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Comparison and Evaluation of Domestic and Foreign Radiation Environmental Standards for Nuclear Power Plants

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Abstract. With the development of the nuclear energy industry and the increasing demand for environmental protection, the impact of nuclear power plant radiation on the environment has gradually entered the public view. This article combs the nuclear power plant radiation environmental management systems of several countries, takes the domestic and foreign management of radioactive effluent discharge from nuclear power plants as a starting point, analyses and compares the laws and standards related to radioactive effluents from nuclear power plants in France, the United States, China, and South Korea. In this paper, the management improvement of radioactive effluent discharge system of Chinese nuclear power plants has been discussed.

Keywords: Radiation environmental impact, dose limit, radioactive effluent

1. Introduction

In order to prevent the excessive release of radioactive materials into the environment and keep the dose of radioactive effluents being as low as reasonably achievable (ALARA), nuclear power plants have generally implemented multi-level radiation environmental control. The dose constraints of nuclear facility has been set under the dose limit for public exposure (1mSv). The study found that the dose constraints are generally set between 0.1 and 0.3mSv in the world. The differences in the control of radioactive effluent from nuclear power plants in various countries are mainly reflected in "Optimization interval" (0.01~0.3mSv/a), management ideas are also different.

In 1995, France abolished the overall requirements for radioactive effluent total discharge amount limits of nuclear power plants in the regulations, replaced by focusing on the control of radioactive effluents of each nuclear power plants, and reviewing and evaluating based on reactor types, power, and environmental factors. Proposing limits on total discharge amount and flow rate of radioactive effluent. The main idea of controlling radioactive effluent from nuclear power plants in the United States is dose management. Generally, there is no limit on the total discharge amount of radioactive effluent discharged from nuclear power plants, but controlling the discharge concentration. The radioactive effluent discharge management idea of China is similar to that of France. The "Regulations on Environmental Radiation Protection of Nuclear Power Plants" (GB 6249-2011) provides the overall requirements for the total discharge amount and discharge concentration of radioactive effluent from nuclear power plants. The National Nuclear Safety Administration (NNSA) sets total discharge amount limits of radioactive effluent from nuclear power plants.

The difference in the discharge limits of radioactive effluents is due to the differences in nuclear power plant radiation environmental regulations and standards. This paper takes the domestic and foreign management of radioactive effluent discharge from nuclear power plants as a starting point, compares the regulations and standards related to radioactive effluents from nuclear power plants in several countries, analyzes the management improvement direction of radioactive effluent discharge from nuclear power plants in China.

2. Dose limits and dose constraints

2.1. Radiation dose

Radiation dose refers to the amount related to the interaction of radiation and matter, which mainly includes absorbed dose, equivalent dose and effective dose. The absorbed dose refers to the average energy received by a unit mass matter of ionizing radiation, the unit is gray (Gy). the equivalent dose reflects the strength of biological effects caused by various rays or particles after being absorbed, the unit is sievert (Sv). The effective dose is the sum of the product of the average equivalent dose received by each organ or tissue and the corresponding tissue weighting factor when the radiation effect of human tissue or organ is considered as a random effect, in the case of whole body is subjected to non-uniform irradiation, the unit is Special (Sv).

2.2. Dose limits for public exposure

The dose limit for public exposure refers to a dose level established for certain practices (referring to occupational activities related to radiation, such as the nuclear industry) and activities that receive constant continuous exposure (such as public exposure related to the radioactive source). The consequences of public exposure above this level are considered unacceptable. The International Commission on Radiation Protection (ICRP) recommended in its publication No.60 (ICRP 60) that the dose limits for public exposure should be set at the boundary between "acceptable" and "unacceptable" [1].

