3.2 Radioactive Waste Management (RWM) in China

Radioactive wastes in China are generated from nuclear fuel cycle, nuclear applications and NORM/TENORM industries.

China's nuclear industry started from the early year of 1950's. Since then, China established a nuclear fuel cycle system covering uranium exploration, mining and milling, conversion, isotope separation, nuclear fuel fabrication, nuclear power generation and spent fuel reprocessing. Currently there are six nuclear power stations (NPP), 10 nuclear reactors, under operation and 3 NPPs under construction.

Nuclear technolgy has been widely utilized in medical, industry, research and education in China and has been increaseing significantly with the social developmen. A nation-wide survey in 2004 showed there were over 12000 isotope users at the end of 2004.

China has a variety of mineral resources and enterprises involving NORM/TENORM. In China, NORM mine refers to non-uranium mines containing relatively high concentrations of natural radionuclides (e.g. rare earth mines and phosphate mines, etc.). The radioactivity level may be enhanced during the processing of the mineral resources.

Safe management of radioactive waste has long been concerned. Radioactive waste produced in the past activity are mostly in safe store. Growing resources are allocated to the stabilization and final disposal of radioactive waste.

3.2.1 RWM Policy

The RWM policy in China is as follows:

(1) The radioactive waste shall be managed in a way as to protect human health and environment, protect future generations and avoid imposing undue burdens on future generations.

2) All facilities or practice must ensure the relevant radioactive waste management facilities being designed, constructed and operated at the same time with the main facilities or practice.

3) The State shall control and manage the whole radioactive waste process from generation to final disposal, and adopt a radioactive waste classification management model

4) The RWM must following principles: minimization producing, collection based on waste types, purification, volume reduction, strict package, safety transportation, in-situ storage, centralized disposal, controlled release, enhanced monitoring.

5) Gaseous and liquid radioactive waste discharged into the environment shall conform to State radioactive contamination prevention and control standards. Units producing radioactive liquid waste must in accordance with State radioactive contamination prevention and control standards requirements treat or store the radioactive liquid waste before discharging it into the environment.

6) Units producing solid radioactive waste, after treating the solid radioactive waste produced, shall hand over the solid radioactive waste to a disposal unit for disposal, and assume the disposal costs.

7) Solid radioactive waste and solidified forms of liquid radioactive waste shall be disposed of according to classification. Low and intermediate level solid radioactive waste shall be disposed of in regional near surface disposal facilities. High-level radioactive waste and other radioactive waste that is not suitable for near surface disposal, including long-lived and high activity spent radiation sources, shall be disposed in the national centralized geological repository.

8) It is forbidden for radioactive waste and radioactively contaminated goods to be brought into or transferred through the People's Republic of China.

3.2.2 RWM Practice

3.2.2.1 Legislative framework

(1) Laws

Law is adopted by National People's congress and issued by the Chairman of the People's Republic of China.

The main law involving RWM include:

- The Act on Prevention and Control of Radioactivity Contamination
- The Act on Occupational Health
- The Act on Environment Protection
- The Act on Environment Impact Assessment

(2) Regulations

Regulations are adopted by State Council and issued by Prime Minister. No specific regulations are available so far for radioactive waste management. However, there do have some relevant regulations existing, which are as follow:

- The ordinance on supervision of civilian nuclear installation

- The ordinance on safety and protection for radioisotope and radiation emitting equipment
- The environmental policy for LILW disposal

