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ANALYSIS ON LONG-TERM STRATEGY FOR RADWASTE MANAGEMENT IN CHINA

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Analysis on Long-term Strategy for Radwaste Management in China

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Radwaste presents a worldwide issue in the management of environmental protection. Most countries carrying out nuclear programs have developed strategies for their radwastes management. China has been executing its strategy, but the development of nuclear power is representing new challenges for the national radwastes management. This paper tries an analysis on the long-term management of radwastes in China.

The exiting system of China's radwastes management is explained. Two important issues on radwastes management i.e. economics and social issues are analyzed. The future issues that will affect China's radwastes management are discussed. A short summary of the national radwastes management in NEA countries is involved in the paper.

The analysis indicates that in China the exiting system of radwastes management is comprehensive but remains to be perfected. Improvements of long-term management need to be made in the aspects of economics and social issue. A financing system for long-term management, as a supplement for the exiting system of radwastes management, is expected to be created.

Keywords: Radwaste, Long-term, Management, Strategy, China

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中国における放射性廃棄物管理の長期戦略に関する分析

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放射性廃棄物は環境保全に係わる世界的な課題を提示している。原子力開発利用計画を実施している大部分の諸国は、これまで放射性廃棄物管理のための独自の戦略を構築してきた。中国も固有の戦略を実施してきたが、原子力発電の開発利用によって新たな課題が発生しつつある。本稿は、中国における放射性廃棄物の長期管理に関する分析をとりまとめたものである。

中国における既存の放射性廃棄物管理システムに関してまず説明した。次に、放射性廃棄物管理における二つの重要な課題、すなわち経済的及び社会的課題を分析するとともに、中国の放射性廃棄物管理に影響する将来的課題についても検討した。又、NEA諸国における廃棄物管理に関しても簡略にまとめた。

この分析によれば、中国における既存の放射性廃棄物管理システムは包括的ではあるが、まだ完全なものではない。長期管理の方法に関して、経済的及び社会的課題の観点からの改善を必要としている。この既存システムを補完するため、長期管理のための資金システムを構築することが期待される。

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1. Introduction

1.1 Background

Today, nuclear electricity generation accounts for about 6% of global energy and 17% of the world electricity production. Nuclear energy has been making a substantial contribution to meeting the energy needs without emitting acid gases and heat-trapping greenhouse gases. However, radwastes, the inevitable by-product of the generation of nuclear energy (Table 1), pose a great problem to human and his environment because of the unique dangers that they are not detected by any human sense, ill effects may not become evident for decades and the inherent radioactivity may remain for thousands years.

Table 1 Indicative volume (m^3) of packaged radwastes
(For a modern PWR of 1 GW during 1 year)

Waste	Reprocessing route	Direct disposal route
Low-level waste	200	200
Medium-level waste	70	70
Vitrified high-level waste	2.5	0
Spent fuel	0	10

Therefore, radwaste has become one source of social issues and attracted more public concern than any other types of waste. Nowadays, the source of radwaste centers in the generation of nuclear power, so the management of radwastes represents one of the important issues affecting the acceptance of nuclear energy.

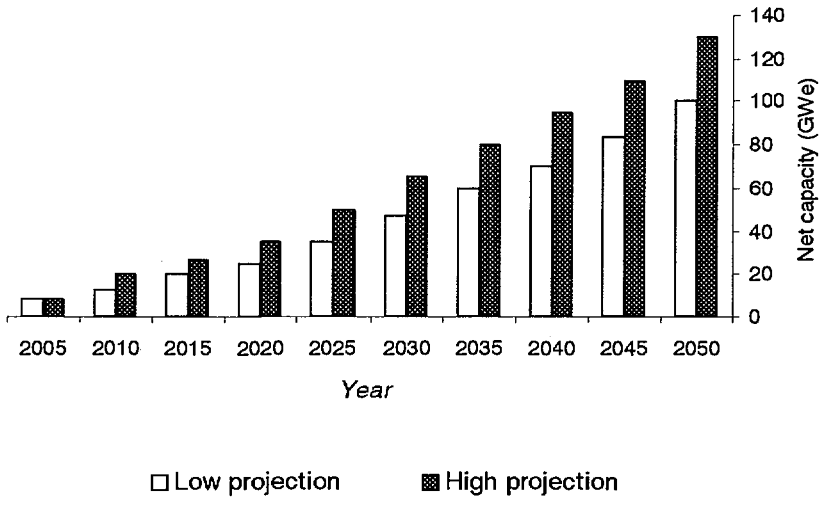
China abounds in energy resource but is not plentiful in term of per capital resource. Moreover, its energy resources are unevenly distributed: coal reserve, the chief energy resource, is concentrated in north, northeast and northwest China. The exploitation is limited by the lack of transportation capacity. Seventy percent of the hydropower potential is scattered in southeast China but only seven percent of the resource has been exploited. Electricity shortage is more and more a serious problem impeding the development of national economy. Hence nuclear energy, a newly developed alternative energy in China, is becoming an important supplement in the energy industry.

China's generation of nuclear electricity began as late as in early 1990s. The nuclear power industry is currently in an early stage with 2.1 million-kilowatt nuclear reactors in operation, which accounts only for 1% of the total power capacity. Nuclear power is being developed in the coastal provinces short of energy resource. At present four plants with 6.6 million kilowatts are under construction (Table 2). By the year 2005, the nuclear power in China will reach an installed capacity of 8.7 million-kilowatt.

The nuclear power industry is expected to expand in the coming century (Fig. 1). It is estimated that the annual growth rate of power generation has to be maintained at least by 6%, in order to meet the demand of the national economy development. According to the strategy of nuclear power development, about 150 nuclear reactors are foreseen for installation in the first half of the 21st century. This means that the nuclear energy industry will develop at an extension of three reactors per year.

Table 2 Nuclear Power in China

NPP	Location	Capacity (We)	Operation
Qinshan-1	Haiyan, Zhejiang	300	1991
Guandong-1	Daya Basin	2x900	1993, 1994
Qinshan-2	Haiyan, Zhejiang	2x600	2001, 2002
Guandong-2	Daya Basin	2x1000	2002
Qinshan-3	Haiyan, Zhejiang	2x700	2003
Lianyungang	Jiangsu	2x1000	2004



(Data Source: Reference 7)

Fig. 1 The nuclear power outlook in China

China has been developing nuclear programs for decades. It can be said that a good record of safe management of radwastes has been achieved. However, the generation of nuclear power gave rise to a structural change in the component of radwastes. This brings challenges for the exiting system of radwaste management. With the growth in programs of nuclear power, there will be an increase in challenges faced by radwaste management. Under this situation, an analysis on the long-term management of radwastes is necessary.

The range of subject matter is too broad to be covered in an article. This paper emphasizes in the administrative, legal and financial aspects of radwaste management.

1.2 Conceptual management of radwaste

Radwastes

The IAEA defines radwaste as " any material that contains or is contaminated with radionuclides at concentrations or radioactivity levels greater than the 'exempt quantities' established by the competent authorities and for which no use is foreseen."

According to the definition above, radwaste means radioactive material (solid, liquid or gases) that is no longer needed at the plant and can be disposed of.

Table 3 gives the general characteristics of waste categories.

Table 3 General characteristics of waste categories

Waste category	Important features
High level (long lived)	High beta-gamma Significant alpha High radiotoxicity High heat output
Intermediate level (long lived)	Intermediate beta-gamma Significant alpha Intermediate radiotoxicity Low heat output
Low level (long lived)	Low beta-gamma Significant alpha Low/Intermediate radiotoxicity Insignificant heat output
Intermediate level (short lived)	Intermediate beta-gamma Insignificant alpha Intermediate radiotoxicity Low heat output
Low level (short lived)	Low beta-gamma Insignificant alpha Low radiotoxicity Insignificant heat output

Management

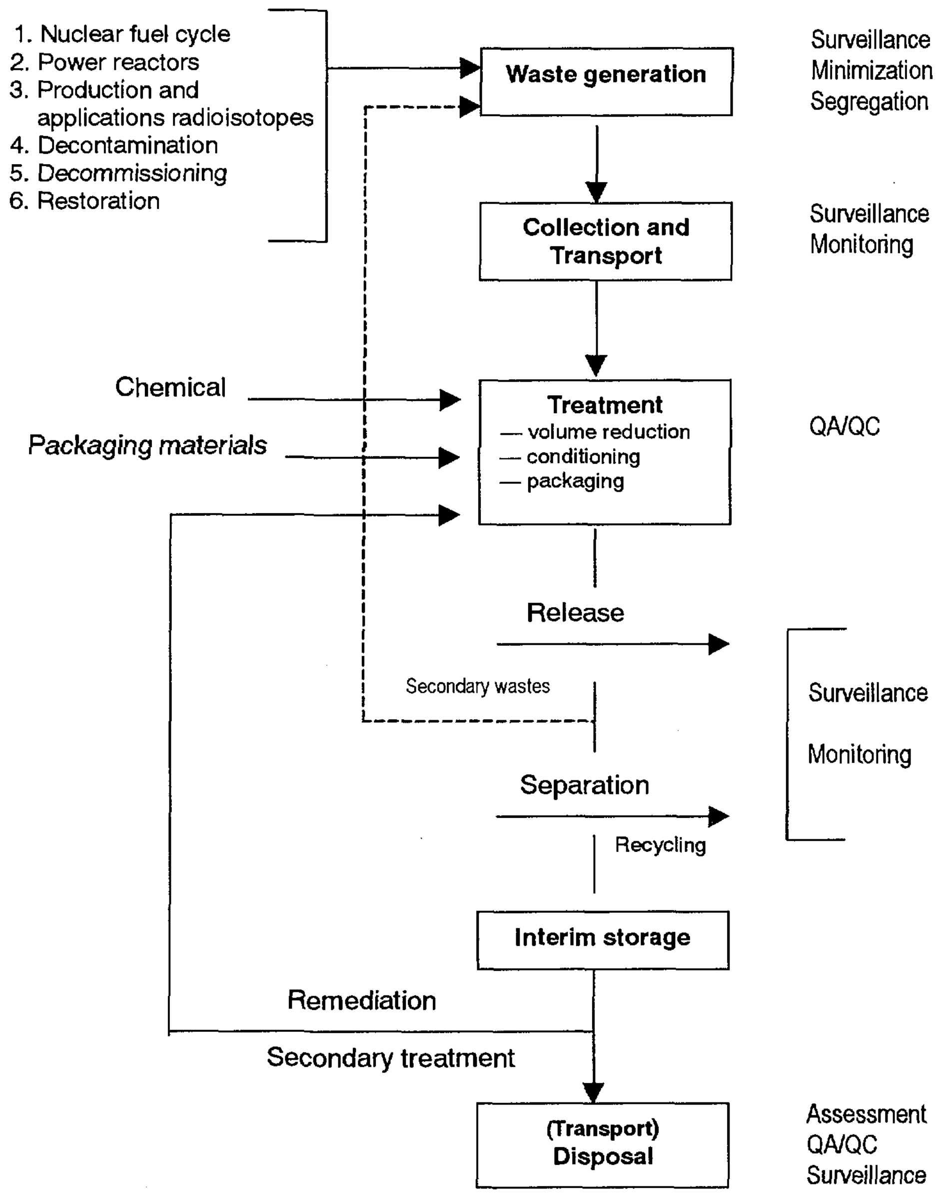
Radwaste management refers to all administrative and operational activities that are involved in the handling, treatment, conditioning, transportation, storage and disposal of waste.

The primary objective in the management of radwastes is to protect current and future generations from unacceptable exposures to radiation from man-made radioactive materials.

In addition to protecting people, now and in the future, there is a need to protect the natural environment. It can be achieved by two ways:

- By containment, generally using a combination of man-made and natural barrier to achieve effective isolation of the wastes till the radioactivity has decayed to levels that no longer pose any unacceptable risk;
- By dispersal, ensuring that the wastes become so dilute in the environment that they do not present any unacceptable risk to people at any time by any pathway.

Fig. 2 illustrates the sequence of subsystems comprising radwaste management system.