International Atomic Energy Agency (IAEA) Safety Series No.115 "International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources" (IAEA BSS-115) stipulates that the annual dose limit for public exposure is 1mSv. In certain case, the maximum effective dose in a single year is 5mSv, the premise is that the average dose within five consecutive years does not exceed 1mSv, as shown in Table 1 [2]

Table 1. Dose limits for public exposure in IAEA BSS-115

Dose	Limits
An effective dose	1mSv, In special circumstances66, a higher value of effective dose in a single year could apply, provided that the average effective dose over five consecutive years does not exceed 1 mSv per year.
An equivalent dose to the lens of the eye	15 mSv in a year
An equivalent dose to the ski	50 mSv in a year

The international regulations on individual dose limits for public exposure are basically the same. The individual dose limits for public exposure set by IAEA and ICRP are generally included in their respective environmental protection regulations or mandatory standards. For example, the French "Public Health Code" R.1333-11 stipulates that the annual effective dose limit for the public exposure due to nuclear activities is 1mSv [3]. The United States Code of Federal Regulations 10 CFR Part 20 stipulates that the total effective dose of individuals within one year cannot exceed 0.1 rem (1 mSv). In 2002, China issued the "Basic Standards for Ionizing Radiation Protection and the Safety of Radiation

Sources" (GB18871-2002), equivalently adopting IAEA BSS-115, and stipulating that the individual annual effective dose limit is 1mSv [4].

2.3. Dose constraints

According to the recommendations of ICRP and IAEA, the optimization of radiation protection should further constrain dose limits for public exposure generated by practices or sources. Therefore, it is necessary to set a dose constraint value when designing and operating a radioactive discharge system. Its function is to leave a margin for the doses produced by global sources and exempt sources while setting an upper limit for the practice or operation of the source under consideration, especially the possible dose of its radioactive discharge. The ICRP publications recommend that the maximum constraint value used in the optimization analysis of a single source for radiation protection should be less than 1 mSv and not greater than 0.3 mSv per year [5].

Many countries have established dose constraints. As shown in Table 2, the dose constraints of nuclear fuel facilities in these countries are generally set between 0.1 and 0.3 mSv, and most of them are around 0.3 mSv. "Regulations on Environmental Radiation Protection of Nuclear Power Plants" (GB 6249-2011) of China requires that the annual effective dose of radioactive materials released by all nuclear power reactors at any site to anyone in the public must be less than 0.25mSv [6].

Table 2. Radioactive dose limit values of several countries [7]

Country	Dose constraint(mSv/a)	Source
Argentina	0.3	Nuclear fuel cycle facility
Belgium	0.25	nuclear reactor
China	0.25	Nuclear Power Plant
Italy	0.1	Pressurized water reactor
Luxembourg	0.3	Nuclear fuel cycle facility
Korea	0.25	Nuclear Power Plant
Netherlands	0.3	Nuclear fuel cycle facility
Czech Republic	0.25	Nuclear Power Plant
Spain	0.3	Nuclear fuel cycle facility
Sweden	0.1	Nuclear power reactor
Ukraine	0.08	Nuclear power reactor
United Kingdom	0.3	Nuclear fuel cycle facility
United States	0.25	Nuclear fuel cycle facility
Hungary	0.09	Nuclear Power Plant

2.4. Radiation protection dose interval

In the public radiation protection system, the dose limits for public exposure are regarded as the upper limit. According to IAEA BSS-115 and the "Application of the Concepts of Exclusion, Exemption and Clearance" (No.RS-G-1.7), Individual effective doses for public exposure of 10 μSv or less per year are exempted doses., and this value is regarded as the lower limit [2, 8].

Based on the internationally accepted "upper and lower limits" and dose constraints, the dose interval for radiation protection of nuclear power plants can be established, as shown in Figure 1. From the exempt value to the value of dose constraint is called the "optimization interval", which is the main concern interval for further radiation environmental impact reducing of nuclear power plants. After the value of dose constraint is set, it will not be associated to the operation of the facility. Instead, the approved discharge limit will be selected as the optimized result and used as the actual limit in operation. When setting discharge limits, it is necessary to leave a margin of flexibility for the operation of nuclear power plants.

