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A Study on Establishment of Unacceptable Radiological Consequence (URC) for Physical Protection against Sabotage

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1. Introduction

The collapse of the Soviet Union, the September 11 terrorist attacks in 2001 and Fukusima nuclear accident in 2011 served as a catalyst for reinforcement of the international physical protection & nuclear security regime. In early stages, physical protection measures focused only on unauthorized removal of nuclear material. But after such events, the international community has started to strengthen physical protection against sabotage as well as the unauthorized removal of nuclear material.

The international community has recommended that a graded approach should be applied to the establishment of the domestic regime for physical protection in accordance with fundamental principle H [1)] of the amended Convention on Physical Protection of Nuclear Material (CPPNM) and INFCIRC/225/rev.5.

In Korea, Currently, the graded approach to unauthorized removal of nuclear material is divided into three categories (CategoryⅠ, CategoryⅡ, CategoryⅢ) based on the IAEA INFCIRC/225/rev.5. Moreover, depending on the categorization of nuclear material, physical protection measures against unauthorized removal are also clearly categorized. But in the case of physical protection against sabotage, the graded approach to the physical protection measures is not applied since Unacceptable Radiological Consequence (URC) for identifying sabotage target & level is not determined.

URC can be established based on either dose limit or design limit. The report by Sandia National Lab. in USA specifies that core damage is used for URC. Calculation of an exact dose is based on various assumptions and processes and subsequently increases uncertainty. Therefore, using design limit for decreasing uncertainty is more effective than using dose limit.

In order to apply the graded approach to physical protection against sabotage, we have taken into consideration legal and institutional standards on domestic and international radiological consequences and intended to provide a reference for the URC establishment by the State.

1) Fundamental principle H : Physical protection requirements should be based on a graded approach, taking into account the current evaluation of the threat, the relative attractiveness, the nature of the material and potential consequences associated with the unauthorized removal of nuclear material and with the sabotage against nuclear material of nuclear facilities

2. Dose Limit

2.1 Domestic Criteria

For protection against sabotage, the State should establish its threshold on radiological consequences in a threat situation.

In terms of safety, consideration is taken into radiological consequences from accident by human error and natural disaster. Meanwhile, radiological consequences have same biological effect over human bodies whether it is caused by a safety accident or a security incident. Therefore, the URC value of physical protection should not be different from that of nuclear safety. Nor should there be conflicts between the two areas in setting such value. We reviewed radiological consequences in safety area that is being applied in Korea.

First, Article 2 of the Nuclear Safety Act enforcement decree defines ‘Exclusion Area’. ‘Exclusion Area’ means the area in the vicinity of the radiation control area and the preservation area, where the exposed radiation dose is feared to exceed the level prescribed by the Nuclear Safety and Security Commission (NSSC). Moreover, Korea Institute of Nuclear Safety (KINS) defines an exclusion area of such size as that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product release would not receive a total radiation dose to the radiation dose to the whole body in excess of 25 rem or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure in technical standard of site criteria [1].

Secondly, Article 23 of Act on Physical Protection and Radiological Emergency (APPRE) and Article 25 of the APPRE enforcement decree define standards for declaration of a radiological disaster. Standards for declaration of a radiological disaster is those cases when the radiation exposure quantity is not less than 1 rem per hour on the basis of whole-body dose and 5 rem per hour on the basis of thyroid dose. This exposure quantity read on the boundary of the site of nuclear facilities [2].

Finally, Article 15 of the APPRE enforcement regulation defines standards for determination of urgent public protective actions. The overall protective action is shown in table I [2].

Table 1. Standards for Determining Sheltering, Evacuation, Iodine Prophylaxis, Distribution, etc.

Urgent Public Protective Action	Determination standards
sheltering	10mSv
evacuation	50mSv
Distribution of Iodine Prophylaxis	100mGy
Temporary relocation	30mSv/first one month, 10mSv/next one month
Permanent settlement	1Sv/lifetime

2.2 Overseas Criteria

In order to obtain the data about URC, we studied the case of USA. First of all, USA set 0.1rem for the URC. KINAC held the meeting with NRC on May 7, 2013 and was able to verify that the US used 0.1 rem for URC which, according to NRC, was conservatively established value as the public dose limit during ordinary times. We further looked for other radiological values in the US legislation and were able to find out that 10 CFR is commonly used as a reference for analyzing radiological consequence.

There were similarities in descriptions between the US 10 CFR 50 and the Korean legislation. Table II summarizes the radiological values which are defined in 10 CFR [3].