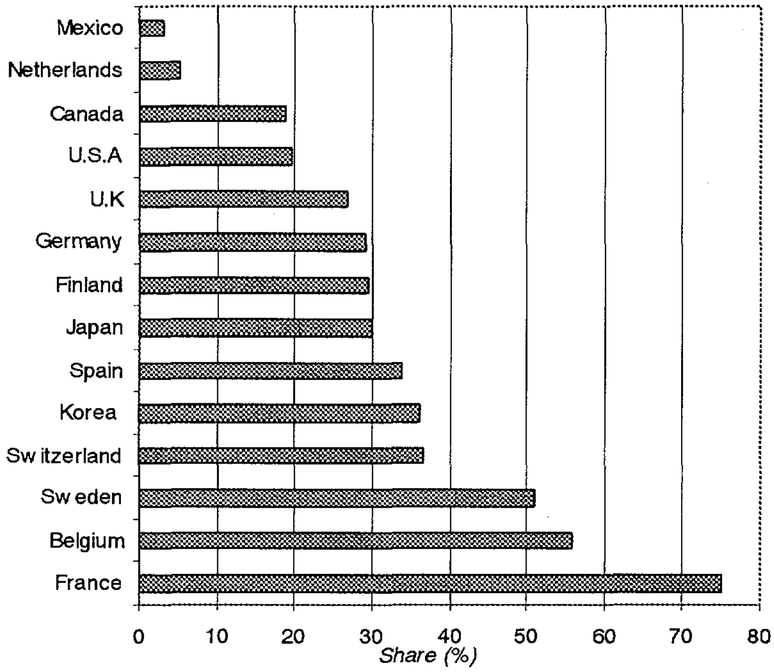
(1) Waste generation: where, the generation process and the quality of the operations are the determining factors.
(2) Collection and transport: collection of wastes offers some opportunities to monitor the exact nature of the wastes and to decide further segregation.
(3) Treatment, conditioning and packaging: the main purpose includes volume reduction, physicochemical and mechanical stabilization of the waste, in view of its confinement in the final repository.
(4) Disposal: several types of geological environment can be suitable and safe for disposal. However, since these environments may show different properties, waste form and disposal environment have to be examined.

Fig. 2 General radioactive waste management scheme

1.3 Strategies of radwaste management in NEA* countries

Nuclear power

In NEA countries, nuclear energy has become the main source of electricity or is an important component of their generating capacities (Fig. 3).



(Data Source: Reference 6)

Fig. 3 Contributions of nuclear energy in NEA countries

Meanwhile, there is a growth in the volume of radwastes. For the year 1990, the total volume of radwastes produced in the OECD countries was 170,000m^3. By the year 2025, it is expected to reach 995,000m^3.

The growing accumulation of radwastes has led most countries to establish waste management strategies, and to take the necessary steps for their implementation. The programs of radwaste management are well in progress in most NEA countries.

Radwaste management

Table 4 summaries the strategies of radwaste management in NEA countries.

* the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD)

Table 4 The national radwaste management in NEA countries

Country	Agency	Responsibility	Strategy
Belgium	National Agency for Radwastes and Enriched Fissile Material (ONDRAF)	Managing all radwastes produced in Belgium and a special waste fund.	Wastes other than reprocessing wastes are conditioned. All wastes will be stored at Mol-Dessel until appropriate disposal facilities are developed. Short-lived low level wastes will be disposed of above ground level or deep underground. Long-lived medium level and high level wastes will be disposed of deep under ground.
Canada	Atomic Energy Control Board (AECB) Atomic Energy of Canada Limited. (AECL) Low-level Radwaste management Office (LLRWMO)	Nuclear regulatory agency. Research in radwaste management. Cleaning up of historic low-level waste.	All wastes from nuclear power generation are stored pending the development of permanent disposal facilities. Spent fuel will be disposed of 500 to 1000m underground in the rock of the Canadian shield. Ontario Hydro and AECL are examining options for the disposal of other long-lived wastes.
Finland	Ministry of Trade and Industry (MTI) Finnish Center for Radiation and Nuclear Safety (FCRNS)	The main authority. Control of nuclear safety and waste management.	Operating wastes (low and medium level) are conditioned and stored on site at the power stations. Repositories for these wastes are either in operation or under construction. Spent fuel will be disposed of in a deep underground repository from 2020 on.
France	National Agency for Radwaste management (ANDRA) Federal Ministry for The Environment, Nature Conservation and Nuclear Safety (BMU)	All long-term operations associated with radwaste management. The competent authority for radwaste management.	Short-lived wastes are disposed of in surface repositories (Centre de 1' Aube). Deep geological disposal of long-lived high level wastes is expected to be commissioned before 2020.

Table 4 (continued)

Country	Agency	Responsibility	Strategy
Germany	Federal Ministry for Environment, Natural Conservation and Nuclear Safety (BMU) Federal Office for Radiation Protection (BfS)	The competant authority for radwaste management Planning, construction and operation of repositories for radwastes.	All categories of waste will be disposed of deep underground, after an appropriate period of storage. The steps are: 1) interim storage; 2) reprocessing or conditioning; and 3) disposal.
Italy	National Agency for Environmental Protection (ANPA) National Agency for New Technologies, Energy and Environment (ENEA)	Oversees the radwaste management, serving as regulator. R&D activities radwastes and for disposal.	Power and experimental fuel cycle wastes are stored at their point of origin. Medicine, industry and research wastes are collected for temporary storage by NUCLECO and other private operators. Work has been carried out on ultimate disposal.
Japan	Atomic Energy Bureau (AEB) of the Science and Technology Agency (STA) Atomic Energy Commission (AEC)	Policy oversight of radwastes programs AEC and AEB Co-ordinate the research and development activities and make the concrete plans for execution in the future and so on.	1) LLW are treated as the responsibility of the private sector. They must be disposed when the technical method of disposal has been determined by the government on the basis of experimental disposal. LLW from power plants is stored at plant sites and disposed of in the nationwide near-surface facility at Rokkasho-mura opened in 1992 and operated by Japan Nuclear Fuel Limited (JNFL). The government is responsible for establishing safety criteria, guidelines and regulations for the shallow land disposal. The waste producers are responsible for carrying out and funding such disposals. Short-lived medical radioisotope waste was gathered at seven regional storehouses starting in 1961, but in 1987 a centralized processing and
	Nuclear Safety Commission (NSC) Nuclear Safety Bureau (NSB) of STA	NSC and NBS provide regulations including safety guidelines and criteria and examine safety assessments, etc.	
	Ministry of International Trade and Industry (MITI)	Oversees radwastes initiated from private firms.	
	Japan Atomic Energy Research Institute (JAERI) Power Reactor and Nuclear Fuel	Supporting organizations	

Table 4 (continued)

Country	Agency	Responsibility	Strategy
Japan	Development Corporation (PNC) Radioactive Wastes Management Center (RWMC) Japan Nuclear Fuel Limited (JNFL).	Supporting organizations	storage site was opened by the Japan Radioisotope Association at its Takizawa Laboratory in Iwate Prefecture. 2) The government takes overall responsibility of HLW for appropriate and steady implementation of the disposal program as well as enacting any laws or policies required in this connection. The electricity utilities are required to secure the funds for disposal and to take responsibility for the necessary research and development. HLW resulting from reprocessing will be vitrified, and stored for 30 ~ 50 years for cooling, then disposed of in a geologic formation at a site to be chosen later, starting at some point a few decades into the next century. Liquid high-level wastes are stored at Tokai reprocessing plant, awaiting the start-up of the vitrifying plant. PNC is required to conduct research and development for geological disposal and make geological environmental surveys. The national policy published in 1992 requires an organization to be set up with responsibilities for HLW site investigation, selection and characterization and for demonstrating disposal technology at the candidate site. 3) Spent fuel from reactors is now being reprocessed at Tokai facility operated by the Power Reactor and Nuclear Fuel Development Corporation (PNC), and also in France and the UK. There is also a commercial reprocessing plant at Rokkasho-

Table 4 (continued)

Country	Agency	Responsibility	Strategy
			mura that is not yet in service. Test operation would begin after all assessments are complete. Full-scale reprocessing is tentatively scheduled to begin in 1999.
Korea	Atomic Energy Commission (AEC) Ministry of Science and Technology (MOST) Nuclear Environment Management Center (NEMC)	Policy-making. Nuclear R&D, nuclear safety, and management of radwastes. Carry out the national radwaste management program.	Low and medium wastes are to be disposed of in a rock -cavern-type of repository on a coastal area or on an island. Spent fuel is to be stored in a central interim storage facility.
Mexico	Federal Electricity Commission (CFE) National Commission of Nuclear Safety and Safeguards (CNSNS) Center Organization for Radwastes (COVRA)	Managing the radwastes from the nuclear power plants. Regulatory activities. All kinds of nuclear wastes.	A permanent repository is to be developed for all low and medium wastes including those from medical and industrial activities.
Netherlands	National Radioactive Waste Company (COVER) Integral National Research Program on Nuclear Waste (ILONA)	All kinds of radwastes Carrying out research on the disposal of radwastes.	Government policy is to create facilities for the long-term storage of all highly toxic wastes that will allow retrieval of the wastes. All radwastes are therefore to be stored centrally, for a period of between 50 and 100 years.
Spain	National Radwastes Company (ENRESA) Ministry for Industry and Energy (MIE) Nuclear Safety Council (CSN)	All activities related to the management of radwastes. Control of nuclear activities, granting the licenses and authorizations. The competent body in charge of nuclear safety and radiological protection.	Low and medium wastes are being disposed of at the near surface repository at EL Cabri. Spent fuel and vitrified high level wastes will be disposed of deep underground.

Table 4 (continued)

Country	Agency	Responsibility	Strategy
Sweden	Swedish Nuclear Fuel and Waste Management Company (SKB) National Co-operative for Disposal of Radwastes (NAGRA)	Managing the radwastes from nuclear utilities. Disposing the wastes from medicine, industry and research.	Operational wastes are being disposed of at the final repository, SFR, at Forsmark. Spent fuel and long lived radioactive residues will be disposed of deep underground after a period of interim storage.
Switzerland	Co-operative for Nuclear Waste Management (GNW) Health and Safety Executive (HSE)	Implements the low and medium level waste repository. Regulates nuclear safety and the accumulation of radwastes.	All radwastes are to be disposed of in repositories in suitable geological formations. Two repository types are envisaged, one primarily for short-lived wastes and one for high level and long-lived medium-level wastes.
U. K	Secretaries of State for Environment, Scotland and Wales (SSESW) Her Majesty's Inspectorate of Pollution (HMIP) Health and Safety Executive (HSE)	Policy-maker. Ensuring compliance with the national management policy. Regulating nuclear safety and accumulation on nuclear licensed sites; HSE and HMIP cooperate to ensure the Implementation of national radwaste management.	Solid low level wastes are being disposed of in near surface facilities at Drigg and Dounreay. An underground deep disposal facility for stocks and future raisings of medium level wastes and selected low level wastes is to be developed. High level wastes from reprocessing will be stored, normally in vitrified form, for at least 50 years. Wastes from the reprocessing of fuel from BNFL's overseas customers will be return to the country of origin.
U.S.A	Department of Energy (DOE) Nuclear Regulatory Commission (NRC) Environmental Protection Agency (EPA)	Wastes storage and disposal Regulation and licensing. Protection standards.	Low level wastes disposal remains the responsibility of each State within which the wastes arise. Several shallow land burial sites are currently in use. System for the disposal of transuranic and high level wastes are to be developed by DOA. A Monitored Retrievable Storage (MRC) facility is authorized for interim storage of spent fuel, but a site remains to be identified.

2. Radwaste management in China

2.1 Waste characteristics

1) Source

The major source of radwastes is the nuclear fuel cycle, which had centered mainly on military programs in the past but now includes civil nuclear program e.g. nuclear power plants. A small amount of low and intermediate level wastes (LL/ILW) is produced during the application of nuclear technology and the production of isotopes.

The waste source is dominantly shared by China National Nuclear Corporation (CNNC), Ministry of Metallurgy Industry and Heath Ministry as shown in Fig. 4.

For the convenience of management, radwastes are divided into three parts:

- Installation waste ---- produced from nuclear installations and belongs to the wastes of nuclear energy development. It includes reprocessing HLW, spent fuels, LL/ILW, and remainings (produced during operation or decommissioning of reactors). The source concentrates in CNNC (CNNC owns uranium mines and plants of milling, enriching, element producing, reprocessing, and nuclear power plants as well as research reactors). Apart from CNNC, some other owners of nuclear installations also share a minor source.
- Accompanying mineral waste ---- comes from Ministry of Metallurgy or other mineral-departments concerned. The wastes are generated in mining or milling of the non-uranium mines accompanying with uranium and thorium.
- Application waste ---- only a small quantity, arises from certain organizations using nuclear materials in medicine, agriculture, research and industry (the source centers mainly in Health Ministry).

2) Classification

In China, three categories of radwastes are defined as follows:

- Low-level wastes (LLW): the wastes emit so little radiation that they need no special shielding and can be handled using simple protective measures such as rubber gloves.
- High-level wastes (HLW): are those in which the temperature may rise significantly as a result of their radioactivity. They need heavy shielding and remote-handing devices.
- Intermediate-level wastes (ILW): are those that lie between HLW and LLW categories. They need shielding generally, metal or concrete, and remote-handing devices to protect people from the radiation they emit.