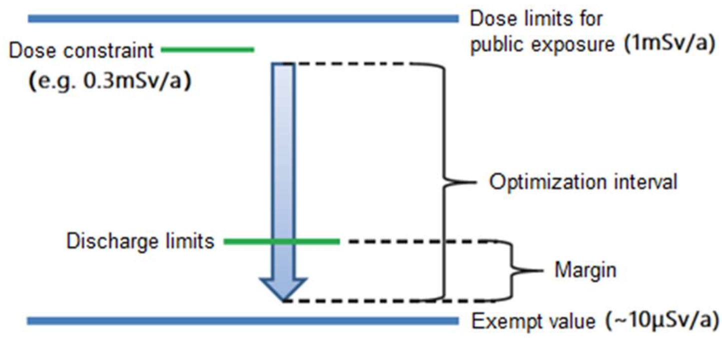

Figure 1. Dose range of radiation protection in nuclear power plants [9]

3. Effluent discharge limits

The differences in the management and control of the radiation environment of international nuclear power plants are mainly reflected in the "optimization interval" (10μSv/a~0.3mSv/a), and countries have different ideas for the management and control of radioactive effluent discharge. This section compares and analyzes the management and control standards for radioactive effluent discharge from domestic and foreign nuclear power plants in terms of total discharge limits, total dose limits, and discharge concentration limits.

3.1. Total discharge limits

In terms of total discharge limits control of radioactive effluent from nuclear power plants, China and France are basically the same. In accordance with Decree No. 74-945 of November 6, 1974 and the order of August 10, 1976, France established the control procedures for the airborne/liquid effluent of nuclear facilities. The order of August 10, 1976, set normative reference values for the discharge limits of radioactive airborne/liquid effluent from nuclear power plants with a thermal power of 3000 MW, as shown in Table 3. The quantification of discharge limits is based on early operational experience and engineering research, and the discharge limits of other power reactor effluents are linearly determined based on this.

Table 3. Airborne/liquid effluent discharge limits in the French 1976 order [10]

Category		Total discharge limits (Bq/a)
Liquid effluents	Nuclides except tritium, potassium-40, radium	1.48×10^{12}
	Tritium	7.4×10^{13}
Airborne effluents	Halogens and aerosols	1.8×10^{11}
	Noble gas	3×10^{15}

With the improvement of discharge reduction technology and management level, the above-mentioned limits are no longer sufficient. Therefore, France promulgated Decree No. 95-540 in 1995 and repealed Decree No. 74-945[11]. Decree No. 95-540 no longer stipulates the discharge limits of radioactive airborne/liquid effluents from nuclear power plants, and stipulates that the annual discharge limit of radioactive effluents from nuclear power plants should be set by Agency for Nuclear Safety (ASN) in accordance with the reactor power and environmental conditions of each nuclear power plant, and is approved by the corresponding ministerial order to take effect. It requires the Institute for Protection and Nuclear Safety (IPSN) to conduct a retrospective review of the historical discharge records of the nuclear power plants.

In 1997, France successively began to update the discharge permit decree of 19 nuclear power plants. In the annex to each decree, the annual discharge limit and radioactive flow of radioactive airborne/liquid effluent were clearly restricted. Table 4 shows the updated annual discharge limit of radioactive effluent of three representative nuclear power plants, namely Dampierre nuclear power plant (4×900MW CP1 reactors), Penly nuclear power plant (2×1300MW P'4 reactors), Civaux nuclear power plant (2×1450MW N4 reactors). Compared with the radioactive effluent discharge limit in the 1976 order, it is found that the updated limit has been reduced. For example, the discharge limit of radioactive liquid tritium in the Dampierre nuclear power plant should be 2.8×1014Bq/a in accordance with the requirements in the 1976 order, while the updated limit is 1×1014Bq/a, which is about 1/3 of the original limit. In addition, after the update, the liquid effluent discharge limit has changed from 2 types to 4 types, the airborne effluent discharge limit has changed from 2 types to 5 types.

