Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22-23, 2025

Review on the Designation of Radiation-Controlled Area in Nuclear Facilities

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Keywords : radiation-controlled area, external dose rate, radiation zone, fuel cycle facility

1. Introduction

The design of nuclear facilities requires stringent radiation protection measures to ensure the safety of workers and minimize exposure. A well-established radiation-controlled area (RCA) is essential for effective radiation management. This study focuses on the key criteria for RCA designation, particularly external dose rates, and aims to provide insights into implementing RCAs for new nuclear facilities.

By analyzing regulatory standards across different types of nuclear facilities, this research examines how dose rate thresholds are determined and compares them with international regulations. The findings will help establish a more systematic approach to RCA designation, ensuring both regulatory compliance and reasonable radiation safety management.

2. Relevant Legislation

The Nuclear Safety and Security Commission (NSSC) Regulation No. 50 on Technical Standards for Radiation Safety Management [1] defines the criteria for establishing RCA. According to Article 3, Section 1, an RCA must be designated if the external dose rate is liable to exceed 0.4 mSv per week. In addition to this dose-based criterion, airborne radioactive concentrations and surface contamination levels are also considered when determining RCA boundaries.

When converted to an hourly basis, the weekly limit corresponds to 0.01 mSv per hour, assuming a 40-hour workweek. In comparison, the United Kingdom's Ionising Radiations Regulations (IRR17) [2] require RCA designation when the external dose rate exceeds 0.0075 mSv per hour, averaged over the workday, indicating a more conservative approach. Meanwhile, U.S. regulations (10 CFR 20) [3] define a radiation area as one where an individual could receive a dose equivalent exceeding 0.05 mSv per hour at 30 cm from a radiation source. However, explicit RCA designation standards based on external dose rates are not clearly defined in U.S. regulations.

While external dose rates serve as the primary criterion for RCA designation, they are not the sole determining factor. It is standard practice to consider additional factors such as airborne contamination and surface radioactivity levels to ensure comprehensive radiation protection.

In Korea, RCAs in operational nuclear power plants (NPPs) are designated based on a combination of radiation dose rates, work hours, and required protective measures. All RCAs must comply with the As Low As Reasonably Achievable (ALARA) principle, aiming to minimize radiation exposure for workers. According to regulatory guidelines, individual radiation exposure should not exceed 100 mSv over five years and 50 mSv per year.

To ensure compliance, RCA boundaries are established by measuring maximum radiation levels at locations where ionizing radiation sources or contaminated surfaces are present, with measurements taken at a minimum distance of 30 cm from these sources. For example, Kori Unit 1 designates all areas as RCAs where external dose rates are expected to exceed 0.4 mSv per week and could significantly impact a worker’s principal body parts.

Additionally, working hours within RCAs are strictly managed to limit individual exposure. Since radiation environments vary across different nuclear facilities, RCA designation criteria differ accordingly, ensuring site-specific radiation safety measures are effectively implemented.

3. Review on RCAs at Nuclear Facilities in Korea

3.1 External Dose for RCAs

To evaluate the criteria for RCAs in domestic NPPs, we analyzed Final Safety Analysis Reports (SARs) from various facilities [4-19]. The analysis indicates that newer NPPs apply more conservative dose limits for RCA designation compared to older facilities.

For instance, the Hanul Units 1 and 2 reactors, which began operation in 1988 and 1989, follow European standards, setting an hourly dose limit of 0.0075 mSv for RCA designation. This threshold aligns with the European annual limit of 15 mSv for workers with a 2,000-hour work schedule per year. In contrast, reactors commissioned in the 2000s adopt stricter dose limits, reflecting a trend toward enhanced radiation protection. Table I presents a summary of dose rate criteria for RCA designation across different nuclear reactors.

Table I: Dose Rates Criteria for RCAs in Nuclear Reactors.