The classifications of radwastes in China are listed in Table 5.

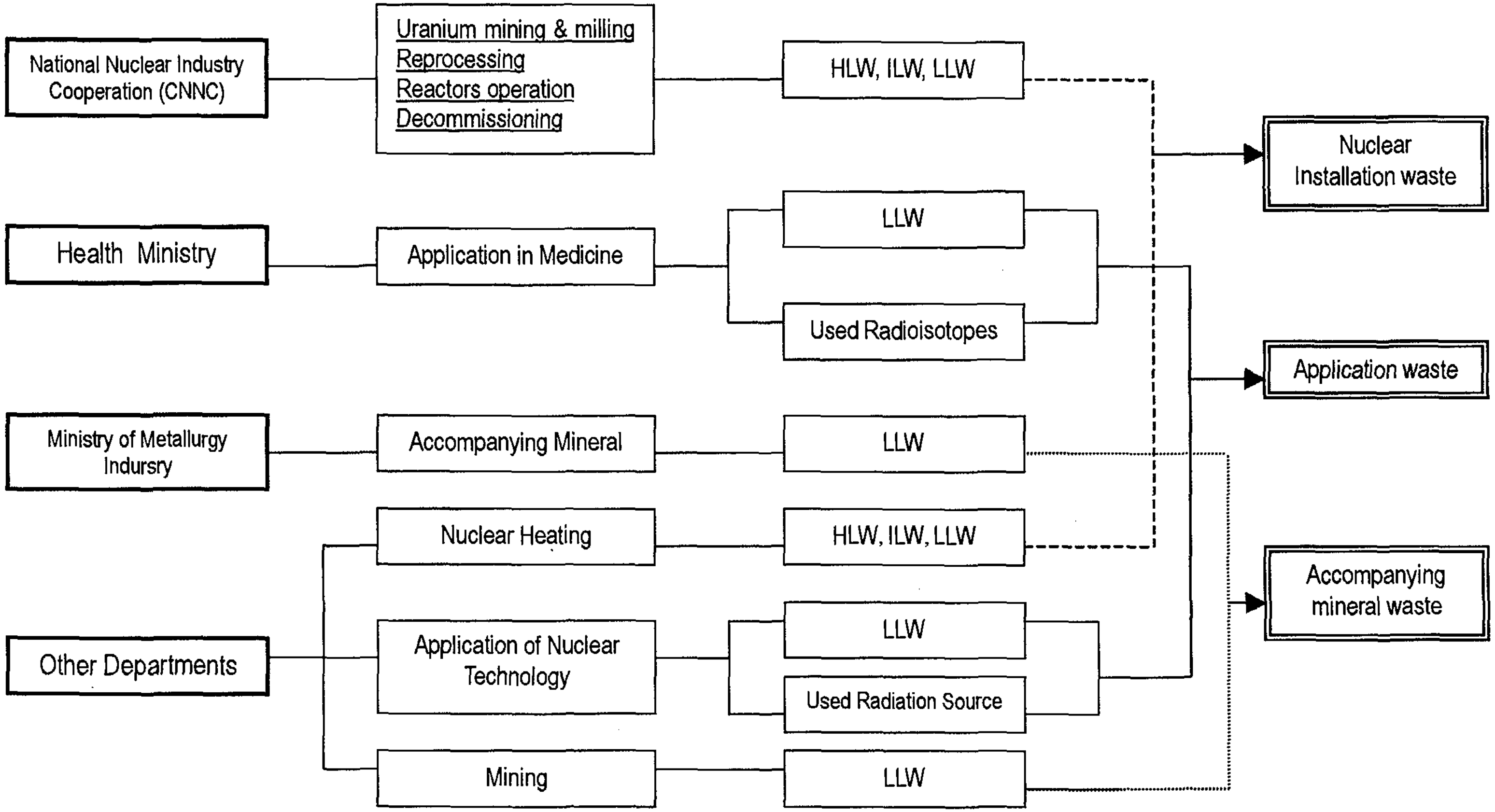


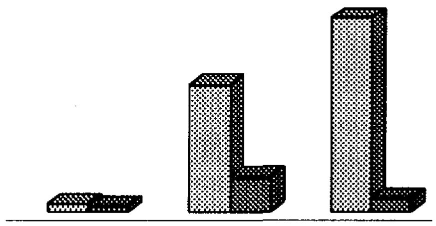
Fig. 4 Sources of radioactive waste in China

Table 5 Classification of radwastes

	Category	Half-life	Activity
Solid (Ci/kg)	Low-level	<60 days	$2\times10^{-6} \sim 10^{-3}$
		>60days	$2\times10^{-6} \sim 10^{-4}$
	Intermediate-level	<60 days	$10^{-3} \sim 10$
		60 days ~ 5 years	$10^{-4} \sim 10$
		5 ~ 30 years	$10^{-4} \sim 1$
		>30 years	$10^{-4} \sim 10^{-1}$
	High-level	<5 years	10
		5 ~ 30 years	1
		>30 years	10^{-1}
Liquid (Ci/l)	Weak-level		$<10^{-8}$
	Low-level		$10^{-8} \sim 10^{-5}$
	Intermediate-level		$10^{-5} \sim 10^{-1}$
	High-level		$>10^{-1}$
	Transuranics	≥20 years	10^{-4}

3) Amount

A considerable amount of radwastes has been accumulated over the past decades. Fig. 5 shows the estimated amount of radwastes generated in national defense, research and application fields. The wastes are being stored in facilities and waiting for treatment and final disposal. In addition, about 3.7×10^{7} tons of tailings and 4.72×10^{7} tons of barren rock are estimated to have been accumulated in mining and milling.

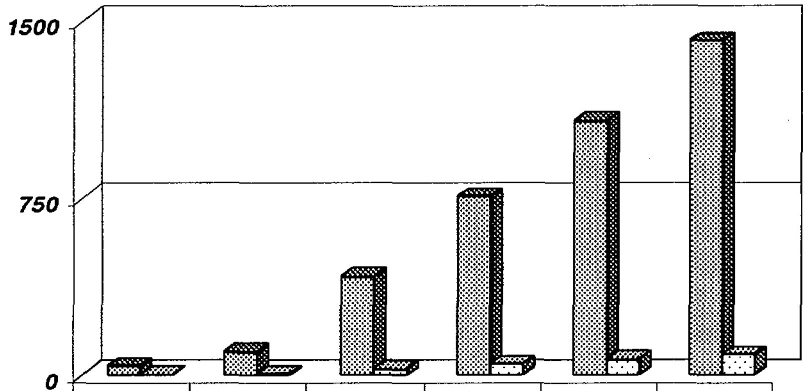


	HLW	ILW	LLW
Liquid (m3)	*1200*	*21000*	*32000*
Solid (t)	*960*	*5700*	*2300*

(Data Source: Reference 10)

Fig. 5 Amount of accumulative radwastes in China

So far, there are three nuclear power reactors in operation. Fig. 6 shows the estimated volume of wastes from nuclear power plants as of 1997. Those wastes are being stored in the temporary facilities within nuclear power plants.



	1992	1993	1994	1995	1996	1997
LL/ILW (m3)	40	100	420	760	1080	1420
HLW (m3)	3	7	27	48	69	90

Fig. 6 Estimated volume of accumulative radwastes from nuclear power plants

2.2 Management

Since the early 1980s, China has steadily developed technology and policy concerning radwaste management. The treatment technology of radwastes, which generally satisfies the demand of nuclear industry, has been developed. The management system is being improved.

The current national strategy involves safe storage of the accumulative wastes, development of disposal facilities and a continuing program of research and assessment to ensure that each type of waste is managed in an appropriate way.

Fig.7 illustrates the scheme of radwaste management in China.

2.2.1 Principle

The basic principles for radwaste management are established as follows:

- The radwastes are produced as low as possible;
- Restricting release of radionuclides into the environment and protecting the environment;
- Implementing efficient volume-reduction and optimum solidification;
- Keeping exposure to public and professional workers as low as reasonably achievable;
- Restricting burdens on later generations, limiting the influence on health of later generations to current acceptable level;
- Implementing feasibility study report, safety analysis report and environment impact assessment report system;
- Establishing licensing system;

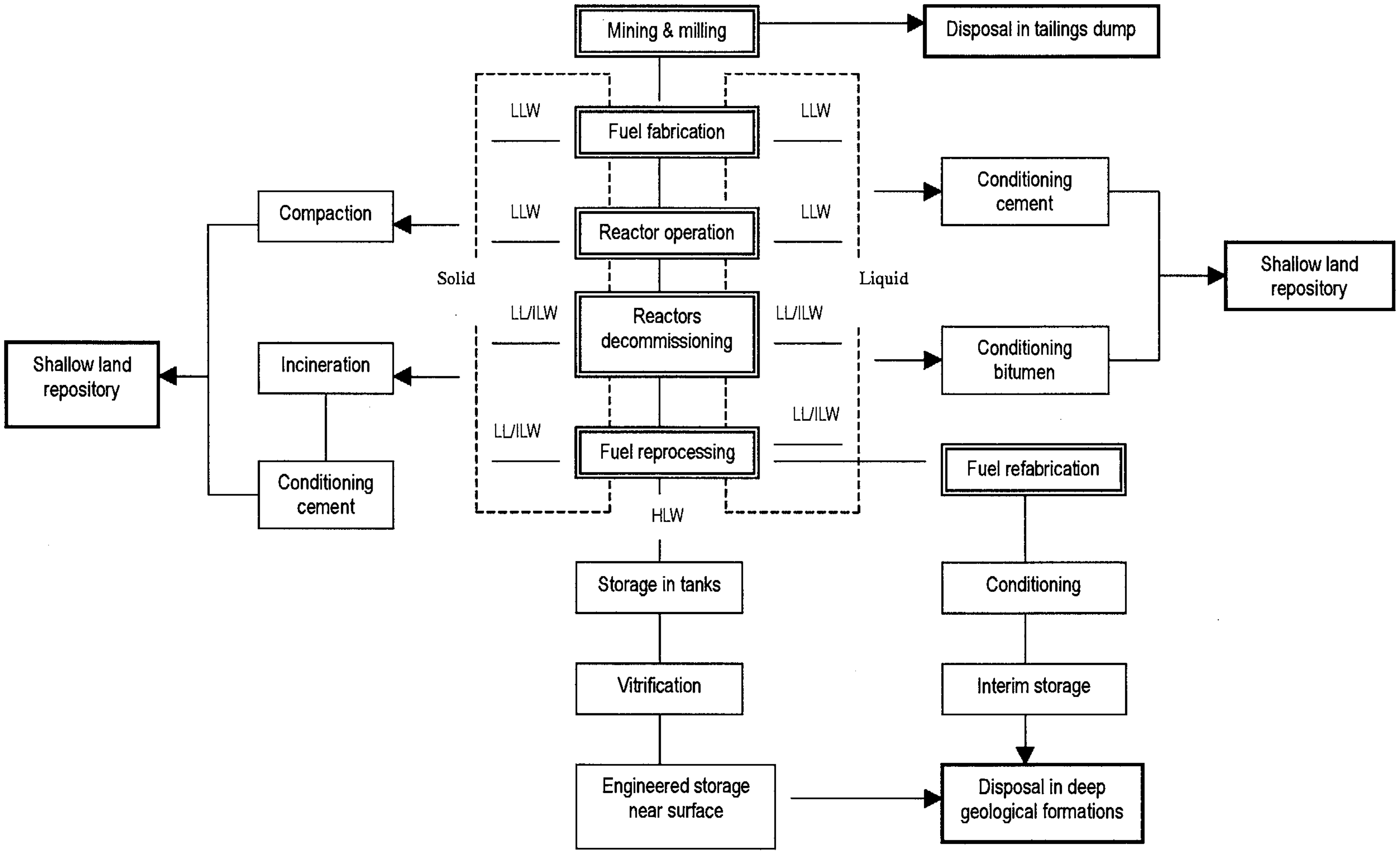


Fig. 7 Scheme of radioactive waste management program in China

- Establishing quality assurance and control system as well as emergency response system;
- Establishing regulation and standard system tallying with advanced international rules;
- Establishing administrative organization and operational organization;
- Separating administrative organization and operational organization to ensure the independent supervision and the evaluation of the radwaste management.