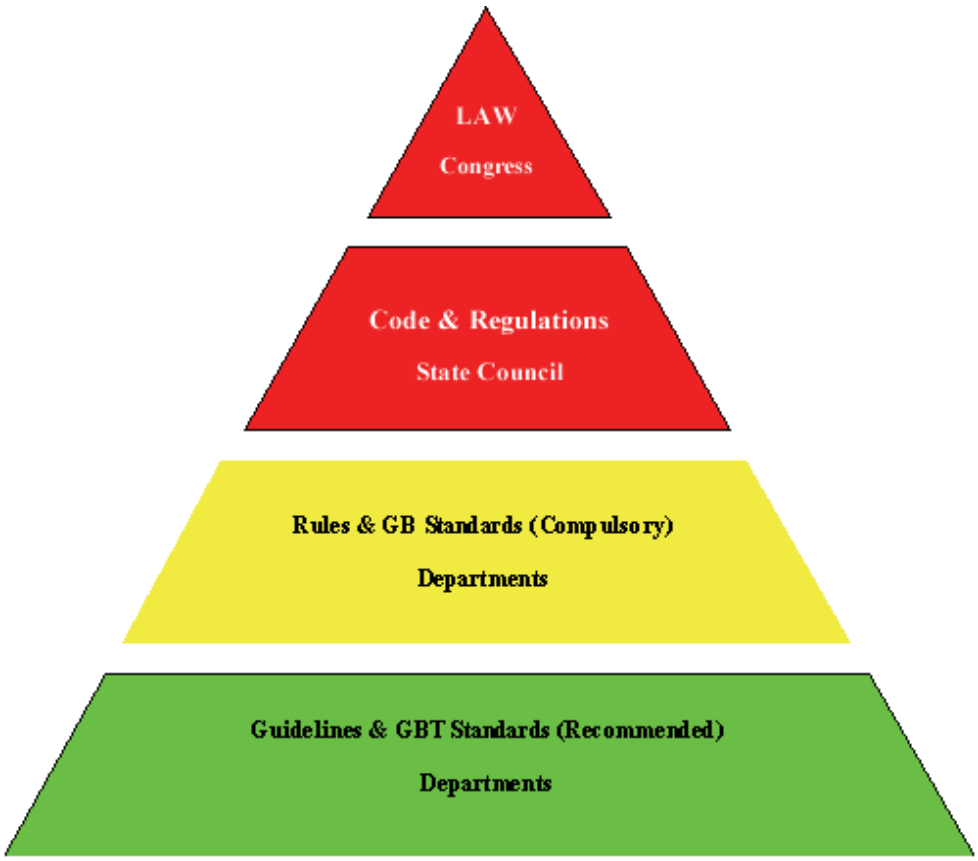

Figure 3.2-1 The hierarchies of legislative system in China.

(3) Department rule

Departmental rule is adopted by competent departments under State Council and issued by the minister of competent department. The important department rules involving RWM are:

- The rule on radioactivity environment management, published by State Environment Protection Administration (SEPA)
- The rule on management of waste generating from nuclear application, published by State Environment Protection Administration (SEPA)
- The rule on safety management of radioactive waste from NPP, published by National Nuclear Safety Agency (NNSA)

(4) technical standards

National Technology Supervision Administration publishes the technical standard. The table 3.2-1 lists some important standards in RWM.

Table 3.2-1 Some important standards in RWM

GB18871-2002	Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources
GB14500-2002	The regulation for RWM
GB9133—95	Standard for Classification of Radioactive Wastes
GB/T4960-1996	Nuclear science and technology glossary-radioactive waste management
GB14589-93	Regulations for interim storage of low-and intermediate-level radioactive solid waste
GB 7023-86	Long-term leach testing of solidified radioactive waste forms
GB145691—93	Characteristic Requirements for Solidified Waste of Low and Intermediate Level Wastes—Cement Solidified Waste
EJ1042—96	Packaging for Low and Intermediate Level Solid Waste—Steel Container
GB13695-92	Authorized limits for normalized release of radioactive effluents from nuclear fuel cycle
GB12711—91	Standard of Safety for Low and Intermediate Level Solid Radioactive Packages
GB9132—96	Regulations for Near Surface Disposal of Low and Intermediate Level Radioactive Waste
GB13600—92	Regulation for Disposal of Solid Low and Intermediate Level Radioactive Wastes in Rock Cavities
GB16933-1997	Accept criteria of waste for near surface disposal
GB15219—94	Quality Assurance for Packing used in the Transport of Radioactive Material
GB14585-93	Regulations for safe management of radioactive wastes from the mining and milling of uranium and thorium ores
GB14586-93	Technical regulations for the environmental management of decommissioning of uranium mining and milling facilities

3.2.2.2 Regulatory framework/body

China takes graded regulatory to radioactive waste regarding potential radioactivity harm to human and environment. Government departments at or above county level take jointly responsibility of regulatory to RWM. Several government departments under State Council

involves RWM regulatory, such as State Environment Protect Administration (SEPA), China Atomic Energy Authority (CAEA), State Development and Reform Committee, Ministry of Health, Ministry of Public Security and some industry departments. But SEPA and CAEA are major regulatory bodies.