Table 4. Annual discharge limits of radioactive effluent from Dampierre/Penly/Civaux nuclear power plant in France

Category		Annual discharge limits (Bq/a)		
		Dampierre (4×CP1)	Penly (2×P’4)	Civaux (2×N4)
Liquid effluents	Tritium	1×10^{14}	8×10^{13}	9×10^{13}
	Carbon-14	2.6×10^{11}	1.9×10^{11}	1.9×10^{11}
	Radioiodine	6×10^{8}	1×10^{8}	1×10^{8}
	Other nuclides	3.6×10^{10}	2.5×10^{10}	5×10^{9}
Airborne effluents	Noble gas	7.2×10^{13}	4.5×10^{13}	2.5×10^{13}
	Radioiodine	1.6×10^{9}	8×10^{8}	8×10^{8}
	Other particles	8×10^{8}	8×10^{8}	1×10^{8}
	Tritium	1×10^{13}	8×10^{12}	5×10^{12}
	Carbon-14	2.2×10^{12}	1.4×10^{12}	1.4×10^{12}

3.2. Total dose limits

Different from the idea of France and China, the control of radioactive effluent from nuclear power plants in the United States is mainly based on dose management, mainly based on three regulations: the "Environmental Radiation Protection Standards for Nuclear Power Operations" (40 CFR Part 190) issued in 1977, "Domestic Licensing of Production and Utilization Facilities" (10 CFR Part 50) issued in 1956, "Standards for Protection against Radiation" (10 CFR Part 20) issued in 1991[12].

40 CFR Part 190 specifies the public dose limit for public exposure of radioactive waste generated during the operation of uranium fuel cycle facilities, as shown in Table 5. The limit of 0.25mSv/a is regarded as the dose constraint of nuclear power plants to the public in the US radioactivity management.

Table 5. Dose limits of 40 CFR Part 190 for Uranium Fuel Cycle Facilities [13]

Dose	Limit per site
Whole body	0.25 mSv/a
Thyroid	0.75 mGv/a
Any other organ	0.25 mGv/a

Annex 1 of 10 CFR Part 50 provides the design objectives of the radioactive dose to the public caused by different types of radioactive effluent discharges from nuclear reactors, as shown in Table 6. The applicant for the permit shall ensure that the construction and operation meet the corresponding design objectives.

Table 6. Design objectives of 10 CFR Part 50 for radioactive effluents released from each nuclear power reactors [14]

Dose	Type of effluents	Limit per unit
Total body from all pathways	Liquid	0.03mSv/a
Any organ from all pathways	Liquid	0.1mSv/a
Gamma dose in air	Noble gas	0.1mGy/a
Beta dose in air	Noble gas	0.2mGy/a
External dose to total body of an individual	Noble gas	0.05mSv/a
External dose to the skin of an individual	Noble gas	0.15mSv/a
Dose to any organ from all pathways	Radioiodine & Particulates in gas (including 3H & 14C)	0.15mSv/a

In addition to 10 CFR Part 20 stipulating the dose limit for public exposure (1mSv/a), it also stipulates that nuclear power plants can use measurement or calculation to prove that the maximum total effective dose caused to individuals during the operation of the facility does not exceed the limit specified in 40 CFR Part 190 (Table 5) to show that its discharges meet regulatory requirements.

The approach to nuclear power plant radiation environment management of South Korea is consistent with that of the United States, and it also focuses on dose management. The Nuclear Safety and Security Commission (NSSC) requires that the operating organization of nuclear facilities should certify that it complies with the provisions of NSSC Announcement 2016-16 Article 16 'Prevention of hazards to environment', which contains two dose standards to the public. (as shown in Table 7):

a) The first standard applies to a single nuclear fuel installation or reactor. In the design phase of a new nuclear power plant, the estimated annual dose of the airborne/liquid radioactive effluent released from the nuclear fuel installation at the boundary of the restricted zone shall not exceed the corresponding dose limit. The dose limit adopts the value in 10 CFR Part 50 of the United States.

b) The second standard applies to nuclear power plants that include multiple nuclear power reactors. The dose limit is set based on the environmental radiation protection standard of the United States Environmental Protection Agency (EPA), which is 40 CFR Part 190.

