface contamination
AC: airborne contamination

APPENDIX 4 – CONTROLLED AREA DELINEATION CRITERIA FOR OPEN SITE INDUSTRIAL RADIOGRAPHY

	Criteria
Finland	Regulations: Controlled area boundary: 60 µSv/h (for the duration of the inspection) Supervised area boundary: 7.5 µSv/h (for the duration of the inspection) Practice: The dose rate considered for the controlled area is the instantaneous dose rate when the source is extended, in control position.
United Kingdom	Regulations: Controlled area boundary: 7.5 µSv/h (average over 8 working hours) Practice: The dose rate is averaged over 1 minute, with the source in the collimator or in its required position for the examination; the source extension phase is considered to be so short that it would only generate a minimal dose at the controlled area boundary.
Switzerland	Regulations: Controlled area boundary: - 0.02 mSv per week in rooms outside the controlled area where non-occupationally-exposed persons might stay for long periods - 0.1 mSv per week in rooms outside the controlled area that are not intended for long stay Practice: To verify compliance with these criteria, the actual frequency and duration of use of the machine and the maximum dose rate during the exposure (source extended, in control position) must be taken into consideration.