HADMÉRNÖK

XIII. Évfolyam 4. szám – 2018.december

DIVIDING OF CONTROLLED AREA IN NUCLEAR POWER PLANTS

ATOMERŐMŰVEK ELLENŐRZÖTT TERÜLETEINEK FELOSZTÁSA

CSURGAI József; SEBESTYÉN Zsolt; SOLYMOSI József

(ORCID: 0000-0003-4770-7997); (ORCID: 0000-0003-3030-856X), (ORCID: 0000-0003-3737-1932)

jozsef.csurgai@uni-nke.hu; sebestyen@haea.gov.hu; jozsef.solymosi@uni-nke.hu

Abstract

In Hungary due to the changes in the radiation protection authority's duties the revision of the legislation has been started. In this context a new decree has been entered into force and the existing legislation has been amended.

The existing domestic legislation does not classify the controlled area from the aspect of radiation protection. However, there are requirements in international recommendations as well as practices applied by individual countries. This difference is based on the use of different reactor types and on the different cultures of each nation.

In our country, the review of the practices can be a major role in the planned nuclear power plant expansion. According to the current plans, two Russian-designed, pressurized water blocks are being built, so before submitting the plans the reviewing of the practices used may be worth.

The purpose of the article is to show the different zones, that is, the division of the territories. This can help in revising the plans, as well as in the development of laws or official guidance.

***Keywords**: radiation protection, controlled area, NPP*

Absztrakt

Hazánkban a sugárvédelmi hatósági feladatok változásának köszönhetően a jogszabályok felülvizsgálata megkezdődött. Ennek keretében új rendelet lépett hatályba, illetve már hatályos jogszabályok egészültek ki.

A hatályos hazai jogszabályok nem tesznek különbséget az ellenőrzött terület sugárvédelmi szempont alapján történő felosztásban. Ugyanakkor a nemzetközi ajánlásokban, valamint az egyes országok által alkalmazott gyakorlatokban megjelennek erre vonatkozóan követelmények. Ennek oka az eltérő reaktor típus alkalmazása és az adott nemzet kultúrája közötti eltérésekben rejlik.

Hazánkban a gyakorlatok felülvizsgálatának nagy szerepe lehet a tervezett atomerőmű bővítés kapcsán. A jelenlegi tervek szerint két orosz tervezésű, nyomott vizes blokkot létesítenek, így a tervek benyújtása előtt érdemes lehet felülvizsgálni az alkalmazott gyakorlatokat.

A cikk célja, hogy bemutassa a különböző zónákat, vagyis a területek felosztását. Ez segíthet a tervek felülvizsgálatában, valamint a jogszabályok, esetleg hatósági útmutatók fejlesztésében is.

***Kulcsszavak:** sugárvédelem, ellenőrzött terület, atomerőmű*

A kézirat benyújtásának dátuma (Date of the submission): 2018.10.07.
A kézirat elfogadásának dátuma (Date of the acceptance): 2018.12.12.

INTRODUCTION

Protecting workers and preventing the release of radioactive contamination into the environment is the most important task of the radiation protection in nuclear power plants (hereinafter: NPP). The boundaries of the controlled area and the classification of areas within the controlled area should be defined so as to be able to supply that purposes.

In our country, four VVER type NPP blocks are operating and two others are planned to be constructed. Due to that, the necessity to determine the classifications of the controlled area is a topical issue. In the planning phase the classification must be prepared that the applicable technical rules can be implemented therein.

In our article we present the possibilities of defining the controlled and supervised area, such as through recommendations from international organizations and examples of international practices, and then we show the classification of the rooms of controlled area. In most countries, the controlled area appears in a certain level of legislation, while the authorities are advised to divide it into a guide, but the most typical are that they do not make a recommendation for dividing, just they review it during the licensing.

Classification of rooms it may be one of the most important aspects to protect workers, because the classes can help to choose correctly the personal protective equipment and it can help to indicate the extent to which the restriction of stay is required. Mostly, the base of the order the restriction of stay in the room is the dose rate while the extent of surface contamination can be used to order personal protective equipment.

DEFINITIONS OF THE CONTROLLED AND SUPERVISED AREAS

In the nuclear industry we can find several different recommendations related to the classification of the controlled and supervised area.

