

The Study on the Way of Radioactive Waste Disposal in China

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Because of the massive development of nuclear power plants in China in recent years, China is facing the challenge of radioactive waste disposal. China has established complete regulatory requirements for radioactive waste disposal, but it also has encountered problems and challenges in low-level radioactive waste disposal in terms of management, selection of disposal facility sites, and implementation of a site selection plan. Three low-level radioactive waste disposal facilities that have been operated in China are described, and their activity limits, locations, and capacities are also outlined. The connotations of “regional” and “centralized” disposal policies are discussed in light of the characteristics of the radioactive waste. The characteristics and advantages of the regional and centralized disposal policies are compared. It is concluded that the regional disposal policy adopted in 1992 can no longer meet the current disposal needs, and China should adopt a combination of the two disposal policies to solve the problem of radioactive waste disposal.

Keywords: Disposal, Nuclear power, Waste

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1. Introduction

China’s nuclear power has experienced more than 30 years of development. At present, there are 45 units under operating and 11 units under construction, with a total installed capacity of more than 50 million kilowatts. The total number of units ranks third in the world [1]. With the rapid development of nuclear power in China, a large amount of low-level radioactive waste has been generated.

However, the construction of disposal facilities for radioactive waste in China is slow. A large amount of radioactive waste generated by the operating nuclear power plants is temporarily stored in temporary storage, and an effective way of disposal cannot be found. As some nuclear power plants are about to decommissioning, new radioactive wastes will be generated, which pose enormous radiation risks to workers, the public and the environment. Therefore, China needs to promote the disposal of radioactive waste and reduce the environmental risk potential of radioactive waste [2].

2. Status of Radioactive Waste Disposal in China

2.1 Overview of China’s Radioactive Waste Management Regulations and Standards System

China continues to strengthen the construction of nuclear safety regulations and standards, and has formed a regulatory and standard system centered on laws, administrative regulations, departmental rules, and technical standards [3]. China’s nuclear and radiation safety regulatory system includes national laws, administrative regulations, departmental rules, guidance documents, and other regulatory requirements documents.

China’s radioactive waste management regulations and standards system is an important part of the nuclear

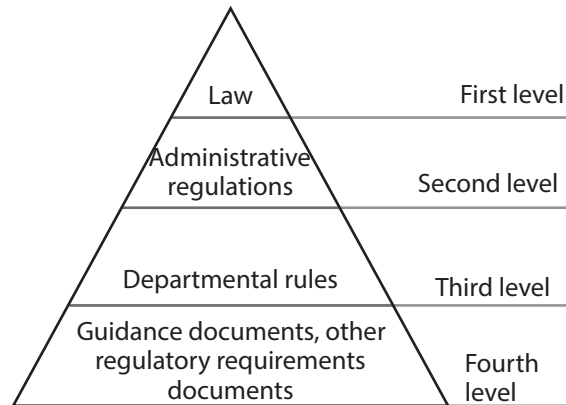


Fig. 1. Hierarchical map of china’s nuclear safety regulations.

and radiation safety regulatory system. It also has a five-level regulatory framework structure, supplemented by different types of technical standards. At present, China has basically established a regulatory and standard system for radioactive waste management, such as waste generation, collection, treatment, transportation, storage, disposal and decommissioning of nuclear facilities, which effectively guarantees the radiation safety of radioactive waste.

2.2 Disposal Requirements for Low-level Radioactive Waste

For low-level radioactive waste (the activity of short-lived radionuclides can be higher, and the activity of long-lived radionuclides is limited), requiring effective containment and isolation for hundreds of years, the waste can be disposed in near-surface facilities with engineered barriers. The depth of near-surface disposal facilities is generally 30 meters from the surface to the ground [4].

The upper activity limit of low-level radioactive waste is shown in Table 1. For radionuclides not listed in Table1, the upper activity limit concentration is 4×10^{11} Bq·kg⁻¹. Typically, low-level waste comes from a wide range of sources, such as ion-exchange resins and solidified radioactive concentrates from the operation of nuclear power plants.