Table 7. South Korea NSSC No. 2016-16 Announcement on the dose limit of nuclear power plant effluents in the prevention of environmental hazards [15]

Category	Effluents	Annual limits per unit	Annual limits per site
Effective dose	Liquid	0.03mSv/a	
Organ equivalent dose	Liquid	0.1mSv/a	
Air absorbed dose by gamma ray	Gaseous	0.1mGy/a	
Air absorbed dose by beta ray	Gaseous	0.2mGy/a	Under the operation of multiple reactors at a single site: a) Effective dose:0.25mSv/a b) Thyroid equivalent dose:0.75mSv/a
Effective dose by external radiation exposure	Gaseous	0.05mSv/a	
Skin equivalent dose by external radiation exposure	Gaseous	0.15mSv/a	
Organ equivalent dose	Particle radioactive substances, ^{3}H, ^{14}C and radioiodine	0.15mSv/a	

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3.3. Discharge concentration limits

The United States 10 CFR Part 20 stipulates the concentration limits of radioactive effluent in the boundary of non-controlled areas. When radioactive materials are released into the environment from nuclear facilities, their concentration shall not exceed the limit in Table 2 of 10 CFR Part 20 Appendix B, depending on the type of release (airborne or liquid). During the demonstration, the discharge concentration of each nuclide in the liquid effluent of the nuclear power plant needs to be compared with the corresponding discharge concentration limit in Table 2 of Appendix B of 10 CFR Part 20, and judged based on the sum of their ratios.

Under normal circumstances, the assessment of the public dose is calculated through the complex propagation pathways of various radioactive effluents from nuclear facilities to the environment. The route by which an individual may be exposed to radioactive effluent is called the "exposure route." The effluent control limit (ECL) is used to monitor the instantaneous discharge concentration of nuclear power plants, and calculates the airborne ECL and the liquid ECL using the most stringent exposure pathway calculations for occupational exposure and inhalation.

$$\begin{aligned} ECL &= \frac{ALI(\mu\text{Ci})}{(2000hrs \times 60min \times 2 \times 10^{4} ml/min)} \\ &= \frac{ALI}{2.4 \times 10^{9}} \mu\text{Ci/ml} \end{aligned} \quad (1)$$

Among them, ALI is the annual radionuclides intake limit of exposure, 2000hrs is the annual occupational exposure time, 2×10^4ml is the air inhaled amount per minute in the "reference group" under "light work" working conditions.

When using the above formula to calculate the ECL of different types of effluents, the coefficients need to be used for correction. To calculate the airborne ECL, it needs to be divided by a correction factor of 300, including the ratio of annual occupational exposure limit to the public exposure limit (50), the ratio about respiratory frequency and exposure time of occupational exposure to public exposure (3), the correction of the radiation exposure coefficient to the difference in age range (2). To calculate the liquid ECL, it needs to be divided by a correction factor of 100, including the ratio of annual occupational exposure limit to the public exposure limit (50), the correction of radiation exposure coefficient to age range (2), and the average annual water intake is $0.73m^3$.

France set a limit on the discharge concentration of radioactive effluent in the 1976 order (as shown in Table 8), but in Decree No. 95-540, the relevant standards on the discharge concentration of radioactive effluent are no longer stipulated, and the discharge flow (Bq/s) limit of the radioactive effluent is stipulated in the discharge permit decree of each nuclear power plant issued by ASN. Table 9 shows the updated radioactive effluent discharge flow limits of the Flamanville nuclear power plant (Units 1 and 2 are 1300MW, Unit 3 is 1650MW). The liquid effluent discharge limits have changed from the original 2 types to 3types. The airborne effluent discharge limits have been changed from 2 types to 4 types. The discharge limits for gaseous tritium, gaseous carbon-14 and iodine have been added.