2.2.2 Strategy

The strategy for long-term management can be broadly stated as follows:

- Any discharge of radwastes to the environment should be as low as reasonably achievable.
- Solid wastes, and solidified wastes resulting from conditioning of waste concentrates or liquid wastes generated during operation of reactors and research laboratories are to be employed in shallow land. Low and intermediate level wastes from operation of fuel reprocessing plants are also permitted in shallow land repositories.
- High level liquid wastes from fuel reprocessing facilities, which are initially stored in near surface engineered storage facilities, with appropriate cooling and surveillance provisions for a period of decades.
- Disposal of high level vitrified and cooled wastes will be in deep geological formations.

1) LL/ILW

The policy of regional shallow land repository sites on LL/ILW was promulgated by the government in 1992. Meanwhile, Ever Clean Environment Engineering Corp. (ECEEC) is authorized to take charge of the operation business.

The main points of regional repository sites policy are as follows:

- Establishing the regional disposal repository and disposing of the wastes as near the origin as possible. The repository should be selected in the favorable location, taking into account the factors of safety, economy, technology and society, and adjoining to existing or planned large-scale nuclear enterprises. It serves not only the nuclear industry and nuclear power plant, but also the nuclear application users;
- Construction of the low and intermediate level radwastes repository shall be regarded as a prerequisite for development of nuclear power and as an important content for the examination of safety analysis and environmental impact assessment of nuclear facilities by the environment protection and safety supervision authorities;
- When new nuclear power plants and nuclear facilities are put into operation, the waste disposal shall be taken into consideration. The temporary storage of

LLW/ILW in situ is limited to be five years;

- It is forbidden for any institution to manage and own LLW/ILW repository, or to use its interim storage facilities as a permanent one, and it is stipulated that all the LLW/ILW must be collected and disposed of at a regional disposal repository with the state license.

The site selection for disposal sites of LL/LIW is conducted in such steps:

- Investigation of files, finding out survey area;
- Field survey and recommendation of candidates;
- Primary reviewing of candidates;
- Further investigation, fetching all the data and materials needed;
- Submitting the feasibility study report, safety analysis report and environment impact assessment report;
- Settlement of disposal site.

Fig. 8 illustrates the conceptual phases of managing system of regional disposal for LL/ILW in China.

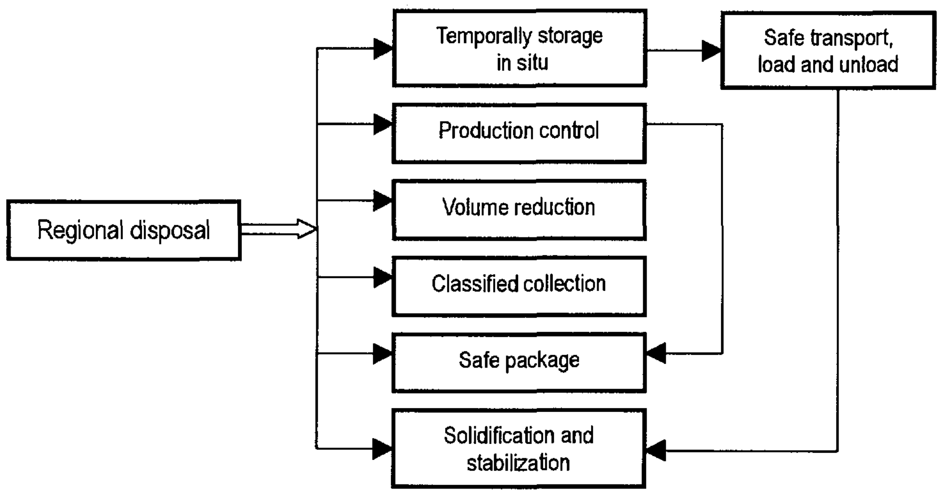


Fig. 8 System of regional disposal for LL/ILW

Table 6 lists the four regional disposal sites for LL/ILW in China.

Liquid LL/ILW from reprocessing are stored in carbon steel tanks, and will be solidified with cement and bitumen.

Weak-level liquid waste and any other material with less activity than the lower threshold for low-level waste are not considered to require the kind of storage and disposal techniques needed for radwastes.

Table 6 Regional repository sites for LL/ILW

(* Total capacity, ** First stage capacity.)

Repository	Status
South China Disposal Repository (240,000 m^3 *, 80,000 m^3**)	The site was chosen in 1993. The major waste source is Daya Bay nuclear power station. The repository design is under construction and the opening of the repository is expected in 1998.
East China Disposal Repository (300,000 m^3*, 80,000 m^3**)	The site selection has been performed by CNNC. Seventeen suitable areas were found according to the geological map, and 21 potential sites were surveyed on the site field. Among them 5 candidates were recommended, such as one shallow land disposal site, two abandoned Pb-Zn mines, one abandoned uranium mine and one artificial cave at Qinshan, Zhejiang province. Repository is planned to open in 2003.
Northwest China Disposal Repository (200,~300,000 m^3*, 60,000 m^3**)	Located in Gobi in Gansu province with a low population density and rare rainfall, it has good condition for disposal. The repository began receiving radwastes in 1997.
Southwest China Disposal Repository	Thirty-eight preliminary disposal sites have been selected on the geological map. Ten of them were surveyed on the site field. At least 3 candidates were chosen for further investigation. Repository is expected to be available in 10~20 years.

2) HLW

As for HLW, the present policy is that storing wastes temporarily and safely, solidifying liquid wastes as soon as possible, meanwhile conducting research activities relating to geologic disposal so as to make necessary technical provisions for the deep geologic disposal decades years after.

Spent fuel from reactors is reprocessed.

Liquid HLW from reprocessing is stored in stainless steel tanks, and will be solidified with borosilicate glass.

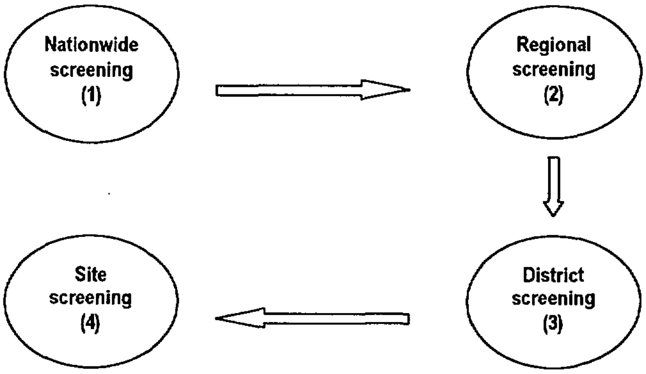
Plans for disposal of HLW and transuranics are being centered on a nationwide investigation of granite-bearing sites for repository consideration. The research related to disposal is in progress.

CNNC developed a program for deep geological disposal in 1985. The program is divided into four different phases as shown in Table 7.

Table 7 Schedule of HLW disposal

Phase	Time
Site selection and site characterization	1985 ~ 2025
Repository design	2025 ~ 2029
Repository construction	2024 ~ 2050
Repository operation	2051~

The site selection process includes four screening stages:



The third stage, district screening, had already been achieved in 1989. Present work focuses on the Beishan area in northwest China. Granite is considered the primary candidate for a host rock. Different kinds of geological characteristics have been studied, and according to the crustal stability the most promising districts have been identified in Qinhongquan and Jiujin, in the southern part of the Beishan folded belt. Investigations are continuing in these areas.

3) Application waste

The management policy on application waste was issued in 1987. The main points are as follows:

- All the organizations (industry, agriculture, medicine, R&D, etc.) producing radwastes and radioisotopes sources should abide by the regulations concerned;
- Setting up special organs and providing professional in the provincial departments of environment protection for taking charge of the management of supervision and environmental control;
- The organizations producing radwastes should reduce the amount and volume of the radwastes as much as possible. The radwastes and spent radioisotope sources must be collected to the signified place (facilities) for a centralized management and disposal. It is forbidden that any organization conducts any disposal activity

in the environment.

- Maintaining regular survey and monitoring activities for the storing facilities as well as the environment.

4) Accompanying mineral waste

The main points of the policy for managing the accompanying mineral wastes are:

- The radwastes arising from mining can be stored in the tailing dumps;
- The small volume of radwastes produced in the processing of rare-element mineral should be collected to the storing place for a temporal storage. They are planned to be transported to the nearby tailing dumps of installation waste or tailing dumps of mineral-accompanying waste for an eventual storage.

2.2.3 Institutional control

1) Responsibilities

At government level, responsibility for radwaste management lies with China National Environmental Protection Agency (NEPA).

NEPA's tasks in nuclear field are:

- Taking supervision responsibility of radwastes treatment and disposal;
- Taking part in emergency response of nuclear accident;
- Establishing regulations and standards of nuclear environmental protection as well as principles of radwaste management.
- Reviewing and approving the environmental impact assessment report of NPP;
- Inspecting the simultaneous construction of NPP with auxiliary projects of radwastes treatment and disposal as well as issuing effluents discharge license.

China National Atomic Energy Agency [Domestic name: China National Nuclear Corporation (CNNC)] is responsible for the safe management, disposal, research and development.

Responsibility for the control of nuclear safety, including high-level radwaste management, belongs to China National Nuclear Safety Administration (CNNSA).

2) Implementation

Under the <<Environmental Protection Law>>, the environmental protection departments are responsible for the centralized supervision, in the meantime, the content departments producing wastes should take the responsibility of management of their wastes. According to this principle, during the carrying out the policy of radwaste management and implementation of management activities, both the environmental protection departments and the producers of radwastes cooperate to fulfill the safe management.

In order to achieve the effective management, a crisscross structure has been created.

(1) To reach the objective of protecting environment efficiently i.e. preventing radwastes from releasing into the environment, radwastes are managed from two sides:

- Vertically, safely controlling all the stages of radwaste management, including waste generation, treatment, storage, transport and final disposal.
- Horizontally, adopting the necessary procedures in the each stage of management above. The procedures include: a) the setting up of standards, b) the examination and approval of the analysis reports on environmental effects, c) in situ investigation, and d) environmental monitoring (Fig. 11).

(2) Considering the nuclear safety and security, environmental protection departments should cooperate with the National Nuclear Safety Administration and the Ministry of Public Security in the management of HLW, spent fuel and application wastes (Fig. 10).

(3) The approaches of management vary from the categories of radwastes (Fig. 12 ~ Fig. 15).

Fig.9 ~ Fig. 15 graphically illustrate this management system of radwastes.

Now, the management of application radwaste is well being implemented as the procedures shown in Fig. 14. The management of installation radwaste, LLW and accompanying mineral radwaste is partially executed as shown in the figures. The practice has proved that the environmental policy of managing radwastes is practicable and efficient.

2.2.4 Financing

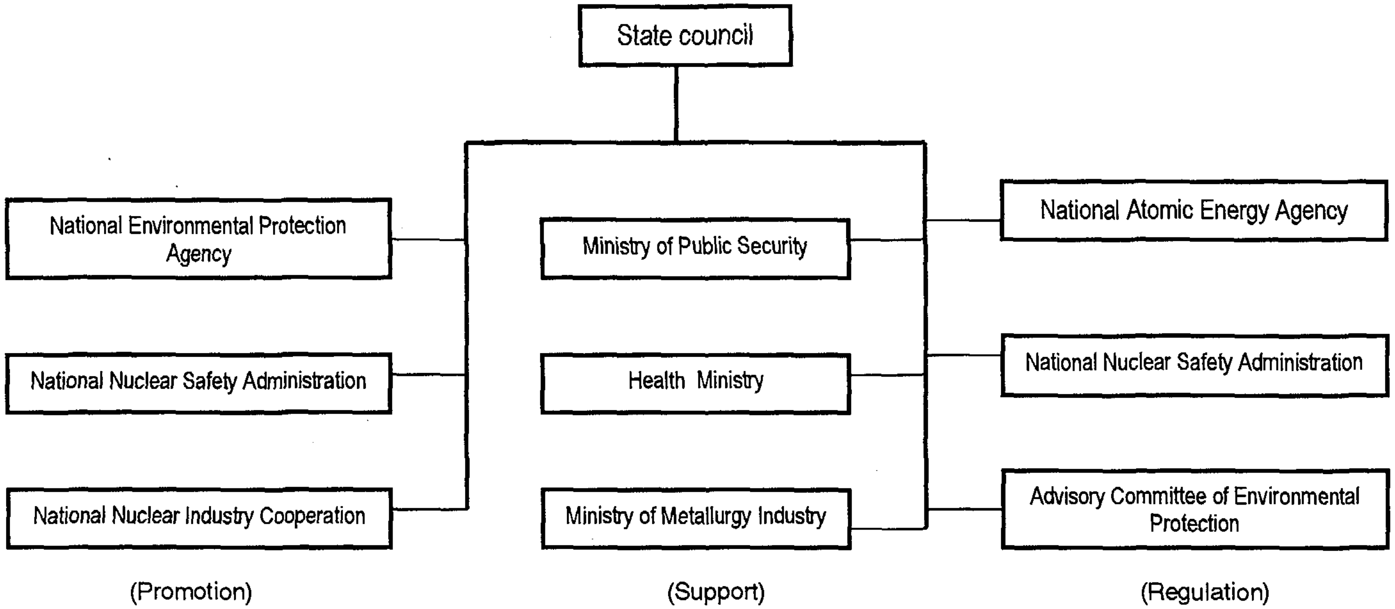
It is a disadvantage that, unlike many other countries, no financing system of radwaste management exits till now in China.