Table 1. Upper limit of activity concentration of low-level radioactive waste

Radionuclide	Half life	Activity concentration (Bq·kg ⁻¹)
¹⁴ C	5.73×10 ³ a	1.00×10 ⁸
⁵⁹ Ni	7.50×10 ⁴ a	1.00×10 ⁹
⁶³ Ni	96.0 a	1.00×10 ¹⁰
⁹⁰ Sr	29.1 a	1.00×10 ⁹
⁹⁹ Tc	2.13×10 ³ a	1.00×10 ⁷
¹²⁹ I	1.57×10 ⁷ a	1.00×10 ⁶
¹³⁷ Cs	30.0 a	1.00×10 ⁹
Transuranic nuclides that emit alpha particles with a half-life greater than 5 years		4×10 ⁵ (average) 4×10 ⁶ (single waste pack)

According to “the Law on prevention and control of radioactive pollution” and “the Law on nuclear safety”, the requirements for low-level waste disposal have been continuously improved, mainly including the following aspects:

- (1) The Law on the Prevention and Control of Radioactive Pollution provides general provisions for low-level and intermediate-level waste which need to be disposed in near-surface, but the provisions do not clearly separate and distinguish low-level and intermediate-level waste [5]. This is not conducive to clarifying the respective disposal methods of low-level waste and intermediate level waste under the new classification system.
- (2) Regarding disposal methods, the Law on Nuclear Safety specifies that low- and intermediate-level radioactive waste can be disposed in near surface or at medium depths, which further enriches and clarifies the disposal methods of low and intermediate-level radioactive waste.
- (3) Regarding site selection, the Law on Nuclear Safety further enhances the participation and initiative of local government in site selection, and increases the requirements for local governments to participate in the preparation of site selection plans for low and medium-level radioactive waste disposal.

2.3 Problems in Low-level Waste Disposal

- (1) A large amount of low-level waste is in urgent need of safe disposal.

With the growth of nuclear power plants in China, the amount of low-level radioactive waste stored in nuclear power plants has increased rapidly [6]. The amount of waste exceeds the design capacity of the temporary storage, so only a new waste storage can be built. In addition, due to the utilization of nuclear technology has developed rapidly, there are nearly 200,000 used radioactive sources. The successive decommissioning of other nuclear facilities will also generate a larger amount of low-level radioactive waste, and it is imperative to improve the disposal capacity. However the Beilong Disposal facility has not disposed waste for more than ten years and is planned to be abolished. So there is a huge gap in low-level waste disposal capacity.

- (2) Resistance to site selection of disposal facility.

“The Law on Radioactive Pollution Prevention and Control” and “The Law on Nuclear Safety” stipulate that local governments shall provide land for low-level radioactive waste disposal and support the construction of disposal facility. However, no corresponding

institutional mechanism has been established, and the site selection of the disposal facility lacks the strong support of the local government. At present, various nuclear power groups have organized the site selection of disposal facilities, but due to the acceptance of the local public, it is difficult to implement the project.

- (3) The site selection plan for disposal facility is difficult to implement.

The construction period of disposal facilities is long, and early planning is urgently needed. China's near-surface disposal facilities have been selected nationwide since the 1980s, but the site selection plan has been delayed. If the disposal planning and disposal policies are not implemented as soon as possible, the lagging situation of disposal capacity will still not change [7].

2.4 Challenge of Disposal Low-level Radioactive Waste in China

In recent years, nuclear power plants have continued to increase, and the application of nuclear technology in health, agriculture and other fields has continued to expand. According to the blue book "China Nuclear Energy Development Report 2021", at the end of December 2021, China has 11 nuclear power units under construction, and the installed capacity of the units under construction has ranked first in the world. The vigorous development of nuclear power also means the generation of a large amount of radioactive waste. Based on the operation of a million-kilowatt nuclear power unit for 60 years, it will generate about 13,000 m³ of low-level radioactive waste. According to official data from the Ministry of Ecology and Environment, at the end of 2019, the total volume of low-level waste generated by all operating nuclear power plants in China was about 16,000 m³. Most of these wastes are in temporary storage and have not been properly disposed.

The existing disposal capacity cannot respond to the disposal demand. It is necessary to improve the correspond-

ing policies and regulations as soon as possible to promote the rational and proper disposal of radioactive waste.

3. Status of Low-level Waste Disposal Facilities

At present, China has three near-surface disposal facilities which disposed nuclear power waste. The basic conditions are as follows.

3.1 Northwest Disposal Facility

The Northwest Disposal facility, local in Jiayuguan City, Gansu Province, mainly disposes low-level radioactive waste that accumulated by the nuclear industry and generated during the decommissioning process. Its disposal capacity is 200,000 m³, and the first-phase project was completed in 1998 with a disposal capacity of 20,000 m³. According to the waste disposal needs in next five years, the construction of the second phase project will be carried out. The main construction contents include some units with a capacity of 90,000 m³ and its related supporting facilities.