Table 2. An Analysis of Acceptable/Unacceptable Consequence Values

	Contents
10 CFR 50.67 10 CFR 100	Alternate source term Design Basis Accident 5 rem in the control room during length of the accident(100% first 24hours, 60% 1-4 days, 40% 4-30 days) 25 rem at the edge of the exclusion area boundary (EAB) for any individual-2hour exposure
Emergency Planning	1 rem whole body, 5 rem thyroid for evacuation (dose rate projected over the duration of the accident)

Secondly, we obtained the URC data from a report produced by the Sandia National Lab., USA [4]. According to this report, there are two basic approaches for defining URC. The first approach is that URC is established for nuclear safety analysis wherein these consequences are defined by establishing prescribed and acceptable limits for radiation does or releases for various categories of the events. Similarly prescribed and acceptable limits for radiation doses and releases can be established for malevolent acts. The second approach for defining URC is based upon a safety analysis that ensures that design limits are met under postulated accident conditions. URC can also be operationally defined as a situation in which design limits are exceeded. It is important to take malicious acts into consideration in identifying URC. In the case of safety, malicious acts are not included in determining design limits.

Finally, we were able to find the URC data from Department of Homeland Security (DHS), Federal Emergency Management Agency (FEMA), Environmental Protection Agency (EPA) in USA. They are using this data for protective actions against nuclear incidents.

The Manual of Protective Action Guides and Protective Actions for Nuclear Incidents published by EPA provides estimated average cancer mortality risks for emergency workers exposed to a whole-body dose equivalent of 25 rem [5]. The details is shown in Table III, as a function of age at the exposure time.

Table 3. Approximate cancer Risk to Average Individuals from 25 rem Effective Dose Equivalent Delivered Promptly

Age at Exposure(years)	Appropriate risk of premature death (deaths per 1,000 persons exposed)	Average years of life lost if premature death occurs (years)
20 to 30	9.1	24
30 to 40	7.2	19
40 to 50	5.3	15
50 to 60	3.5	11

The DHS, FEMA, EPA are documented and disseminated ‘guidance on dose limits for workers performing emergency services’ based on research. Table VI summarizes the emergency action dose guideline which is defined in guidance.

Table 4. DHS/FEMA and EPA Emergency Worker Dose Guidelines [5]

Dose limit (whole body)		Emergency Action Dose Guidelines Activity performed
5,000mrem	5rem	All activities
10,000mrem	10mrem	Protecting major property
25,000mrem	25rem	Lifesaving or protection of large populations
More than 25,000mrem	More than 25rem	Lifesaving or protection of large populations, Only by volunteers who understand the risks

3. Design Limit

We referred to the safety analysis report in order to investigate design limit of the Korea nuclear power plants. The document provided success criteria for mitigating initiating event. When such criteria are not met, events and accidents occur.

Such criteria are as follows;

First, Departure from Nucleate Boiling Ratio (DNBR) should be no more than 1.3. Second, reactor coolant system pressure should be less than 110% of design pressure and 193.33 kg/cm^2A (2,750 psia). Third, main steam system pressure should be less than 110% of design pressure and 98.2 kg/cm^2A (1,397 psia). Forth, peak linear heat generation rate should be no more than 689 W/cm (21KW/ft).

4. Results

The study on various standards led to the conclusion that each value has advantages and disadvantages respectively in setting URC.

In case of Korea, there are a lot of regulation objectives including use facilities of radioisotope. We consider three things in determining URC. First, we can apply URC to all nuclear facilities and regulation objectives. Secondly, there is no conflict with safety standards. Thirdly, there is some ground about biological effect caused by radiation.

If URC is determined at 25rem per 2 hours (whole body dose) in the exclusion area, then it is possible to apply this value to the all nuclear facilities. The value has an advantage that it has been already analyzed for the effects on the human body. And, there is no conflict with safety standards.

As mentioned above, many assumptions and processes needed for calculating the exact dose, which increases uncertainty. Therefore we should consider design limit for nuclear power plants to decrease such uncertainty. In other words, it is recommended that the State consider application of the two limits (dose and design) to critical nuclear facilities including nuclear power plants if possible. In such case, reference should be made to the safety analysis report for nuclear power plants.

Table 5. A Comparative Table for Defining URC

	Advantage	Disadvantage
25rem/2H in the EAB	-It can apply all nuclear facilities -It doesn't have any conflicts with safety -It has ground about consequence	-It has uncertainty from many assumption and process
Other radiological value	-It can apply all nuclear facilities -It doesn't have any conflicts with safety	-It doesn't have ground about consequence -It has uncertainty from many assumption and process
Design limit	-It has few uncertainty -It doesn't have any conflicts with safety	-It can apply only NPP
Hybrid between dose and design limit	-It can apply all nuclear facilities -It doesn't have any conflicts with safety -It has ground about consequence -It has few uncertainty	

Finally, URC is a very important factor for regulating nuclear facilities against sabotage. Therefore, the State should analyze radiological consequences of each nuclear facility and conduct in-depth discussions with nuclear facilities before establishing URC.

REFERENCES

[1] The Nuclear Safety Act, amended by Act No.11715, March 23, 2013

[2] The Act on Physical Protection and Radiological emergency, amended by Act No.11994, August 10, 2013

[3] 10 CFR 50

[4] SAND2004-2866, A Systematic Method for Identifying Vital Areas at Complex Nuclear Facilities, 2004

[5] EPA 400-r-92-001, Manual of protective action guides and protective actions for nuclear incidents, 1991