The management costs of the military radwastes are born from the State budget.

As for the management cost of LL/ILW from nuclear power plants, the government issued:

- The initial funds for the construction of sites should be disposal settled. The funds will be shared by both the state bank (as a long-term load) and the plant owners (collected from the construction funds of the reactors).
- The repository sites should be operated with a charge-service.

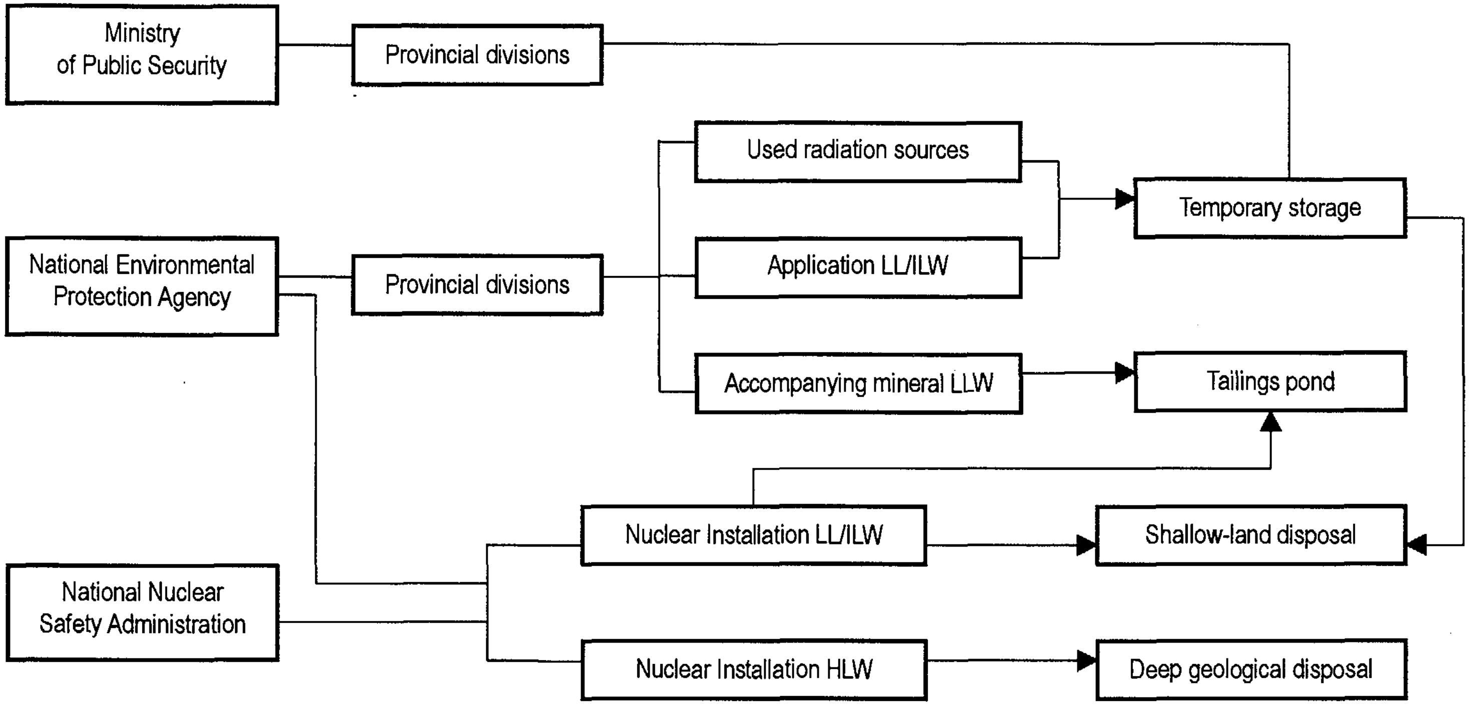
At present, the capital investment of LL/LIW disposal repositories is collected from CNNC, the local government (including NPP) and loans from the bank. The income collected from the foundation and radwastes disposal charge will be used for repaying the loans, maintaining the operation and for expenses of post-enclosure supervision.



This structure comprises three sides: the promotion, regulation and support sides:

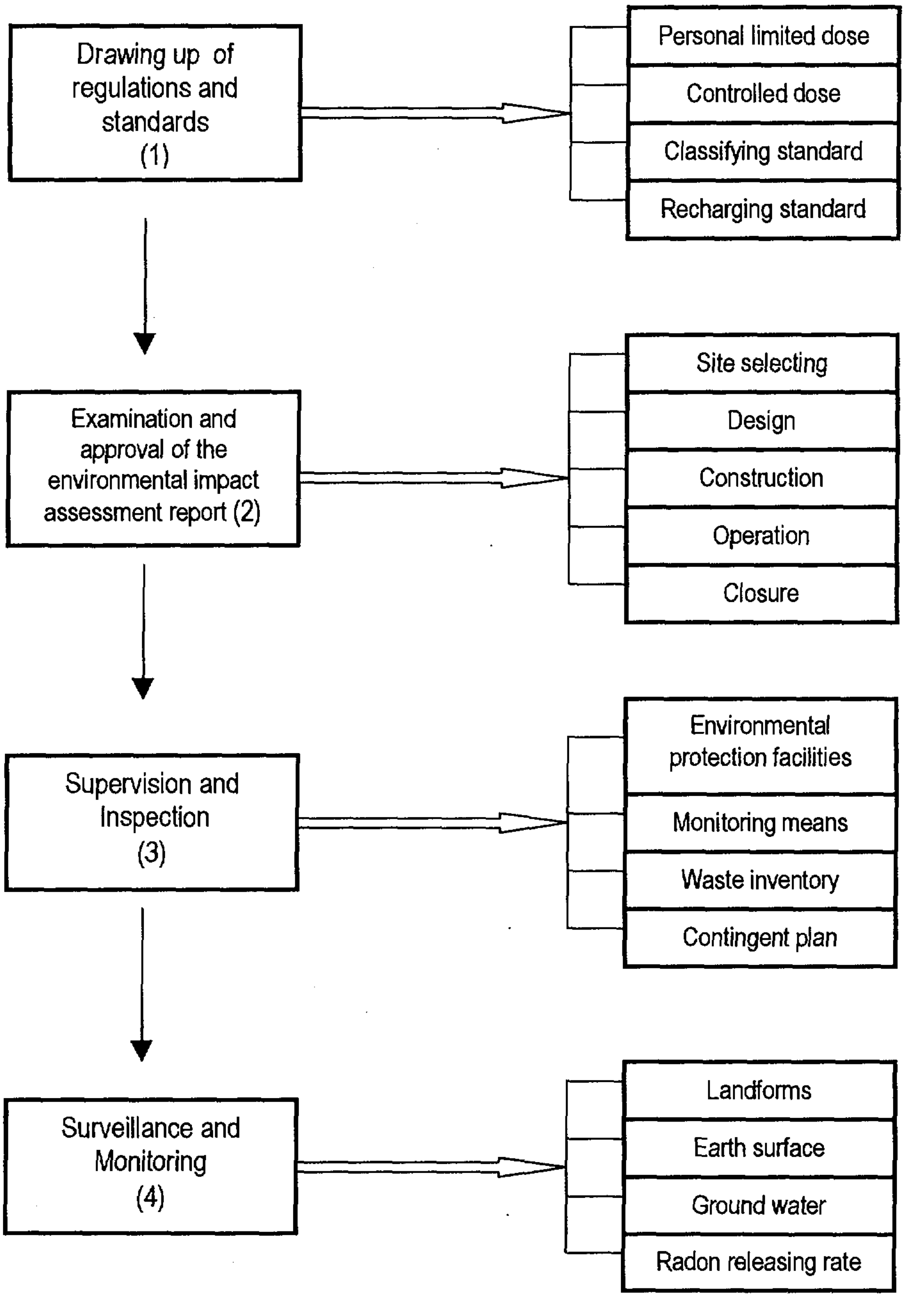
- The promotion side, including the National Environmental Protection Agency, the National Nuclear Safety Administration and the National Nuclear Industry Cooperation, co-ordinates the implementation activities and makes the concrete plans for execution in the future and so on.
- The regulation side, including the National Nuclear Safety Administration, the National Atomic Energy Agency, and Advisory Committee of Environmental Protection, provides management regulations, safety guidelines and criteria etc.
- The support side, including the other waste producers such as the Health Ministry, Ministry of Metallurgy Industry etc. and Ministry of Public Security, participates the management or provides assistance in the implementation of management.

Fig. 9 Structure of Radioactive Waste Management in China



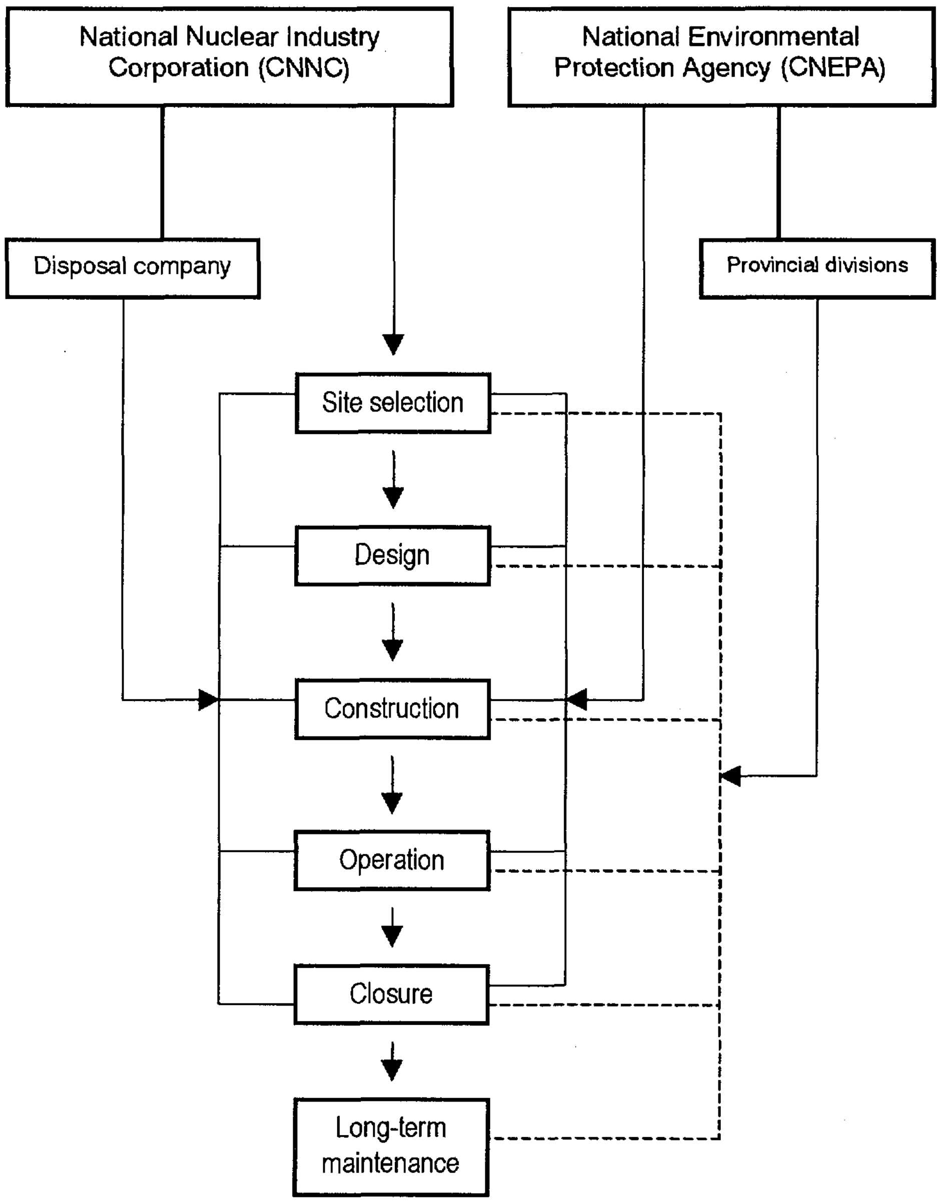
The figure generally illustrates the administrative association among the National Nuclear Safety Administration, National Environmental Protection Agency and Ministry of Public Security in the management of radwastes disposal. It is further illustrated in the Fig. 12 ~ Fig. 15.