SEPA (NNSA) shall integrate supervision and management of radioactive contamination prevention and control work for the whole country. It's functions and duties on RWM are:

- To enact policies, regulations, standards and technical guides.
- To perform surveillance and inspection on radioactive waste management, investigating and approve the disposal of liquid, gaseous and solid radioactive wastes; supervising and monitor the releases of wastes; handling accidents involving contamination of the environmental jointly with other departments.
- To be responsible for nationwide radiation environment monitoring, and to compile national radiation environment quality report every year.
- To review and approve the radiation environment impact report of the installations.
- Issue the license of radioactive waste management facilities
- To review and prove radioactive waste management activities in civilian nuclear facilities, nuclear application.
- To review and prove decommissioning activities of nuclear facilities.

China Atomic Energy Agency (CAEA) is responsible for

- Development of policies concerning the peaceful uses of nuclear energy.
- Development of industrial standards for the peaceful uses of nuclear energy
- Control of nuclear materials
- Acting as the lead body for nuclear accident response, in particular for organizing the State Committee of Nuclear Accident Coordination.
- Reviewing and approving the nuclear energy development project
- Reviewing and approving the R&D project

Provincial environment protection administration is in charge of regulatory to NORM/TENORM waste.

3.2.2.3 Responsibility of license holder

- Compile and submit license applying documents
- Submit Safety Analysis Report and Environment Impact Report
- Monitoring and controlling the radioactive waste release, and submit the monitoring report to the competent authorities.
- Compile and carry out the RWM system operation and maintenance rules，training
- Compile quality assurance program and set up quality assurance system
- Report the operation status to relative departments
- Compile and carry out emergency plan

- Make and keep the files of the waste
- Submit the other documents required by the regulatory departments

3.2.3 Criteria Used to Define and Characterize Radioactive Waste

Radioactive wastes are classified for various purposes and at different levels. For the strategy purpose, the waste classification and relevant disposal strategy are regulated in the Radioactive Pollution Prevention and Control Act (the ACT 2003). In fact, as early as 1988, a specific standard was issued entitled "The Standard for Classification of Radioactive Wastes (GB9133-1988)". The GB9133-1988 was revised based on the IAEA's safety guide "Classification of Radioactive" and formed the revised version GB9133-1995, Both GB9133-1988 and GB9133-1995 are issued as national standards. Besides, the "Regulations for Radioactive Waste (GB14500-2002)" introduces two waste streams into the regulatory regime, the NORM waste and the nuclear applications wastes (radioisotope uses and disused radiation sources). The nuclear application wastes are further classified according to the waste characteristics and processing approach.

Classifications of radioactive wastes in the ACT

In the ACT, the wastes are classified according to their disposal options and the radioactive characteristics. Radioactive wastes are classified into surface facility disposable waste (Uranium (Thorium)/NORM waste), near surface disposable waste (low-and-intermediate level radioactive waste), geologically disposable waste (high level radioactive waste and Alpha waste), and the dischargeable waste (the gaseous and liquid waste). The following quotas from the ACT:

Article 37. Tailings repositories shall be constructed for the storage and disposal of tailings produced during the operation of uranium, thorium and other radioactive mines; tailings repositories shall conform to radioactive contamination prevention and control requirements.

Article 40. Gaseous and liquid radioactive waste discharged into the environment shall conform to State radioactive contamination prevention and control standards.

Article 43. Low and medium level solid radioactive waste shall be sent for near surface disposal conforming to State regulations for the area.

High level solid radioactive waste shall be sent for centralized deep geological disposal.

Alpha waste shall be disposed of in accordance with the provisions of the previous paragraph.

Classifications of radioactive wastes in GB9133-1988 and GB9133-1995

The GB9133-1988 applied to all radioactive wastes arising from production, tests and treatment, storage, transportation, decommissioning and disposal. The lower limits were defined for each of the waste classes to separate radioactive waste from non-radioactive waste. In term of the physical forms of the waste streams, the wastes are classified into gaseous waste, liquid waste and solid wastes. Both gaseous waste and liquid waste are subdivided according to the level of radioactivity concentration. The solid waste is firstly divided into four types according to the half-lives, then further divided into different levels. See table 2 for detail.

The GB9133-1995, which was revised based on the updated IAEA radioactive waste classification scheme. Solid wastes are divided into high-level waste (HLW), long-lived low and intermediate-level waste (LILW-LL), short-lived low-and-intermediate-level waste (LILW-SL) and exempt waste (EW). Table 3.2-2 lists the major characteristics of each of the waste classes and links the waste classes to disposal approaches. Fig. 3.2-2 shows the scheme of radioactive waste classification. GB9133-1995 keeps the waste classification for the options, which is more concerned with optional safety, such as shielding and field radiation protection.