The sources of waste received by the Northwest Disposal Facility are come from CNNC Jiayuguan Co. Ltd. Waste packaging forms include 200 L, 400 L, FA-V steel boxes and a small number of special-shaped packages. The surface dose rate of the waste package is less than 20 mSv·h⁻¹, and the specific activity of the nuclide is less than the upper limit of the low-level waste activity concentration. Based on the disposed waste, the total activity of dispose facility is 1.58×10^{16} Bq.

3.2 Longhe Disposal Facility

Domestic nuclear power owners (including China National Nuclear Corporation, China General Nuclear Power Group Co. Ltd., State Power Investment Group Co. Ltd.) and the Gansu Provincial Government jointly invested to

Table 2. The limit of each nuclide of low-level waste received at longhe disposal facility

Radionuclide	Activity concentration limit (Bq·kg ⁻¹)	Total activity limit (Bq)
¹⁴ C	1.00×10 ⁸	8.00×10 ¹⁵
⁶³ Ni	1.00×10 ¹⁰	8.00×10 ¹⁷
⁹⁰ Sr	1.00×10 ⁹	8.00×10 ¹⁶
⁹⁹ Tc	1.00×10 ⁷	8.00×10 ¹⁴
¹²⁹ I	2.58×10 ⁵	9.01×10 ¹⁰
¹³⁷ Cs	1.35×10 ⁸	1.08×10 ¹⁶
²⁴¹ Pu	1.35×10 ⁷ (average) 8.12×10 ⁷ (single waste pack)	1.08×10 ¹⁵
Transuranic nuclides that emit alpha particles with a half-life greater than 5 years	4.0×10 ⁵ (average) 4.0×10 ⁶ (single waste pack)	3.20×10 ¹³

build Longhe Disposal Facilities in Jinta, Gansu province.

The planned total disposal capacity of the disposal facility is 1 million m³, and it is planned to be constructed in five phases projects. The first-phase project has a disposal capacity of 40,000 m³, with a total of 20 disposal units. The disposal capacity is designed to be no less than 4,000 m³·a⁻¹.

The sources of low-level waste at Longhe Disposal Facility mainly include: cement solid waste from incineration ash of combustible waste, cement solidification waste from nuclear power operation, low-level waste from other nuclear facilities, and used radioactive sources, etc.

The total activity of the first-phase project in Longhe Disposal Facility is 6.43×10¹⁵ Bq (excluding used radioactive sources), see Table 2 for details.

3.3 Yangjiang Disposal Facility

Yangjiang disposal facility is located in Guangdong Province. It is a supporting facility of Yangjiang Nuclear Power Plant. It mainly disposes of low and medium radioactive waste generated from the operation and decommissioning of nuclear power plants in Yangjiang city. The total capacity is 340,000 m³, and 17 disposal tunnels are planned

to be constructed. The total activity of the received waste is about 1.91×10¹⁸ Bq. The first-phase project mainly builds two disposal tunnels with a disposal capacity of about 45,000 m³, which mainly receive low and intermediate level waste generated during the operation of nuclear power plants. The project was licensed by the National Nuclear Safety Administration in 2019, and construction has start in 2020.

The total radioactive activity of the waste received by the first-phase project of the Yangjiang Disposal Facility is about 1.64×10¹⁶ Bq. See Table 3 for the nuclide and activity information.

200 L metal drums, 400 L metal drums, High Integrity Containers (HICs), and concrete drums are considered as acceptable waste packaging containers for this disposal facility.

4. The Options of Waste Disposal

4.1 Characteristics of the Waste

The radioactive wastes of nuclear power plants mainly generated from the annual refueling overhaul and expected

Table 3. Nuclide and activity of waste received at yangjiang disposal facility

Radionuclide	Total activity limit (Bq)	Radionuclide	Total activity limit (Bq)
⁵¹ Cr	6.76×10^{14}	¹³⁴ Cs	1.88×10^{13}
⁵⁴ Mn	8.17×10^{14}	¹³⁷ Cs	2.05×10^{14}
⁵⁷ Co	1.81×10^{11}	⁶³ Ni	7.23×10^{15}
⁵⁸ Co	2.32×10^{15}	¹⁴ C	2.01×10^{14}
⁵⁹ Fe	8.85×10^{10}	⁹⁹ Tc	3.76×10^{10}
⁶⁰ Co	3.81×10^{15}	¹²⁹ I	3.96×10^9
⁹⁵ Nb	3.78×10^9	²³⁹ Pu	7.74×10^{10}
⁹⁵ Zr	1.83×10^9	²⁴¹ Pu	2.86×10^{12}
¹⁰⁹ Cd	8.73×10^{10}	³ H	1.32×10^{12}
^{110m} Ag	1.08×10^{15}	⁹⁰ Sr	7.99×10^{11}
¹²⁴ Sb	2.00×10^{11}	-	-