International Atomic Energy Agency (hereinafter: IAEA) prescribes for the employers, registrants and licensees to establish and maintain controlled and supervised areas, to monitor the radiation protection of the workplace.

In the controlled area specific measures are required to prevent and control the spread of contamination under normal operation and the likelihood and the magnitude of exposures in accident conditions. Controlled areas required to be restricted with even structural boundaries to provide that the radiological conditions meet the relevant requirements. Each facility should minimize the number and size of their controlled areas.

IAEA define supervised area as, where occupational exposure needs to keep under review, even though specific measures are not necessary. Delineation of radiological areas with potential exposures beyond 6 mSv/year effective dose. [1]

The European Nuclear Society classifies the areas of radiation protection into three different level based on the radiation exposure (effective dose).

Monitoring areas are in which persons may receive an effective dose of more than 1 millisievert or organ doses higher than 15 millisievert for the eye lens or 50 millisievert for the skin, hands, forearms, feet and ankles in a calendar year.

In controlled areas persons may receive an effective dose of more than 6 mSv or organ doses higher than 45 millisievert for the eye lens or 150 millisievert for the skin, hands, forearms, feet and ankles in a calendar year.

The third category, which is introduced is the Exclusion area, which is a part of the controlled areas where the local dose rate may be higher than 3 mSv per hour. Controlled areas and exclusion areas are to be fenced off and marked permanently and be clearly visible. [2]

ZONES OF THE CONTROLLED AREA

Different nations use different ways to divide the controlled area of an NPP into zones with radiologically aspect, in addition, this division may depend on the type of the NPP. In the following, we want to show you what opportunities you can find in the international practices.

Recommendation of IAEA

In the nuclear power plant rooms should be classified into planning zones on the basis of their likely dose rates, surface contamination levels and concentrations of airborne radionuclides. These zones constitute the controlled areas. The general practice is to divide the controlled areas of a NPP into three or more radiation and contamination zones, including zones that may not be accessible during operation. [3] The zoning should be consistent with national legislation and regulatory requirements.

The greater the radiation or contamination related risks of a zone, the greater is the need for access requirement and specific requirements such as the need to separate safety trains.

The document also gives two examples of classification criteria used in the design phase. The first is a recommendation, the second one contains the rules, which are used in the Forskmark NPP.

Access requirement	Design dose equivalent rate (μSv/h)	
	Mean	Maximum
Uncontrolled areas on-site	-	1
Continuous (> 10 person-hours per week)	1	5
1–10 person-hours per week	10	50
< 1 person-hours per week	100	500
1–10 person-hours per year	1000	10000
< 1 person-hours per year	10000	[1]

1. table: Example of radiation zoning that may be used for design purposes [3]

Zone identification	Blue zone	Yellow zone	Red zone
Radiation zones	<25 μSv/h	25-1000 μSv/h	>1000 μSv/h
Surface contamination zones	For total β < 40 kBq/m^2	40-1000 kBq/m^2	>1000 kBq/m^2
	For total α < 4 kBq/m^2	4-100 kBq/m^2	>100 kBq/m^2
Zones for airborne contamination	1 DAC[2]	1-10 DAC	>10 DAC

2. table: Classification of zones within the controlled area in Swedish NPP [3]

[1] Dose rates in excess of 10 mSv/h are acceptable provided that the exposure time is correspondingly short.
[2] DAC: derived air concentration.

EXAMPLES ON THE CLASSIFICATION SUPERVISED AREAS AND ZONES

Classification of the controlled and supervised areas in Finland

The Radiation and Nuclear Safety Authority (STUK) in Finland if the effective dose exceed 1 mSv or the equivalent dose to an eye 15 mSv or the equivalent dose to hands, feet or skin 50 mSv per year, then the area shall be defined at least as a supervised area. Where the external radiation dose rate may exceed a value of 3 μSv/h or where a 40 hour weekly stay may cause an internal radiation dose exceeding 1 mSv per year, shall be defined as a controlled area. Limit values set for surface contamination as well as limits when leaving the controlled area are presented in Table I. [4]

Radioactive subtances	Workplace and tools	Workers	
	Lowest zone of controlled area Bq/cm^2	Clothes Bq/cm^2	Skin Bq/cm^2
Alpha emitters (radiotoxicity class 1)	0.4	0.4	0.2
other nuclides	4	4	2