Table 3.2-2 Classification of radioactive waste based on radioactivity and decay life

<table>
<tr><td></td><td>Waste</td><td colspan="5">Radioactivity Level</td></tr>
<tr><td>Gas</td><td>LLG</td><td colspan="5">$A \le 4x10^7 Bq/m^3$</td></tr>
<tr><td></td><td>ILG</td><td colspan="5">$A > 4x10^7 Bq/m^3$</td></tr>
<tr><td>Liquid</td><td>LLL</td><td colspan="5">$A \le 4x10^6 Bq/L$</td></tr>
<tr><td></td><td>ILW</td><td colspan="5">$4x10^6 Bq/L < A \le 4x10^{10} Bq/L$</td></tr>
<tr><td></td><td>HLW</td><td colspan="5">$A > 4x10^{10} Bq/L$</td></tr>
<tr><td rowspan="5">Solid</td><td></td><td colspan="4">Radioactivity limits (A, Bq/kg)</td><td rowspan="2">Thermal capacity (kW/m^3)</td></tr>
<tr><td>$t \le 60d$</td><td>$60d < t \le 5a$</td><td>$5a < t \le 30a$</td><td>$30a < t$</td></tr>
<tr><td>HLW</td><td></td><td></td><td>$A > 4\times10^{11}$</td><td>$A > 4\times10^{10}$</td><td>> 2</td></tr>
<tr><td>ILW</td><td colspan="2">$A > 4\times10^6$</td><td>$4\times10^6 < A \le 4\times10^{11}$</td><td>$4\times10^6 < A \le 4\times10^{10}$</td><td>$\le 2$</td></tr>
<tr><td>LLW</td><td colspan="3">$A \le 4\times10^6$</td><td></td></tr>
<tr><td></td><td>α Waste</td><td colspan="5">radioactivity greater than 4×10^6 Bq/kg for α emitter half-life longer than 30a</td></tr>
<tr><td colspan="2">Exempted waste</td><td colspan="5">waste with very limited radioactive material that the effective dose for any member of the public is less than 10μSv, the collective effective dose committed by one year is no more than 1 man.Sv</td></tr>
</table>

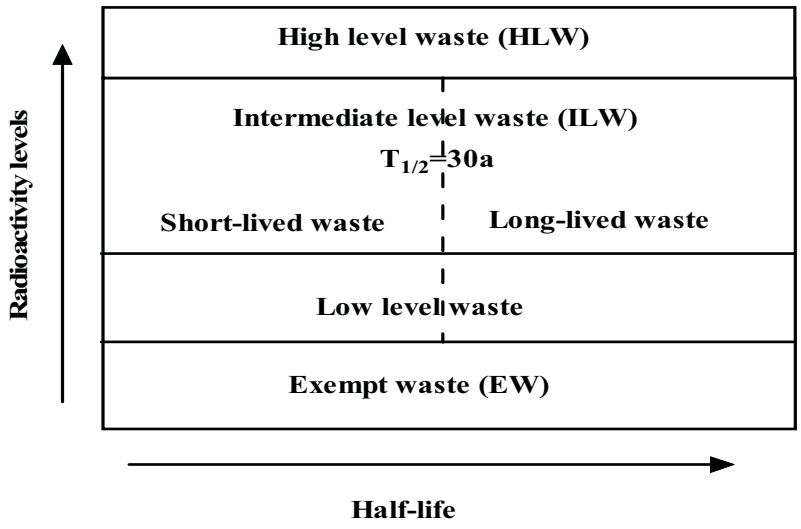

Figure 3.2-2 Radioactive waste classification system

Table 3.2-3 Typical characteristics of waste classes and the disposal options

Waste classes	Typical characteristics	Disposal options
1. Exempt waste (EW)	Activity levels at or below clearance levels given in Ref. [4], which are based on an annual dose to members of the public of less than 0.01 mSv	No radiological restrictions
2. Low and intermediate level waste (LILW)	Activity levels above clearance levels given in Ref. [4] and thermal power below about 2kW/m^3	
2.1. Short lived waste (LILW-SL)	Restricted long lived radionuclide concentrations (limitation of long lived alpha emitting radionuclides to 4000 Bq/g in individual waste packages and to an overall average of 400 Bq/g per waste package); see paragraphs 324 and 325	Near surface or geological disposal facility
2.2. Long lived waste (LILW-LL)	Long lived radionuclide concentrations exceeding limitations for short lived waste	Geological disposal facility
3. High level waste (HLW)	Thermal power above about 2kW/m^3 and long lived radionuclide concentrations exceeding limitations for short lived waste	Geological disposal facility