Table 8. Airborne/liquid effluent discharge concentration limits in the French 1976 order

Category		Limits on atmospheric volumic activity	Limits on volumic activity in sea water for a single plant	Limits on volumic activity in river water for a single plant	Limits on volumic activity in river water for all plants
Liquid effluents	Radionuclides other than tritium, potassium 40 and radium	-	7.4Bq/L	0.74Bq/L	3.7Bq/L
	Tritium	-	740Bq/L	74Bq/L	1480Bq/L
Airborne effluents	Total β volumic activity of particulates	7.4mBq/m^3	-	-	-
	Total γ volumic activity of gases	740Bq/m^3	-	-	-

Table 9. Airborne/liquid effluent discharge concentration limits of the Flamanville nuclear power plant in France

Category		Radioactive flow (Bq/s)	Radioactive flow from the chimneys of Units 1 and 2 (Bq/s)	Radioactive flow from the chimney of Unit 3 (Bq/s)
Liquid effluents	Tritium	800×D (1)	-	-
	Radioiodine	1×D (1)	-	-
	Fission products or activated beta or gamma sources	7×D (1)	-	-
Airborne effluents	Tritium	-	1.2×10^6	9.0×10^5
	Noble gas	-	1.0×10^7	1.0×10^7
	Radioiodine	-	1.1×10^2	1.1×10^2
	Fission products or activated beta or gamma	-	1.1×10^2	1.0×10^2

(1) D: discharge flow (L/s)

3.4. Comparison of domestic and foreign effluent discharge standards

In Decree No. 95-540, France deleted the content on the total discharge amount limits and discharge concentration limits of radioactive effluent of nuclear power plants, and began to review 19 nuclear power plants in 1997. The new limit is stipulated in the decree issued by the ASN in units of nuclear power plants or reactors. The annual discharge limit of radioactive airborne/liquid effluent, radioactive flow rate, etc. are clearly restricted in the appendix of each decree.

The United States controls the impact of radioactive effluents discharge of nuclear power plants to the environment and the public from two aspects: the discharge concentration of radioactive effluents and the dose for public exposure caused by radioactive effluents. 10 CFR Part 20 specifies the concentration limits of radionuclides in the effluents at the boundaries of non-controlled areas of nuclear power plants. 40 CFR Part 190 specifies the dose limit at the boundary of the non-controlled area of nuclear power plants.

In China, GB 6249 stipulates that the dose constraint value of nuclear power plant is 0.25mSv/a, and the control value of the total discharge amount of radioactive effluent from nuclear power plants is specified. The concentration of other radionuclides should not exceed 1000Bq/L. In addition, nuclear power plants need to re-evaluate the application value of effluent discharges every five years, and it need to be reviewed and approved by the National Nuclear Safety Administration (NNSA). Generally, the discharge concentration limit is not specified in the approval document.

Through the investigation of the relevant laws and regulations on the radioactive effluent discharge of nuclear facilities, it is found that the above-mentioned countries have different ideas on the control of radioactive effluents. Both France and China have set annual discharge limits (Bq/a) for radioactive effluent. The difference is that France deleted the overall annual limit of radioactive effluent for a reactor with a thermal power of 3000MW in the 1976 order in 1995, and stipulated the discharge limit of radioactive effluent in the discharge permit document issued by ASN. While the control values in GB 6249 are still in use in China. By comparing the total discharge amount limits of radioactive effluents from nuclear power plants in China and France, it is found that the updated the total discharge amount limits of French nuclear power plants are smaller than that of the same nuclear power plants of China. As shown in Table 10, the discharge limit of the radioactive effluent from Dampierre nuclear power plant except for carbon-14 is less than the approved value of the Ningde nuclear power plant. In addition, France has set an annual discharge limit for liquid iodine, and GB 6249 approval document does not separately set an annual discharge limit for liquid radioiodine.

France and China set limits on the discharge concentration of radioactive effluent from nuclear power plants, but the difference is that, in France, the discharge concentration limit is set separately for each nuclear power plant in the form of radioactive flow (Bq/s), while, in China, the overall discharge concentration of radioactive effluent from the nuclear power plant is regulated by GB 6249.