operation events. It is mainly composed of concentrate, waste resin, waste filter core, maintenance waste (wood, metal, and dirt), ventilation filter, etc. All these radioactive wastes are treated by solid waste treatment systems and other facilities. By collecting, classifying, temporarily storing, compressing, barreling, solidifying, the purpose of effectively containing and treating solid radioactive waste is achieved, and a standard solid waste package is formed to meet the national requirements. According to the source of the waste, the radioactive solid waste generated by nuclear power plants is divided into three categories: process waste, technical waste and other radioactive waste.

4.2 Regional Disposal Policy

As early as 1992, the State Council issued China's environmental policy on radioactive waste management, which is known as "Document No. 45 [1992] of the State Council". In addition to the requirement to speed up the treatment of radioactive waste, the document requires that operators such as nuclear power plants must promptly dispose of the radioactive waste, convert it into a stable solid form that meets the disposal requirements, and the storage period shall not exceed 5 years [8], and also proposed a regional

disposal policy for low-and intermediate-level radioactive waste, that is, the construction of disposal facilities in Northwest, Southwest, East China, South China and other regions. Since then, China has successively built two low-level waste disposal facilities in Northwest (Jiayuguan) and South (Shenzhen). At December 31, 2016, 12,762.4 m³ of prepared low-level waste was stored in the radioactive waste storage facilities. The two near surface disposal facilities received only 2,116 m³ wastes from power plants. There is a significant lag in the progress of radioactive waste disposal.

There is no major safety risk in the disposal of low-level waste itself, and there is no technical obstacle. The construction of disposal facilities lags behind the development of nuclear power mainly due to historical reasons, social reasons and policy issues.

This disposal method still used in China so far includes the Yangjiang disposal facility and the Northwest disposal facility.

4.3 Centralized Disposal Policy

"Centralized disposal" model breaks through the boundaries of six regions and concentrates more nuclear power

plant wastes in one region for disposal, which is a further concentration on the basis of “Regional disposal”. This has many advantages and can solve many problems. First, it can form scale. Only with scale can it generate economy, contribute to local economy, and can mobilize the enthusiasm of local governments; Second, it can reduce the number of disposal facilities, it can reduce safety risks and the possible impact on the environment; Third, it can reduce social risks and minimize the “NIMBY effect”, which has good social benefits; Fourth, it can improve the efficiency of management and supervision, reduce the cost of disposal. The advantages of “Centralized disposal” are mainly reflected in three aspects: safety, social acceptability and economy. The currently built Longhe disposal facility is the representative of centralized disposal.

5. Conclusions

- 1) Yangjiang disposal facility and Northwest disposal facility, as representatives of regional disposal, have effectively solved the disposal of low-level waste in regional nuclear plants, and provided a basic guarantee for the healthy and sustainable development of nuclear power plants.
- 2) The construction of centralized disposal facilities in the northwest region can achieve win-win marketization and make up for the shortcomings of other disposal modes. It has obvious advantages in economy and safety, but in-depth research work is still needed in the following aspects, mainly including: Detailed economic analysis to determine the rationality of the pricing and charging model for the collection, storage and disposal of waste; the consensus of all parties involved (enterprises, local governments, and the central government); negotiate and formulate a disposal management mechanism acceptable to all parties; Money management.
- 3) “Centralized disposal” has many advantages and can solve difficult problems in waste disposal. First, it can

form scale. Only with scale can it generate economy, contribute to the local economy, and can mobilize the enthusiasm of local governments; Second, it can reduce the number of disposal facilities; Third, it can reduce social risks and minimize the “Not In My Backyard”, which has good social benefits; Fourth, it can improve management and supervision efficiency and reduce the cost of nuclear power.

- 4) The combination of regional disposal and centralized disposal is the best solution to solve the problem of low-level waste disposal in China. Both disposal methods have their merits. Enterprises should be given more choices, from the three aspects of safety, economy and society. Taking all aspects into consideration, appropriate disposal plans are adopted respectively. For provinces with a large scale of nuclear power, regional disposal can be selected to find a suitable site, and safe and economical operation can also be achieved, such as the Yangjiang disposal facility. For provinces with small scale of nuclear power, the option of transporting waste to Longhe disposal facility for centralized disposal can be adopted.

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