Sub-classification of nuclear application waste in the Rule

In the rule, the radioactive wastes are subdivided according to the half-lives, waste forms. According to half-lives of the radionuclides contained in the wastes the radioactive wastes are classified into three categories: short half-lived waste ($T_{1/2} \leq 60d$), medium half-lived waste ($60d < T_{1/2} \leq 5.3a$), and long half-lived waste ($T_{1/2} > 5.3a$).

The radioactive wastes include six types: (1) Contaminated materials (metals and non-metals) and protection items; (2) Contaminated tools and equipment; (3) Solidified waste forms of miscellaneous low level radioactive liquids; (4) Animal carcasses and excreta; (5) Spent radioactive sources; and biological waste.

3.2.4 RWM Facilities

Radioactive waste management facilities can be grouped into waste treatment facility, on-site storage facility, provincial storage facility, and disposal facility.

Each NPP has on-site storage facility, and specific treatment facility, generally including waste segregation, cementation and compaction. Most of the large-scale nuclear facilities, such as fuel manufacture plant, have their own treatment and storage facilities for radioactive waste. There are some treatment facilities of incineration, solidification, and compaction.

The provincial storage facilities are designed for interim storage of radioactive wastes arising from nuclear applications. Currently, there are total 25 such storage facilities in China. Some such storage facilities have capacity to treat and conditioning accepted waste by evaporation-concentration, compaction and cement solidification. Some such storage facilities built in early stage are being modified in recent years.

Two near-surface disposal facilities are already built up. One is the Guangdong Beilong LILW Disposal Site, which is located near the Daya Bay nuclear power plant, in the humid area with annual average precipitation over 2000 mm. Figure 3.2-3 is the picture of the Beilong LILW Disposal Site. It is composed of three areas, the administration area, the waste receiving and storage area, and the disposal area. According to the design, the first phase would have a capacity of 80,000 cubic meters. So far, three disposal cells have been constructed and ready for receiving waste emplacement. During the emplacement of waste, the disposal cell is equipped with a mobile rain shelter, which is used to prevent raining intrusion. There is also a pipeline network below the disposal cells, which is designed to deliver infiltrating water to a collection tank and monitoring stations. Another disposal site is located in the North-West of China, very dry area with annual average precipitation around tens of millimetres. This disposal facility is in trial operation, which serves for low-and-intermediate level radioactive wastes in the region and around.

Figure3.2-3 The picture of the Beilong LILW Disposal Site (Credit of Guangdong Nuclear Engineering Cooperation)

3.2.5 Inventory of Radioactive Wastes

The survey shows that there are total around 3,000 m^3 solid waste stored in NPPs at the end of 2003. The amount of spent fuel is 740 THM or so, some of them store in-site of NPPs and some have been sent to the reprocessing pilot plant for storage.

Based on the nation-wide survey in 2004, there are total more than 66,000 spent sources and over 7300 m^3 solid waste generated from nuclear applications at the end of 2004. Around 35,400 spent sources have been stored in specific storage facilities for nuclear application wastes located in province where waste is generated. The rest of spent sources are still stored by users themselves and some measures is being taken to send them to specific storage facilities for nuclear application wastes.

China has a variety of mineral resources and enterprises involving NORM/TENORM. At present, China has still not comprehensive nation-wide investigation data on TENORM waste inventory and only segmental data is available.

3.2.6 Nuclear Facilities in the Process of being Decommissioned and the Status of Decommissioning Activities at those Facilities

The activities of nuclear facilities decommissioning start at the end of 1980's in China. At present, decommissioning of some uranium mining and milling facilities and nuclear application facilities have been finished and decommissioning of some research reactors and nuclear fuel cycle facilities is being planned or undergone.

The decommissioning of some laboratories and testing installations have been finished, such

as radiochemical laboratory in Dalian Institute of Applied technology under China National Nuclear Corporation, nuclear chemical engineering laboratory at Tianjin University, etc, and the decommissioning wastes have been removed and some buildings are reused.

In addition, the decommissioning of some research reactors, such as micro neutron source reactor at Shanghai Institute of Measurement and Testing Technology, and heavy water research reactor in China Institute of Atomic Energy, is preparing for decommissioning.