3. table: Limit values for surface contamination in nuclear facilities

Categorization of the controlled zones in Finland

In Finland authority recommends, that the rooms in the controlled area shall be divided into zones based on external dose rate, surface contamination and airborne radionuclide concentration. In case of these limits are locally exceed the recommendations of the guidance in question is restricted by access barriers and visibly marked with signs indicating the radiation situation, potential stay limitations and the protective equipment required. Exceptional radiation sources shall be visibly marked. Based on the following table, there shall be at least three rooms. [5]

	External dose rate	Surface contamination (surface activity)	Derived Air Concentration (DAC)
Zone 1	≤ 25 μSv/h	Beta emitters ≤ 4 Bq/cm² Alpha emitters ≤ 0,4 Bq/cm²	≤ 0.3 DAC
Zone 2	25 μSv/h - 1 mSv/h	Beta emitters 4 - 40 Bq/cm² Alpha emitters 0.4 - 4 Bq/cm²	0.3-30 DAC
Zone 3	≥ 1 mSv/h	Beta emitters ≥ 40 Bq/cm² Alpha emitters ≥4 Bq/cm²	≥ 30 DAC

4. table: Recommended zone classification of a nuclear facility in Finland [5]

Classification of the controlled and supervised areas in United Kingdom

In the regulation of the United Kingdom (hereinafter: UK), the Ionising Radiations Regulations 1999 defines the controlled and supervised area.

The regulation defines controlled area, where any employee is likely to receive an effective dose greater than 6 mSv a year, in supervised area the limit is 1 mSv a year, in respect of an employee aged 18 or above. [6]

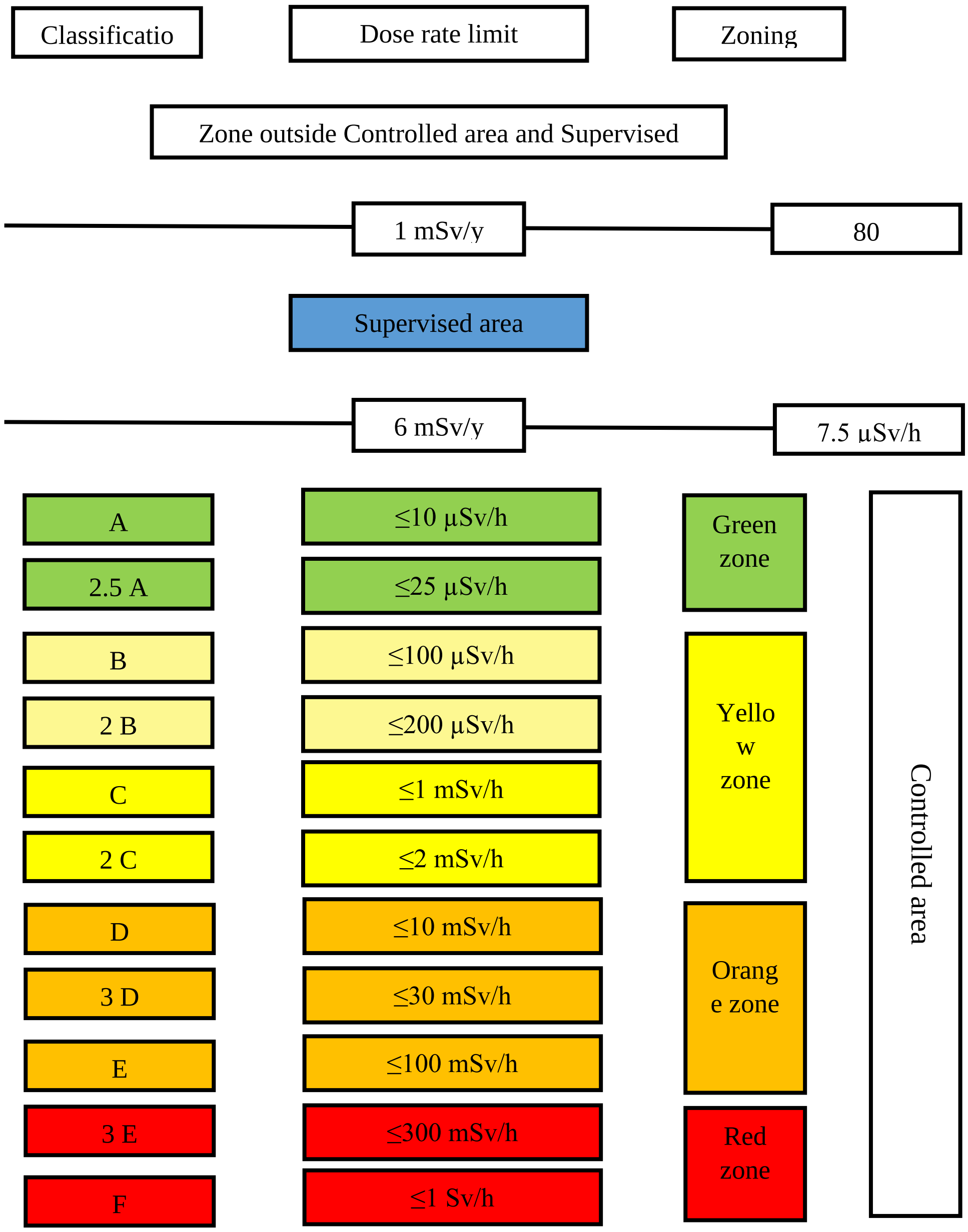
In the United Kingdom, the local regulator (Office for Nuclear Regulation, hereafter: ONR) published a guide document, which is contain regulations of the controlled and supervised area. [7]