Fig. 10 The management of radwastes disposal in China



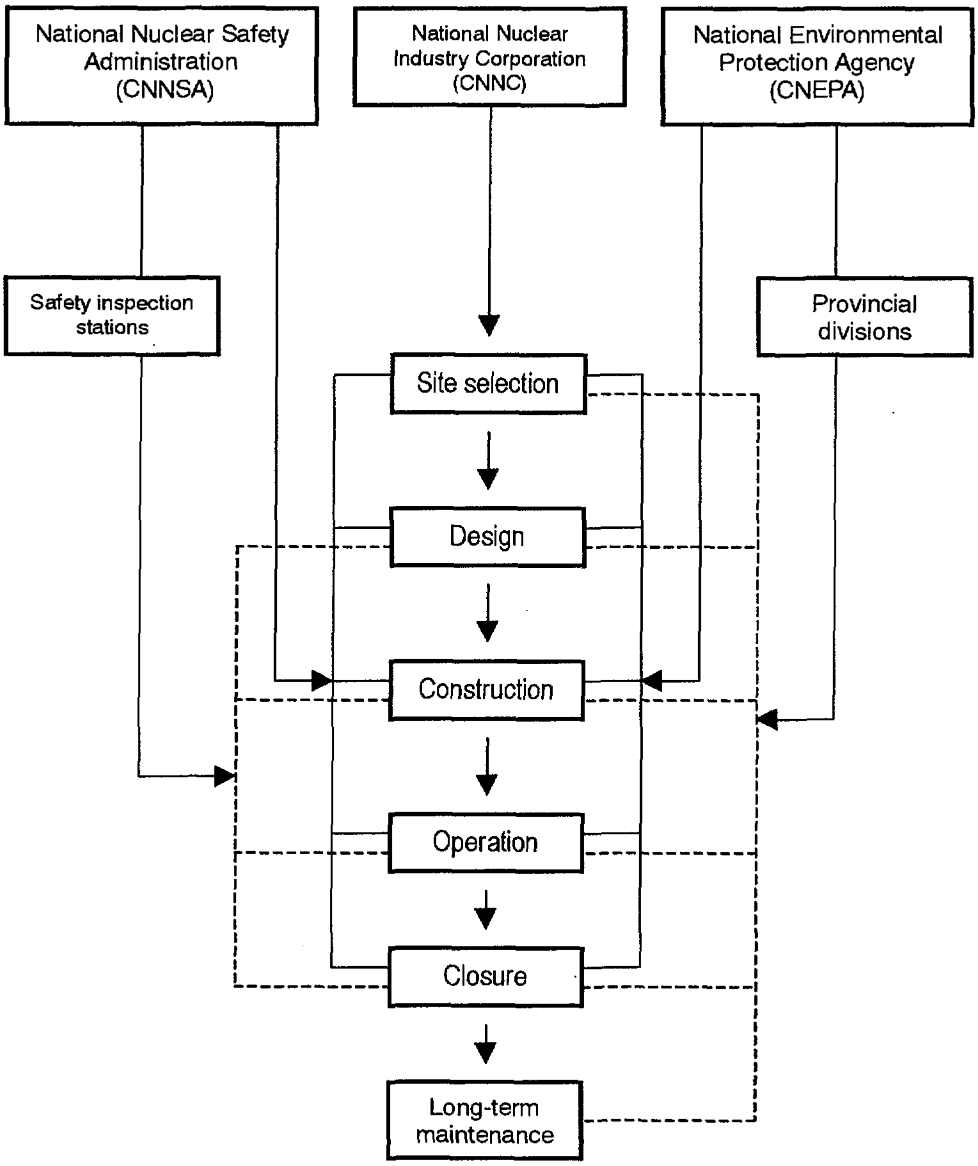
There are subsystems in radwaste management: waste generation, collection and transport, treatment, conditioning and packaging, and final disposal. (Fig. 2) Every subsystem above-mentioned should cover the procedures shown in this figure, i.e. (1), (2), (3) and (4). The departments of Environmental Protection and CNNC co-operate to take the charge of the implementation of management.

Fig. 11 Environmental management of radwastes



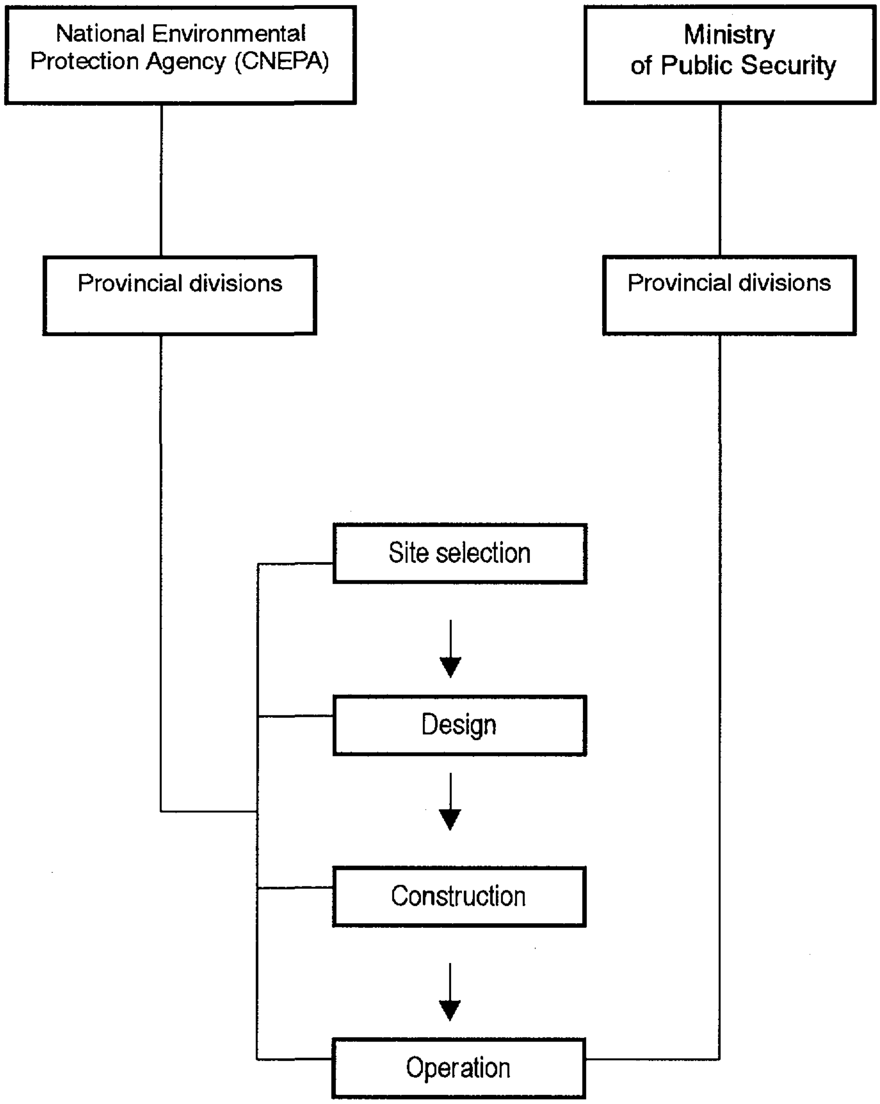
CNNC acts the duty of providing the waste disposal company (ECEEC), which is in charge of all tasks concerning the disposal, with instruction as well as professional supervision. Meanwhile, CNEPA gives its provincial divisions instruction and takes the charge of the final examination and approval of the safety analysis reports on disposal activities. Its provincial divisions are responsible for environmental supervision, monitoring activities during all the stages of the disposal sites from operation to post-closure.

Fig. 12 The management of installation LL/ILW



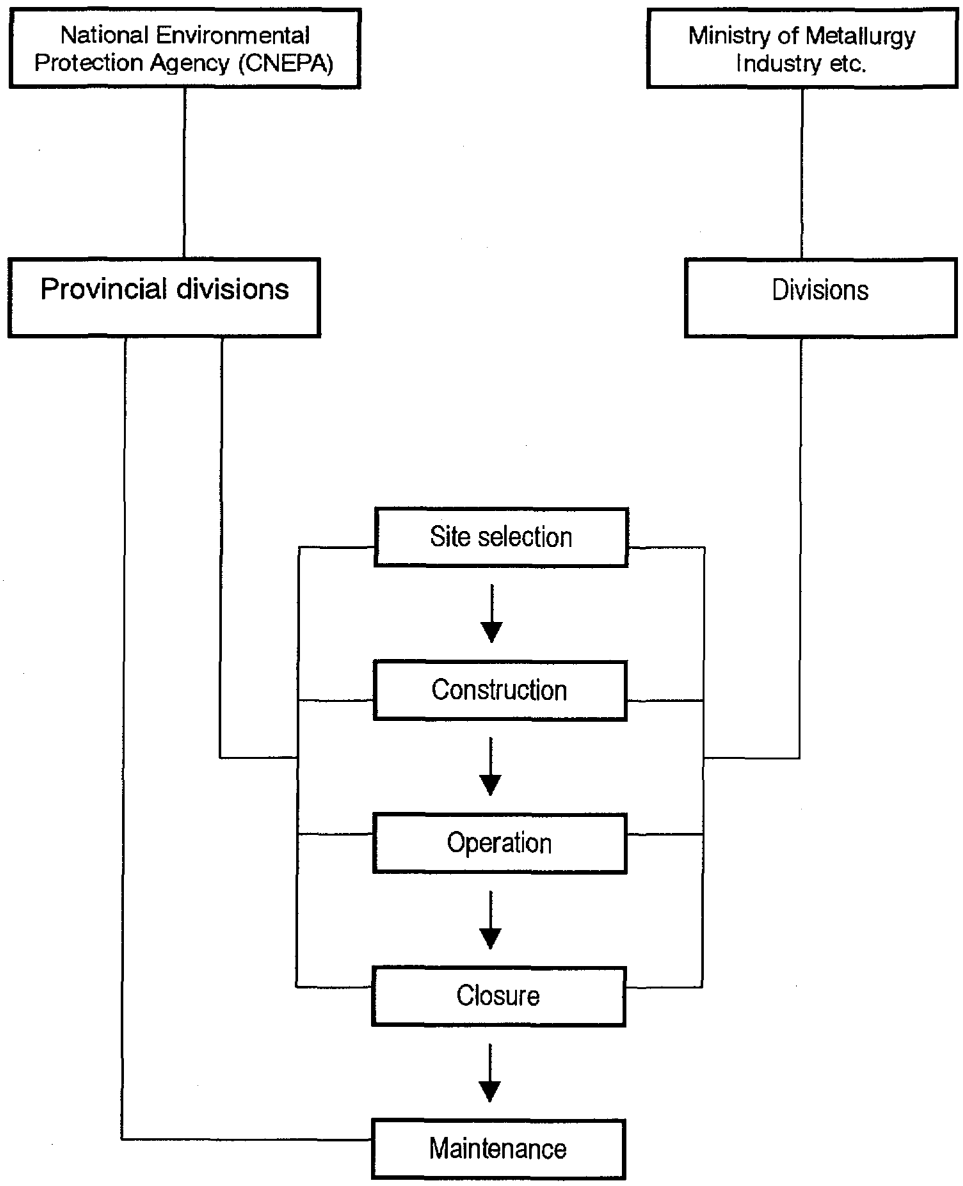
CNNC is in charge of disposal activities covering all stages from site selection to closure of disposal repositories. The CNNSA and its provincial divisions are in charge of safety supervision, examination and approval of the safety analysis reports. The CNEPA and its provincial divisions are responsible for the environmental supervision, examination and approval of assessment reports of environmental impact.

Fig. 13 The management of high-level radwastes



The application wastes are collected to be stored in the temporal facilities before being delivered to the final disposal repositories. The CNEPA and its provincial divisions are in charge of activities including all stages from site selection to operation of the storing facilities. The divisions of Public Security provide the temporal facilities with guarantee of security.

Fig. 14 The management of application radwastes



The accompanying mineral wastes are disposed of in the tailing ponds. The waste producers, e.g. Ministry of Metallurgy Industry etc. should be responsible for conducting all disposal activities from site selection to closure of the tailing ponds. The CNEPA and its provincial divisions are in charge of the activities related to environment supervision.