Reactors	Dose rate (mSv h^{-1})	Remark
Hanul Units 1 & 2	≥0.0075	Non-regulated control zone if less than 0.025 mSv h^{-1}
Kori Units 1, 3 and 4, Hanbit Units 1 and 2, and Hanul Units 3 and 4	≥0.005	
Kori unit 2	≥0.0025	
Shin-Kori Units 1 & 2, 3 & 4, and 5 & 6 Hanbit Units 5 & 6, Hanul Units 5 & 6, and Shin-Wolsong Units 1 & 2, Wolsong Units 1, 2, 3 & 4	≥0.001	More stringent criteria applied (Commissioned since 2000s)

To further examine RCA criteria in non-nuclear power plant facilities, we analyzed RCA standards at research reactors and spent fuel processing facilities operated by KAERI. The HANARO research reactor and its associated Irradiated Material Examination Facility (IMEF) apply a dose limit of 0.00625 mSv h^{-1}, while the Post-Irradiation Examination Facility (PIEF), a spent fuel processing facility, uses a less conservative standard of 0.01 mSv h^{-1} for RCA designation. Table II highlights these dose rate standards, showing that nuclear fuel cycle facilities generally have less stringent RCA limits compared to NPPs, with differences of at least a factor of one to ten. This comparison highlights that NPPs enforce stricter RCA criteria than research reactors or nuclear fuel cycle facilities, reflecting differences in radiation exposure risks and operational priorities.

Table II: Dose Rates Criteria for RCAs in Research Nuclear Reactor and Nuclear Fuel Cycle Facilities.

Facility	Dose rate (mSv h^{-1})	Remark
Post Irradiated Examination Facility (PIEF)	≥0.01	If NSSC rule applied (based on 40 hour workweek) [20] Nuclear fuel cycle facility (Nuclear Safety Act, Ch. IV, section 1) [21]
HANARO Research Reactor, Irradiated Material Examination Facility (IMEF)	≥0.00625	Research Reactor (Nuclear Safety Act, Ch. III, Section 3) [22]

3.2 Zoning within RCAs

The classification of sub-areas within an RCA can varies depending on the specific needs of each facility. Even NPPs may have different criteria for each site, but it is common to see a highly detailed classification system with six or more levels. Table III shows the radiation dose rate ranges for each RCA zone during normal operation of Shin-Kori Units 1&2 and 3&4, Hanbit Units 5&6, and Shin-Wolsong Units 1&2 [23]. Some examples of specific areas within each zone are shown in Table IV.

Even among NPPs, zoning criteria differ from site to site. However, most NPPs implement a detailed classification system with at least six levels. Table III presents the radiation dose rate ranges for each RCA zone during normal operation at Shin-Kori Units 1&2 and 3&4, Hanbit Units 5&6, Hanul Units 5&6, and Shin-Wolsong Units 1&2 [23]. Examples of specific areas categorized within each zone are listed in Table IV.

Table III: RCA zones in Shin-Kori Units 1&2, 3&4, Hanbit Units 5&6, Hanul Units 5&6, and Shin-Wolsong Units 1&2.

Zone	Description (allowed working hours)	Dose rate (mSv h^{-1})
1	Unlimited access	<0.001
2	Controlled access (40 h week^{-1})	0.001–0.01
3	Controlled access (8 h week^{-1})[a]	0.01–0.05
4	Controlled access (2 h week^{-1})[b]	0.05–0.2
5	Controlled access (0.5 h week^{-1})[c]	0.2–1
6	Restricted access (access permit required)[d]	1–10
7	Restricted access (access permit required)[d]	10–5000
8	Restricted access (access permit required)[d]	>5000

[a]8–40 working hours allowed for Shin-Kori Units 3 and 4.

[b]2–8 working hours allowed for Shin-Kori Units 3 and 4.

[c]0.5–2 working hours allowed for Shin-Kori Units 3 and 4.

[d]Radiation safety staff only for Shin-Kori Units 3 and 4.

Table IV: Examples of RCA Zones in Shin-Kori Units 1&2, 3&4.

Zone	Examples of Compartment
2	Truck bay
3	Normal discharge air purification unit room in the nuclear fuel handling area
4	Reactor building cooling water heat exchanger room
5	Waste water storage tank sump pump room
6	Nuclear fuel handling operating area
7	Purification filter room of the spent fuel storage pool
8	Spent fuel storage pool

Unlike NPPs, the research reactor HANARO and its associated facilities, IMEF, and PIEF use a simpler four-tier RCA classification system, as shown in Table V and VI.

Table V: RCA Zones in HANARO Research Reactor and IMEF.

Zone	Description (allowed working hours)	Dose rate (mSv h^{-1})
6000	Unlimited access	<0.00625
7000	Controlled access (40 h $week^{-1}$)	0.00625–0.0125
8000	Controlled access	0.0125–0.5
9000	Restricted access (access permit required)	>0.5

Table VI: Examples of RCA Zones in HANARO Research Reactor and IMEF.