Practices from the UK to classify the controlled zones

In the UK there are several nuclear reactors in operation and are under construction. All of them is given the basis of the principles to divide the premises of the controlled zone.

The legislation of the UK requires that the designated areas should be further divided where appropriate, with associated controls, to restrict exposure and prevent the spread of radioactive material. It also says that the further division of designated areas should be based upon the levels of radiation, contamination and airborne activity, measured and/or expected as a result of planned work activities within normal operations. (Safety Assessment Principles for Nuclear Facilities) [8]

The French regulatory classification for using to the EPR reactors we can find in the generic design assessment of AP1000. See in the 1. figure. [9]



1. figure: This is the French regulatory classification. It is likely to change depending on the final zoning limits used by the operator for the UK EPR [9]

In June 2006, the UK's Health & Safety Executive, which licenses nuclear reactors, suggested a two-phase licensing process similar to the process in the United States of America (hereinafter: USA). The first phase is the generic design assessment process. Considering third-generation reactors, a generic design authorisation for each type will be followed by site- and operator-specific licences. Phase 1 would focus on design safety and take around three years to complete, while phase 2 is site- and operator-specific and would take around 6-12 months.

For now, the generic design assessment of Areva UK EPR (December 2012) and Westinghouse AP1000 (March 2017) are completed and the generic design assessment of Hitachi-GE ABWR (due December 2017) and CGN HPR1000 (due 2021) are under way. [11]

The dividing system, which is used for the AP1000 reactor is very similar to the system of the French EPR, but with fewer allocations being used. The classification used for the AP1000 is shown in the following Table. [12]

Designation	Maximum Design Dose Rate	Access	Typical UK Area Designation Arrangements
0	≤0.5 μSv/h	Unlimited general occupancy	Undesignated area
I	≤2.5 μSv/h	No restriction on access	Supervised area
Restricted Radiation Zones			
II	≤25 μSv/h	Occupational access	Further subdivision for normal operations Areas >2.5 μSv/h subject to limits on continuous occupancy
III	≤150 μSv/h	Periodic access	Access restricted to 1 to 10 hours per week
IV	≤1 mSv/h	Limited access	Access restricted to <1 hour per week
V	≤10 mSv/h	Controlled access	Access restricted to a few hours per year at most
VI	≤100 mSv/h	Normally restricted	Post-accident: limited No access during normal operations Limited post-accident access
VII	≤1 Sv/h	Normally severely restricted	Post-accident: restricted No access during normal operations Very limited post-accident access
VIII	≤5 Sv/h	Normally inaccessible	Post-accident: severely restricted No access during normal operations Extremely limited post-accident access
IX	>5 Sv/h		No access

5. table: Westinghouse's AP1000 Zoning Criteria for Radiation [12]

The classification based on to the surface contamination, as shown on the following table.