Table 10. The approved values of radioactive effluent from the Daya Bay, Sanmen, Ningde, and Taishan nuclear power bases and the GB 6249 multi-reactor site control values

Category		Approval Value/Control Value of annual radioactive effluent discharge (Bq/a)				
		Daya Bay NPP (6 units)	Sanmen NPP (2 units)	Ningde NPP (4 units)	Taishan (2 units)	Control Value of GB 6249 (4 times)
Liquid effluents	Tritium	2.25×10^{14}	8.52×10^{13}	1.75×10^{14}	1.41×10^{14}	3×10^{14}
	Carbon-14	3×10^{11}	7.1×10^{10}	2×10^{11}	1.12×10^{11}	6×10^{11}
	Other nuclides	1.3×10^{11}	2.28×10^{10}	8×10^{10}	1.27×10^{10}	2×10^{11}
Airborne effluents	Noble gas	7×10^{14}	2.36×10^{14}	1.1×10^{15}	1.45×10^{14}	2.4×10^{15}
	Radioiodine	2.5×10^{10}	1.28×10^{10}	1.18×10^{10}	1.38×10^{9}	8×10^{10}
	Other particles	3.8×10^{9}	1.91×10^{10}	6.2×10^{9}	5.14×10^{8}	2×10^{11}
	Tritium	2.4×10^{13}	9.46×10^{12}	1.94×10^{13}	1.56×10^{13}	6×10^{13}
	Carbon-14	2.2×10^{12}	6.4×10^{11}	1.48×10^{12}	1.48×10^{12}	2.8×10^{12}

Different from China and France using the radioactivity (Bq) to manage the discharge of radioactive effluent from nuclear power plants, the United States and South Korea focus on the radioactive dose (Sv) received by the public as the measurement standard. The operating organization needs to calculate the "exposure route" for the discharge of radioactive effluents to verify its compliance with regulations.

In addition, 10 CFR Part 20 of the United States provides the concentration limits of radioactive effluents at the boundaries of non-controlled areas. Nuclear power plants can prove that their discharge meet the dose limit for public exposure in two ways [16]:

a) Prove through measurement or calculation that the maximum total effective dose to individuals during the operation of the facility not exceed the dose limit specified in 10 CFR Part 20: 0.25 mSv for the whole body, 0.75 mSv for the thyroid, and 0.25 mSv for any other organ.

b) Prove that the annual average concentration of radioactive substances released in the airborne/liquid effluent at the boundary of the non-controlled area does not exceed the value specified in Table 2 of Part 20 Appendix B.

4. Conclusion

In order to keep the dose of radioactive effluent at ALARA, nuclear power plants have generally implemented multi-level radiation environmental control. The following conclusions have been obtained through the investigation and comparison of IAEA, ICRP, other international institutions and some countries on nuclear power plant radiation environment related regulations and standards:

a) Internationally, 1mSv/a is generally used as the radioactive dose limit for public exposure, and the consequences of exposure to individuals above this level are considered unacceptable.

b) The annual dose limit value is set under the public personal dose limit. Most countries set it between 0.1mSv~0.3mSv, and it is 0.25mSv in China.

Through comparison with the US radioactive effluent management system, it is found that:

a) In terms of total discharge limits, the United States stipulates the total annual dose limit of radioactive effluent from nuclear power plants in 10 CFR Part 50, while China stipulates the total discharge activity limit in the GB 6249 and NNSA approval documents.

b) In terms of discharge concentration limits, the United States has set separate limits for the discharge concentration of each nuclide in 10 CFR Part 20, while China stipulates the discharge concentration limit of radionuclides except tritium and carbon-14 in GB 6249.

By comparing with the French radioactive effluent management system, it is found that:

a) In terms of total discharge amount limits, the annual limits for radioactive effluent discharges from French nuclear power plants except for carbon-14 are lower, but the gap is within an order of magnitude. In addition, France stipulates discharge limits of 9 types of radioactive effluent, one more type than China. France has set a separate discharge limit for liquid radioiodine.

b) In terms of discharge concentration limits, in China, GB 6249 has stipulated overall limits, and the discharge permits issued by ASN in France set limits on the discharge flow of radioactive effluent from nuclear power plants.