Zone	Examples of Compartment
6000	General areas such as offices, truck bay
7000	Hot cell operation area
8000	Service areas, including the decontamination room
9000	The interior of the hot cells and pools

This simplified zoning system reflects the differences in operational radiation exposure risks between nuclear power plants and research reactors or fuel cycle facilities.

4. Conclusions

In nuclear fuel cycle facilities, the external dose limits for RCA designation are generally less stringent than those applied to modern NPPs. While newer NPPs often adopt a conservative threshold of 0.001 mSv h^{-1}, nuclear fuel cycle facilities typically set a higher limit of 0.00625 mSv h^{-1}. This discrepancy reflects differences in radiation exposure risks and operational priorities. Furthermore, NPPs implement a highly detailed, multi-level RCA classification system with up to seven zones, whereas research reactors and fuel cycle facilities use a more simplified three-level system. The less restrictive zoning approach in fuel cycle facilities likely stems from their relatively lower radiation hazards compared to nuclear power plants.

When establishing RCAs in new nuclear fuel cycle facilities, applying the same stringent dose limits used in NPPs may impose unnecessary radiation management burdens. Therefore, it is essential to set reasonable dose thresholds that comply with regulations while maintaining practical radiation protection measures.

A comprehensive approach to RCA designation should go beyond external dose rates to consider additional factors, such as airborne radioactivity and surface contamination levels, which may necessitate expanded control zones. Additionally, specifying dose limits for each RCA zone while taking permitted working hours into account is crucial. This zoning information can inform shielding design considerations such as wall thickness ultimately enhancing occupational radiation safety.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 53910-25).

REFERENCES

[1] Rules of the NSSC 50, Rule on Technical Standards for Radiation Safety Management, Article 3 (Radiation Controlled Area), 2023 (in Korean).
[2] Work with Ionising Radiation, Ionising Radiations Regulations 2017 (IRR17), Approved Code of Practice and Guidance, Health and Safety Executive, L121 (2nd ed.), 2018.
[3] 10 CFR Part 20, Standards for Protection Against Radiation, 2025.
[4] Korea Hydro and Nuclear Power. Kori Unit 1 Final Safety Analysis Report, Chapter 12 Radiation Protection. Revision 9. KHNP; 2019 (in Korean).
[5] Korea Hydro and Nuclear Power. Kori Unit 2 Final Safety Analysis Report, Chapter 12 Radiation Protection. Revision 9. KHNP; 2009.
[6] Korea Hydro and Nuclear Power. Kori Units 3 & 4 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2008.
[7] Korea Hydro and Nuclear Power. Hanbit Units 1 & 2 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 1999.
[8] Korea Hydro and Nuclear Power. Hanbit Units 3 & 4 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2018.
[9] Korea Hydro and Nuclear Power. Hanbit Units 5 & 6 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2018 (in Korean).
[10] Korea Hydro and Nuclear Power. Hanul Units 1 & 2 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2018.
[11] Korea Hydro and Nuclear Power. Hanul Units 3 & 4 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2016 (in Korean).
[12] Korea Hydro and Nuclear Power. Hanul Units 5 & 6 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2017 (in Korean).
[13] Korea Hydro and Nuclear Power. Shin-Kori Units 1 & 2 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2017 (in Korean).
[14] Korea Hydro and Nuclear Power. Shin-Kori Units 3 & 4 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2016 (in Korean).
[15] Korea Hydro and Nuclear Power. Shin-Kori Units 5 & 6 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2016.
[16] Korea Hydro and Nuclear Power. Shin-Wolsong Units 1 & 2 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2018 (in Korean).
[17] Korea Hydro and Nuclear Power. Wolsong Unit 1 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2013 (in Korean).

[18] Korea Hydro and Nuclear Power. Wolsong Unit 2 Final Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2017 (in Korean).
[19] Korea Hydro and Nuclear Power. Wolsong Units 3 & 4 Fin al Safety Analysis Report, Chapter 12 Radiation Protection. KHNP; 2018 (in Korean).
[20] Application for Facility Installation Approval of Spent Fuel Processing Facility, Chapter II Location, structure, equipment and experimental method of the facility, 2021 (in Korean).
[21] Nuclear Safety Act, Chapter IV, Section 1 Nuclear Fuel Cycle Business, 2024.
[22] Nuclear Safety Act, Chapter III, Section 3 Construction and Operation Research Reactor, 2024.
[23] S. Kim et al., A Methodology to Designate Radiation-Controlled Areas in Decommissioning Nuclear Power Plants, Energy Sci Eng., Vol.11, pp.3204-3214, 2023.