Fig. 15 The management of non-uranium mineral dumps

3. Assessments

3.1 On present strategies

Waste management is an important factor to be taken into account at the early stage in the development of nuclear system. Most NEA countries pay great attention to the radwaste management and have established strategies, which are characterized as the following points:

- Safe management is assured administratively and legally: 1) Responsibility for safety lies with the operators of facilities; 2) Responsibility for regulations lies with governments, who define the legal framework; 3) Responsibility for enforcing regulations lies with regulatory bodies, generally independent of operators and government, who awards licenses to sites satisfying government regulations, and withdraws licenses from sites failing to satisfy them.
- Financing management is involved in the strategies. Funding mechanisms that enable costs to be met decades in the future have been established while satisfying the principle of " the polluter pays".
- Social issues have been taken into consideration. Public acceptance of the basic principles and the specific proposal must be obtained before any management process is implemented.

Looking back, it seems disadvantageous that, in China, the issue of radwaste management had not been attached with much importance during the long period of development of national nuclear industry. The nuclear industry started in mid 1950s, but military programs had dominated the national nuclear industry for a long time. During the past period of decades, although a good record of radwaste management was achieved, the philosophy in the management had been the safe storage of the radwastes. Waste treatment and disposal were not the critical issues until the middle of 1980s, when the nuclear power programs started. Since then the government has, however, paid more attention to the radwaste management and a notable progress has been made. The radwaste management began to grow in importance in the national protection of the environment. The generation of nuclear power in China has brought the radwaste management into a new era.

The status described previously indicated that a comprehensive system of radwaste management has been established in China. The practice of management has demonstrated that the structure and enthusiasm exit to move forward on the strength of past success with confidence.

The current national strategy involves the use and development of a range of disposal facilities and a continuing program of research and assessment to ensure that each type of waste is disposed of in an appropriate way. The strategy will continue to be fine-tuned in the light of advice that the government receives from nuclear industry and the results of its ongoing research program.

In line with national policy guidelines, radwaste management in China's nuclear industry is directed to ensure that nuclear wastes are: 1) stored safely in a suitable manner awaiting identification of disposal routes; 2) stored in a form that does not exclude future treatment; 3) minimized as far as possible.

The national management strategy is effective, since it deals with not only quantities of wastes already in store, but also the wastes produced by use of nuclear power.

To be comprehensive, the national strategy covers the wastes from defense programs as well as civil source. Defense wastes had enjoyed priority in the national management of radwastes, but they are now declining in production and possess only a relatively small part of their picture and their characteristics compared with the civil wastes.

3.2 On future subjects

The national strategy should continue to be underpinned by the following basic objectives, which are derived from the experience of NEA countries:

- The strategy is flexible enough to take full account of possible future developments that will affect waste management requirements.
- All practices giving rise to radwastes must be justified.
- The principle of as low as reasonably achievable (ALARA) continues to be adopted with economic and social factors being taken into account.
- The effective dose equivalent from all source, excluding natural background radiation and medical procedures, should not exceed 1mSv in any one year.
- For a disposal repository, the risk or probability of fatal cancer to any member of the public from any moment of radioactivity from the facility, should not be greater than a radiation dose of .1mSv in any one year.

China's nuclear industry developed from a military background with all its attendant requirements for secrecy. In addition, the nuclear industry was considered to be in the forefront of technology, therefore, its exponents gave an impression of intellectual arrogance for a long time. Thus two important factors i.e. economic and social factors had not been considered in the management of radwastes.

Being at the early stage of nuclear power industry, there is no financing system for long-term management of radwastes in China. The exiting funding method, which is used for financing construction of disposal repository sites of LL/ILW from nuclear power plants, does not provide guarantee of the expenditure over the long period of monitoring and surveillance of the disposal site after it is sealed. In fact, management of radwastes from ongoing power plants is a short time operation, which is an integrated part of the nuclear power production not involving the future costs for decommissioning and waste management. From the point of view of long-term, it is absolutely necessary to set up a financing system for long-term management of radwastes, and the provisions regarding waste management should be included in the legislation concerned.

Before the start of nuclear power program, the ordinary public in China knew and concerned little about issues of nuclear and radwaste management. However, that situation has been changing gradually due to the development of civil nuclear programs. Now more and more Chinese intend to show their concerns on nuclear and waste management.

The civil nuclear programs were involved in the nuclear system years ago and now become the backbone of the national nuclear industry. Not considering the factors of economic and social issue, the exiting system of waste management is considered to be imperfect. With the growing programs of nuclear power in China, these two factors should be taken into consideration in the management strategy of radwastes.

4. Future issues

4.1 Accumulative wastes

The accumulative wastes have been stored in the nuclear facilities since they were produced and are waiting for treatment and disposal. It is so long a time that those facilities are believed to be de facto permanent storing sites. In fact, those wastes hold big hidden perils upon the environment. Therefore, the accumulative wastes pose a serous problem to the national radwaste management, which is facing with challenge of storing the accumulative wastes safely, as well as the development of the disposal facilities and the technology of waste treatment and disposal.

However, the pressure is being mitigated since the activities of treatment and disposal are going ahead. In particular for the management of LL/ILW, disposal activities are being carried out in two regional repository sites, namely the Northwest Disposal Site and the South China Disposal Site. The other regional disposal sites will be constructed and opened in the near future. In this respect, the facing challenge that maintaining the normal and economical operation of disposal sites on the prerequisite of safe management presents as a subject for operator of the repository sites.

4.2 Decommissioning of reactors

A further factor will be the wastes from the decommissioning of reactors (for defense production). Subject to any possible advantage of delay to permit the level of radioactivity to be reduced by natural processes, the surplus reactor should be dismantled and the resulting wastes should be disposed of as soon as appropriate disposal routes are available. The current situation is that the wastes produced in the operation period of reactors are being stored in facilities within the reactor sites. So when the decommissioning is carried out, operators have to manage both the wastes resulting from decommissioning and the wastes accumulated before. What is more, located in the remote areas, the roads are not only inconvenient for trans-shipment of wastes, but also fraught with risks and radiological hazards.

Nevertheless, decommissioning wastes will not be qualitatively different from the radwastes arising during the operation of reactors, and the appropriate waste management procedures are therefore likely to be similar. It is essential that forward planning includes the need to make provision for those wastes. The department concerned should: 1) select a suitable alternative for the decommissioning; 2) take steps at the design stage to optimize the volume and mass of waste materials; 3) prepare plans, within the period in which disposal facilities are being developed, for the decommissioning and equipment needed for the treatment, conditioning or storage of the resulting wastes; 4) consult the international experience of reactor decommissioning, such as in USA and Canada. There is no doubt that the experience is useful and helpful for the reactors decommissioning in China.

Fortunately, some research and provision relating to the decommissioning are in progress.

4.3 Nuclear power plants

4.3.1 Reactor-type

Several types of reactors were selected for the generation of nuclear power in China. Table 8 lists the reactors to be installed up to 2005.

Table 8 Nuclear power generators up to 2005

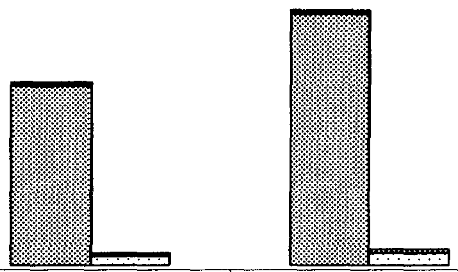
NPP	Original	Type	Capacity (We)	Operation
Qinshan-1	China	PWR	300	1991
Guandong-1	France	PWR	2x900	1993, 1994
Qinshan-2	China	PWR	2x600	2001, 2002
Guandong-2	France	PWR	2x1000	2002
Qinshan-3	Canada	HWR	2x700	2003
Lianyungang	Russia	WWER	2x1000	2004

The multiple types of reactors may bring about difficulties not only for the management of power production but also for the management of radwastes. Waste management strategies required may be different from those various reactors. Taking Canadian HWR for example, it belongs to the heavy water moderated, natural uranium fuelled reactor. Compared with other types of reactor, much more radwastes are foreseen to be produced during the operation.

It is now uncertain that what types of reactor will be adopted beyond the year 2005. Anyhow such potential problems should be given an earlier attention.

4.3.2 Economics

As have been mentioned, there will be a growing generation of nuclear power in China and the amount of nuclear power radwastes will increase remarkably. Fig. 16 shows the estimated volume of nuclear power wastes to be produced up to 2050.



	Low projection	High projection
LL/ILW (m3)	314000	440000
HLW (m3)	16000	22500

Fig. 16 Volume of radwastes expected to arise in China up to 2050

It is unavoidable that there will be economic challenge in the management of the wastes from nuclear power plants.

1) Costs

The costs of radwaste management are conceived very high. Today, billions of dollars are annually spent worldwide on activities which aim at safe isolation of radwastes from the living environment. Although the high costs in managing radwastes, nuclear power is proved a benefiting production and the cost of radwaste management is only a few percent of the value of the electricity production that has given rise to the waste.

For nuclear power production, managing radwastes from ongoing electricity production at the power plants (mostly low and intermediate level waste) is generally not considered to be a financing problem. The costs for this management are generally considered as inevitable parts of the total production costs and should subsequently be covered by the power plant owner's income from sale of its product, i.e. electricity. The total costs are dominated by the management of high level and long-lived wastes.

2) Challenge

Economic challenge that is likely to be faced with in China in the long-term management of radwastes can be expressed as the following points:

- Who should pay for costs that do not occur today but inevitably will have to be covered some day in the future?
- What financing principle should be adopted?
- How to guarantee a lifetime resource ahead so that the fund will be always available when needed?
- What financing system should be designed?

"Polluter pays" is a feasible and reasonable basis for funding management, directly to apply to some radwaste management activities but not to others.

Expenditure on short-term operations, which can be financed directly from operating income, such as disposal in an existing repository, are covered by the waste producer immediately, either directly from his investment and operating budget or by payment to the waste management company. Some stages of longer-term operations, such as the construction and operation of temporary stores or disposal sites, can be covered in the same way. In fact, "Polluter pays" principle has been already practiced in China for funding the construction and operation of the regional repository sites of LL/ILW.

Others, such as the disposal of high-level wastes, which requires a period of cooling of several decades, contains a long interval between the time when the waste is generated and the time when the expenditure is incurred. Furthermore, expenditures of management may continue over a long period, for example for the period of monitoring and surveillance of a disposal site after it has been sealed. Therefore such longer-term management requires special funding provisions, which will take into account the longer period between waste generation and disposal, as well as the uncertainties and timing of the activities concerned.

3) Financing long-term management

Practice in NEA countries

In NEA countries, the funding method adopted in practice varies from country to country, depending on the waste management strategy selected and on how nuclear program develops. In a number of countries, for example Spain, Sweden and the USA, money from electricity sale is used to establish an independent fund which is intended to cover the cost of waste disposal. In others, for example Canada, France and Germany, an independent fund has not been established. In most countries, the development costs and costs of research and development associated with deep geological disposal are paid for by the waste producers.

Table 9 summaries financing long-term management in some countries.

Financing methods

There are several methods of financing long-term management. Four typical methods are prevalent in some countries:

- payments to specialized waste management bodies;
- the establishment of a fund to cover longer-term management;
- direct contributions to cover current investment and running costs;
- born from the public fund.

They are described and discussed as follows:

A. ***Pay a levy to a body:*** *Operators of power plants and electricity utilities pay a levy to a specialized body to cover their future costs for the storage and disposal of waste. The levy is paid from the time of transferring waste for storage or disposal, or is paid when waste is generated in power plants.*

B. ***Establish a fund:*** *The exiting nuclear operators have to contribute regularly (e.g. annually) to a special fund, which will cover the future cost of the storage and disposal of their waste.*

Method A and method B are considered to be flexible financing methods, since the regular payments from nuclear power producers or electricity utilities over long periods can be borrowed and used for supplementing major investment projects. They have points in common such as:

- They presuppose that the long-term nuclear programs will be carried out;
- The fund is taken from the income of existing nuclear operators;
- Payment by operators is probably proportional to the volume of waste;
- Various arrangements can be introduced for payment by utilities.