Classification	Surface Contamination Bq.cm^{-2} βγ	Airborne Activity Derived Air Concentration (DAC)	Typical Area
White	<4	<0.01	Non-active areas
Green	Usually <4	<0.03	Most of the RCA during normal operations.
Amber	Possibly >4	<0.1	Some parts of containment during shutdown e.g., around SGs and Reactor Vessel Closure Head (RVCH) stand.
Red	>4 expected	>0.1	Flask pit before and during decontamination Vessel and pump rooms during breach of containment.

6. table: Westinghouse AP1000 Zoning Criteria for Contamination [12]

In the UK there is an Advanced Boiling Water Reactor is under construction, where the classification of the workplace differs from the previously introduced practice. The classification which will use to divide the workplaces is demonstrated in the following table.

Radiation Zone				
Designation		Radiation Level μSv/h		Minimum Acceptable Range μSv/h
Undesignated	R0	<2.5		$10^{-1} – 10^{2}$
Supervised	R1	2.5-7.5		$10^{-1} – 10^{4}$
Controlled	R2	7.5 - $5x10^{1}$		$10^{-1} – 10^{4}$
	R3	$5x10^{1}$ - $5x10^{2}$		$1-10^{4}$
	R4	>$5x10^{2}$		$10-10^{4}$

7. table: Minimum acceptance range for installed radiation monitoring equipment for each radiological zone. [13]

The HPR1000 is a pressurised water reactor (PWR) that has been developed by CGN, which is a Chinese company with over 30 years' experience of designing, constructing and operating nuclear power stations. The controlled areas of the HPR1000 are divided into different sub-zones to facilitate management, the radiological protection management and occupational radiation exposure control. For HPR1000 (FCG3), the controlled area is subdivided in 4 sub-zones indicated by colours as follows:

a) Green zone: sub areas corresponding to lowest dose rates (up to 10 μSv/h).
b) Yellow zone: sub areas with controlled access, medium irradiation risk, special radiation protection dispositions are required. The maximum dose rate is 1 mSv/h.
c) Orange zone: these areas are exceptional access areas, with high irradiation risks. Any access requires special authorisation, with special radiation protection dispositions. The maximum dose rate is 100 mSv/h, or can rapidly increase to reach these values.

d) Red zone: access to these areas is usually forbidden. These areas are demarcated by a warning beacon and are separated from other areas by physical barriers (e.g. walls, doors).

For HPR1000 (FCG3), the above 4 sub-zones are further subdivided according to the dose rate of rooms, known as the room radioactive classification. The classification of radiation zones for HPR1000 (FCG3) is presented in 8. table. [14]

Designation	Dose Rate Limit	Zoning
Undesignated area		
---	≤0.5 μSv/h	
Supervised area		
---	≤2.5 μSv/h	White
Controlled area		
A	≤10 μSv/h	Green zone
2.5A	≤25 μSv/h	Yellow zone
B	≤100 μSv/h	
2B	≤200 μSv/h	
C	≤1 mSv/h	
2C	≤2 mSv/h	Orange zone
D	≤10 mSv/h	
3D	≤30 mSv/h	
E	≤100 mSv/h	
3E	≤300 mSv/h	Red zone
F	≤1 Sv/h	
3F	≤3 Sv/h	
G	>3 Sv/h	

8. table: Classification of Radiation Zones in HPR1000 (FCG3) [14]

A similar example on that is the distribution of the Sizewell PWR reactor, which is introduced on the following table. [15]

Radiation Zone		
Designation		Radiation Level μSv/h
Supervised	R1	0.5-3
Controlled	R2	3-50
Controlled	R3	50 - 500
Controlled	R4	>500

9. table: Classification of radiation zones in Sizewell PWR [15]

The controlled area is divided according to the value of the surface contamination into 3 different groups. [15]

A contamination controlled “area C2” shall be designated where the loose contamination level averaged over an area not exceeding 1000 cm^2 (floor or ceiling) or 300 cm^2 (other cases), exceeds or may exceed the following values:

Contamination controlled area (C2):

> 0.2 $Bq.cm^{-2}$ (Ac-227, U-232, Am, Cm, Cf, Pu, Th)
> 0.4 Bq. cm^{-2} (Pb-210, Ra-228, and alpha emitters)
> 4 Bq. cm^{-2} (other radionuclides)
> 40 Bq. cm^{-2} (C-14, S-35, Cr-51, Mn-54, Fe-55, Ni-63, or, tritium contamination level
> 10,000 Bq. cm^{-2} (or that could result in effective dose higher than 0.5 mSv). [15]