Based on the above-mentioned practices nuclear power plant radiation environment management in serval countries, it can be seen that the control of radioactive effluents from nuclear power plants is relatively comprehensive in China, with both annual total discharge limits and discharge concentration limits. It not only puts forward the overall requirements, but also reviews the discharge of nuclear power plants one by one. However, the annual total discharge limits set by GB 6249 and the limits approved by NNSA are looser than those of French nuclear power plants.

Compared with the United States, the discharge concentration limits of effluent from nuclear power plants in China are not classified by nuclides. The operation optimization of the plant lacks restriction and impetus. Therefore, on the basis of current effluent discharge control standards in China, it is necessary to further reduce the annual total discharge limit of radioactive effluents and improve the control indicators of discharge concentration. This is conducive to enhancing effluent discharge management and improving the effluent discharge control system. The control indicators for radioactive effluent discharges of nuclear power plants in China can be improved from two perspectives. On the one hand, it can follow the United States' approach to enhance the restriction of GB 6249 on the discharge concentration indicators, on the other hand, it can follow the practices of France, incorporates the discharge concentration limits of radioactive effluents into the review of nuclear power plant discharge permits, set appropriate indicators according to the power and reactor types to further optimize the discharge limits.

References

[1] ICRP. 1990 Recommendations of the International Commission on Radiological Protection[J]. 1991,21(1-3).

[2] IAEA. International Basic Safety Standards for Protection Against Ionizing Radiation and for the

Safety of Radiation Sources[S]. Vienna: 1996.

[3] Legifrance. Code de la Santé Publique[Z]. France: 1953.

[4] General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China. Basic Standards for Ionizing Radiation Protection and Radiation Source Safety[S]. 2002.

[5] ICRP. The 2007 Recommendations of the International Commission on Radiological Protection[J]. 2007,37(2-4).

[6] Ministry of Environmental Protection, General Administration of Quality Supervision, Quarantine and Inspection. Nuclear power plant environmental radiation protection regulations[S]. 2011.

[7] IAEA. Setting Authorized Limits for Radioactive Discharges: Practical Issues to Consider[S]. Vienna: 2010.

[8] IAEA. Application of the Concepts of Exclusion, Exemption and Clearance[S]. Vienna: 2004.

[9] IAEA. Regulatory Control of Radioactive Discharges to the Environment[S]. Vienna: 2018.

[10] Legifrance. Arrêté du 10 août 1976 relatif aux régles propres aux centrales nucléaires de puissance équipées de réacteurs à eau ordinaire applicables aux limites et modalités de rejet de leurs effluents radioactifs gazeux, mesures de surveillance de leur environnement et contrôle par l'Office de protection contre les rayonnements ionisants, pris en application de l'article 14 du décret 945 du 6 novembre 1974[Z]. France: 1976.

[11] Legifrance. Décret n°74-945 du 6 novembre 1974 Relatif aux Rejets d'effluents Radioactifs Gazeux Provenant des Installations Nucleaires de Base et des Installations Nucleaires Implantees sur le Meme Site[Z]. France: 1974.

[12] Si Young Kim Y J L T. Regulatory requirements for radioactive effluent control in U.S. nuclear power plants: Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, 2017[C].

[13] EPA. Environmental Radiation Protection Standards for Nuclear Power Operations[Z]. Washington, DC: U.S. Government Printing Office: 1977.

[14] NRC. Domestic Licensing of Production and Utilization Facilities[Z]. Washington, DC: U.S. Government Printing Office: 1956.

[15] Tae Young Kong S K Y L. Regulations on radioactive effluents released from Korean nuclear power plants[J]. International Journal of Environmental Studies, 2018,75(1):154-159.

[16] NRC. Standards for Protection against Radiation[Z]. Washington, DC: U.S. Government Printing Office: 1991.