In the contamination controlled area C3 airborne contamination levels for designation exist for each specific radionuclides (generally, C3 level corresponds to more than 0.01 DAC). The general values (lower air activity) 0.01 $Bq \cdot m^{-3}$ for alpha emitters, and 10 $Bq \cdot m^{-3}$ for beta emitters. If possible, the access to C3 areas is restricted with physical barriers and an Accredited Health Physicist decides, on a case-by-case basis, what kind of suits or respiratory protective clothing has to be worn.

In Sizewell NPP the rooms of controlled area are also classified according to surface contamination and radiation conditions.

Classification of areas in the USA

In the USA, the regulator of the nuclear safety the Nuclear Regulatory Commission (hereinafter: NRC) applies the classification of high radiation and very high radiation area. [16]

Into the high radiation area the accessibility of the individuals may receive a dose equivalent of 0.1 rem (1 mSv) in 1 hour at 30 centimetres from the radiation source or 30 centimetres from any surface. Very high radiation area the receiving absorbed dose could exceed of 500 rads (5 grays) in 1 hour at 1 meter from a radiation source or 1 meter from any surface. [3]

In case of high radiation area the licensee has to ensure that, the entrance of the area has to have a control device, with visible and audio alarm signal or has to be locked, except during periods when access to the areas is required.

In case of the very high radiation areas, the licensee shall institute additional measures to ensure that an individual is not able to gain unauthorized or inadvertent access.

The regulation also prescribe posting requirements in the areas.[4]

Classification of areas in Hungary

In their article [17] Sebestyén at all have presented the current structure of the Hungarian legal system, and justified that the regulation of radiation protection appears in several laws for nuclear facilities.

On the top level, the Act on Atomic Energy [18] regulates the general issues of the peaceful use of atomic energy. The second level of the regulation are the governmental and ministerial decrees. Such governmental regulations are the Govt. decree 118/2011 (VII. 11.) and its annexes, the Nuclear Safety Codes (hereinafter: NSC) [19] and Govt. decree 487/2015 (XII.30) [20], which contains radiation protection requirements.

The Hungarian legislation requires in two different decrees that the controlled and supervised area have be assigned. The applicable rules in the controlled area are laid down in the NSC and in the Govt. decree 487/2015. also. The classification under the two regulations is essentially the same, they do not contradict each other. There are historical reasons for

[3] (Note: At very high doses received at high dose rates, units of absorbed dose (e.g., rads and grays) are appropriate, rather than units of dose equivalent (e.g., rems and sieverts)).
[4] "CAUTION, HIGH RADIATION AREA" or "DANGER, HIGH RADIATION AREA." and "GRAVE DANGER, VERY HIGH RADIATION AREA."

discrimination, before 2016 radiation protection supervision was provided by another authority than the surveillance of the nuclear safety. The legislation has been developed accordingly. The site of the facility should be divided controlled, monitored and free zones, taking into account expected and measurable dose rates and radioactive contamination, as well as the expected doses.

Controlled zones are areas under the effect of special regulations including radiation protection specifications due to potential irradiation or contamination by radioactive material. Entering or exiting the area should be monitored.

Licensees should designate supervised areas and inside them controlled areas in a given radiation hazardous workplace or work area, where appropriate, on the basis of an assessment of the expected annual doses and the probability and magnitude of potential exposures.

The purpose of the controlled area is the protection against ionising radiation or preventing the spread of radioactive contamination and to which access is controlled;

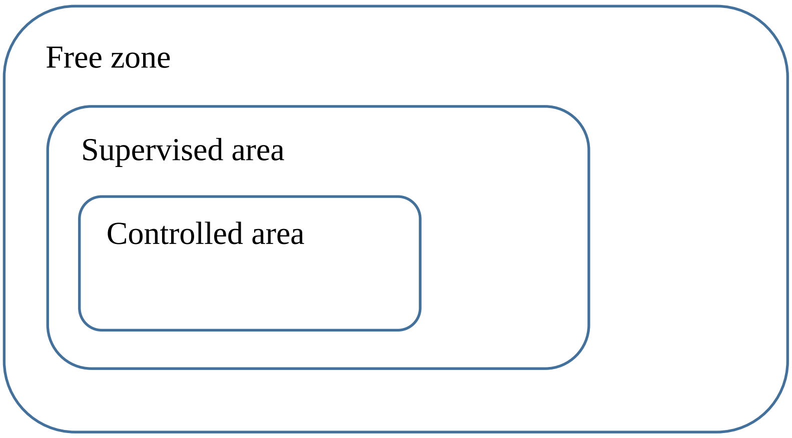
The designation of supervised and working areas shall be regularly reviewed and if the radiation protection related changes occur.

The use of atomic energy shall regularly review the working conditions in controlled and supervised areas.

The work area shall be designated as a controlled area where the annual individual dose from the practice may exceed 1 mSv effective dose, 15 mSv for the lens of the eye or where the dispersion of radioactive contamination or the probability of potential exposure shall be controlled.

Under normal circumstances, the special radiation protection provisions and safety rules determined shall not be applied in a supervised area.

For the better understanding the Hungarian requirements the following figure demonstrates the positions and arrangements of the free zone, supervised area and controlled area to each other.



2. figure: site of the facility, divided to controlled, supervised and free zones

The classification of the controlled rooms

In Hungary the Gov. decree for nuclear safety regulate that rooms within the controlled zone must be classified in nuclear power plants but do not specify their aspects. The decree require that access should be restricted and that the rooms or the places at risk of exposure should be marked by the person entering the room to know the conditions to be counted. [19]

In our country, before the HAEA would have received the scope of the radiation protection, the HAEA has prepared a guide for the requirements of technical radiation protection with entitled "Technical Radiation Protection and Radioactive Waste Management in the Operation of Nuclear Power Plants". The guide stipulates that the licensee must classify the rooms of controlled zone according to the prevailing or expected radiation situation in three classes as follows: [21]

- Class I: unmanageable rooms. In addition to operating the reactor block, access to these rooms is not possible at all or can only be enhanced with intensified radiation protection.
- Class II: restricted areas. In these rooms, staff can enter with time limitations according to the actual level of dose or contamination.
- Class III: manageable rooms. With the applied protection allows employees to spend their entire working hours in the rooms.

The guide has expired since then, so there is no detailed requirement to classify the rooms.

The radiation protection requirements are currently in 487/2015. Government Decree. Prior to the entry of the 487/2015. governmental decree, the radiation protection requirements were in the Ministerial Decree 16/2000 (VI. 8.) of the Minister of Health on the Implementation of Certain Provisions of the Act CXVI of 1996 on Atomic Energy and before it the Ministerial Decree 7/1988 (VII. 20.) of the Minister of “SZEM” on the Implementation of Certain Provisions Ministerial Decree 12/1980 (IV. 5.) of (MT) on the Implementation of Certain Provisions of the Act I of 1980 on Atomic Energy. [22] [23]

The Paks NPP uses 3 classes to classify the premises of the controlled area and the values of each category were developed according to the requirements of a previous regulation. By the Annex 10 of the of the Act I of 1980 on Atomic Energy, the rooms of the controlled zone, dose-equivalent rate performances arising from external radiation to be considered in planning in a limited manageable room group of under 28 μSv/h and in a freestanding room group is under 14 μSv/h.

CONCLUSIONS

In our article, we have presented several practices to classify the controlled area in nuclear power plants.

There may be relatively large differences between each exercise, but there are some commonalities too. The licensees have to establish and maintain a clear and achievable regulation to classify the workplace of the NPP. The classification of the areas and zones are usually based on the typical dose rate and the surface contamination of the area. They have to preventing unauthorized entry to the controlled areas or to the area of the NPP and monitor the radiation conditions.

In our country similarly to the Finnish example, the rooms should be divided into 3 groups. In other countries, like in the UK or apply much more classes to differentiate the areas and zones. However, the large number of categories have advantages and also disadvantages. The classification can be relatively straightforward in case of small number of categories, the measures required for review may be more easily implemented, but much less information is available from the room. If we use a large number of groups, reviewing may be cumbersome, as it is easier to change the room category and more frequent reclassification may be required, which makes the registration of the room categorization more difficult. At the same time, the category can provide more information about the state of the room, and the design of the work can be done more accurately.

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