Table 9 Funding Long-term Management

Country	Method
France	Financing such costs is regarded as the internal responsibility of power producer, that is Electricite de France (EdF),
Britain and Germany.	The nuclear utilities are making allocations in their accounts for paying.
Belgium, Netherlands	Nuclear utilities are required to set aside the money for future decommissioning costs. But the responsibility for disposal of nuclear waste rests with a government agency. This agency receives payment from the utilities when waste is delivered and part of the payment is directed to a fund, intended to cover future costs.
Finland, Sweden and the USA	By legislation, special funds have created for financing waste disposal. In Finland and Sweden, the nuclear energy fee is different for different reactors. In Sweden the fee covers disposal of HLW and decommissioning wastes, whereas in the USA the fund covers only the costs for disposal of HLW.
Canada	Utilities collect money from their customers for disposal, but invest in their own capital projects, keeping account of what has been collected and the interest earned. The base and amounts collected vary depending on national policy.
Switzerland	A central fund for financing decommissioning costs has been created by government provisions. The utilities have to pay a minimum fee to the fund and at the same time they make supplementary allocations for decommissioning costs.
Swiss	The utilities have a financial responsibility for all waste handling, they also make internal allocations to funds intended to cover costs for waste handling in the future
Spain	By legislation, a funding system has been created, which is handled by a separate waste handling company owned by the nuclear utilities. The fund shall cover costs both for waste management and decommissioning.

Method A assumes that nuclear power programs will continue or even step up over a long period. It does not afford the guarantees regarding the availability of the fair distribution of costs among generations.

Method B need not to consider the question of who should be responsible for carrying out disposal operations and it ensures a link between the waste producer and future expenditure. The setting up of a fund can make each operator bearing a charge equivalent to the actual cost of managing his waste, and provide the possible guarantee so that the necessary finance would be available when required. It has advantages:

- This is a good method from the standpoint of long-term safety;
- There are fair distributions of costs among power plants; and
- Not being totally depended on the continuation of nuclear power programs.

The disadvantage is that there are problems in calculating the contributions to be paid, because some factors such as the uncertainty in estimating costs, currency depreciation, rates of interest etc. have to be taken into account.

The other two methods are not based fairly on the legal obligation of the operator, which underlies his financial responsibility for waste management.

*C. **Pay at disposal incurs:** The nuclear operators bear the cost when the expenditure for waste disposal was actually incurred, without anticipated payment.*

This method is a deferred financing of waste disposal. The advantages are:

- It can avoid the highly uncertain estimates on which anticipated financing is based from the time waste is produced, and
- It can provide finance, including loans, on clearly economic terms.

However, the disadvantages are obvious:

- The income, which is from operations and conducted at the time waste is produced, may no longer be available. Therefore, it should be based on the assumption that an adequate financial basis is available to cover future management costs in the light of forecasts of nuclear power production. But this method gives no guarantee in this respect and means transferring a major part of the burden of radwaste management to future generations.
- The financial obligation of existing operators for managing waste that they have generated will be replaced by obligation of future operators. This is unfair.

*D. **Pay from public funds:** The costs of long-term waste management are covered in public funds, e.g. by being included in the State budget.*

This method reflects the particular responsibility of Government in the management of radwastes. It can provide a solid guarantee for funding management. The State's overall expenditure will benefit successive generations, this is essential since it corresponds to both present and future interests. This method can also confirm that the burden in consumers will be approximately proportionate to their consumption of electricity. However the method may be considered to be unfair for the non-consumers of nuclear electricity.

4) A tentative financing system for long-term management --- expected to be established in China

Considering the long-term management of radwastes, a financing system needs to be created in China. Among the methods mentioned-above, a fund is considered an appropriate method. Besides the advantages mentioned previously, there are such features in the establishment of a fund:

- Nuclear power programs in China is growing and are expected for a huge increase in the next century;
- It is important to create a system for financing the future costs of radwaste management at the beginning stage of nuclear power production.
- Today's consumers of nuclear power electricity should pay a price, which included all waste handling costs, to insure that the present generation does not leave a financial burden as a heritage to future generation. A fund would satisfy the needs of future management.
- Wastes management costs that will occur in the future in connection with the inevitable final disposal of today's radwastes. A fund would establish a combination between today' consumers and the future managers of wastes.
- This method has been well adopted in some countries.

The financing system is designed to comprise two subsystems: funding system and guarantee system.

The funding system

Fig. 17 shows the funding system, which is also described in Table 10. Where, the dotted lines with arrows mean cash flows.

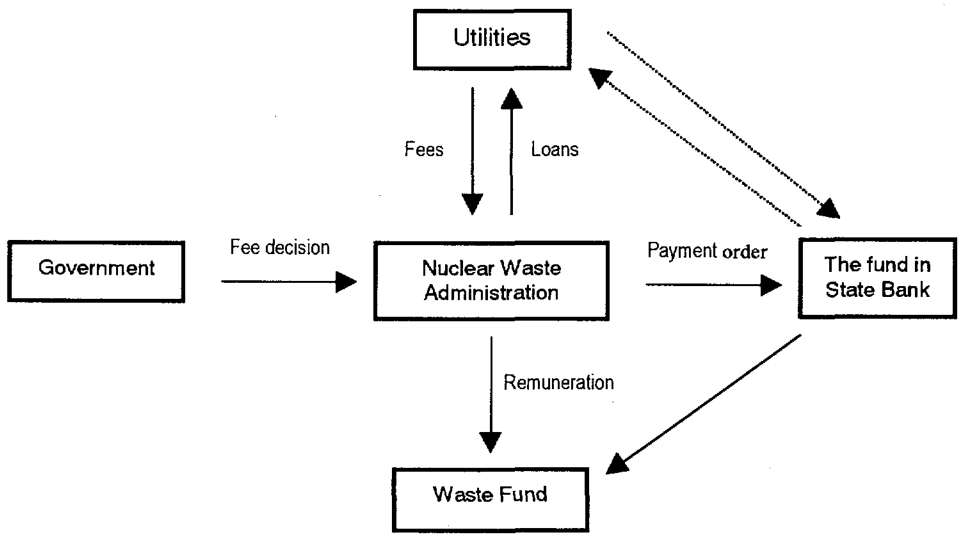


Fig. 17 Configuration of the funding system

Table 10 Funding system for long-term management

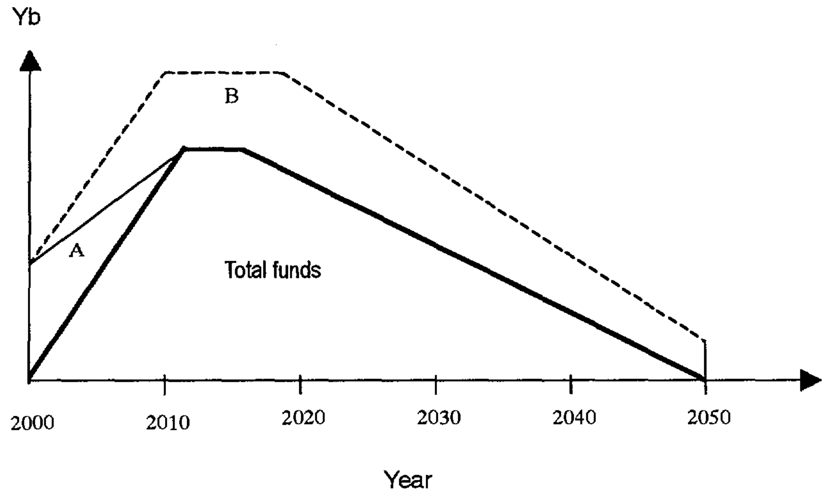
Structure	Description
A government agency (e.g. *China Nuclear Waste Administration*) An independent body (e.g. *China Nuclear Waste Fund*)	Taking the responsibility of supervising financing, e.g. examining and evaluating issues relating to the application of the funds and determining the level of the fee to be paid. Managing the funds. Utilities i.e. the reactor owners should pay a fee to the Nuclear Waste Fund.
Fee	1. Paid by the reactor owners and collected to the fund; 2. Covers the costs of: • Safe handing and final disposal of nuclear fuel used in the reactor; • Safe decommissioning and dismantling of the reactor; • Research and development activities required for achieving the safe management. 3. Determined by government annually on the basis of different available estimates including the amount of radwastes, the earning period per reactor etc. and would vary depending upon the utility concerned. The fee can be expressed as Fen per kilowatt-hour (Fen/kWh) of electricity supplied by the reactor (1 Fen = 0.01 Yuan RMB) and it can be adjusted on the basis of the actual situation. 4. Calculated on the basis of the estimation of future power production at the nuclear power plants and collected by the Waste Fund.
Fund	1. Collected by Waste Fund. 2. Deposited into the State Development Bank at an interest-bearing account.
Utilities	1. Can borrow their deposits for long-term energy investments after deduction of expected expenditures during the term of the loan. 2. Reimbursed by the State from the accumulated funds to cover the costs that may currently have for waste management activities.

Guarantee system

It is necessary to establish a guarantee system, in order to secure the funding of the radwaste management program. Table 11 describes the guarantee system, which is also illustrated by Fig. 18.

Table 11 Guarantee system for long-term management

Structure	Description
Guarantee 1	Guaranteeing the availability of sufficient funds if the nuclear power plants would be shut down before operating for earning period.
Guarantee 2	Guaranteeing the financing of the radwaste management program in the case the accumulated funds are found to be insufficient.
Amount for calculating the fee	The basis for determining the level of the fee. It is based on the earning period per reactor.
Amount 1	For guaranteeing the availability of funds in the event of the premature shutdown of a reactor.
Amount 2	The amount that is over and above the basic amount to guarantee financing if the funds are found to be insufficient as a result of the occurrence of possible events (for example additional cost risk, premature scheduling risk and real interest rate risk).
Utilities	1. Provide adequate guarantees for the difference between the Amount 1 and the accumulated funds (i.e. Guarantee 1 = Amount 1 – accumulated funds). 2. Provide adequate guarantees for Amounts 2 determined by the government (i.e. Guarantee 2 = Amounts 2). 3. Entitled to the repayment of any surplus funds after the completion of the waste management program. In special circumstances, the government can grant permission for premature repayment.



Yb = Yuan billion,
A = Guarantee 1 (A + Total funds = Amount 1),
B = Guarantee 2 (=Amount 2)

Fig. 18 Guarantee system for radwaste management fund

As for an explanation, the fund is assumed to end in 2050. It is possible to accumulate guarantees for the Amount 2 over a certain period of time. Fig. 18 shows that B (Guarantee 2) reduced gradually as the radwaste management program is carried out. In the year 2050, when the waste management program is expected to be completed, guarantees are returned for B.

It should be mentioned that the financing system described above is a simplified assumption, which is provided here as a platform for future research.

4.4 Social issue

The growth of the nuclear power option is impeded in many countries by public concerns over the safety and environmental consequences of producing electricity using nuclear reactors. Public concerns have in some cases postponed or prevented the start of waste disposal. This indicates that such social factors as public understanding, acceptance and participation are essential to the achievement of safe management of radwastes.

In 1986 when Chinese government decided to install a nuclear power generator at Daya bay in Guandong province near Hong Kong, the decision met a strong local opposition. In order to implement the project, the government made a great effort for obtaining understanding and acceptance from the local public. The similar protest occurred when a regional radwastes disposal site, the South China Disposal Repository for LL/LIW, was planned for construction. This means that many Chinese are reluctant to accept nuclear power and they do not have confidence in the safety of radwaste management.

In China, there are kinds of concerns from the public about nuclear power and radwaste management, such as:

- Possible accidents with nuclear power plants.

This is a popular concern of people about nuclear power plant. People are frightened by the accidents at Three Mile Island in 1979 and at Chernobyl in 1986.

- Nuclear power is not advisable because of its radwastes.

The main components of this public concern are the day-to-day operational safety of nuclear reactors, and the question of what to do with radwastes.

- Radwaste is an abstract concept.

There are many misunderstandings and misperceptions about radwastes and they breed fears. In the mind of some members of the public, the perceived risk from radwastes is high. They see radwastes as uniquely dangerous, particularly because of the association with radiation and hence with cancer, one of the most dreaded of diseases.

- Safety of radwaste management.

Much public concern is focused on the impact of waste management. They fear that the radwastes cannot be safely contained, and that it has the potential for seriously harming the environment and people.

In order to achieve safe management, it is vital to the public to understand and accept the following facts by carrying out information programs:

- Any useful product in existence produces waste in one form or another. The important thing is not if it produces waste but how much waste is produced, how bad it is in nature, and whether they are manageable. The properties of radwastes are now well known and the radwastes are extremely small in volume so they are considered manageable enough.
- Today, after decades of research, development and industrial applications, it can be stated confidently that safe technological solutions for radwaste management exist.
- For high level and other long-lived wastes, temporary storage followed by disposal deep underground is being confirmed as an effective way of satisfying the requirements both for current and for future generations. Other categories of waste are easy relatively to ensure safety, and disposals are being implemented.
- Long-term waste management can be guaranteed through a framework of laws and regulations applied to current activities. Such laws and regulations can be satisfied. They are now well in progress with this.

One important aspect of long-term radwaste management is to develop and implement waste disposal. Now two repository sites of LL/ILW are ready for operation in China. In order to advance the management, it is necessary to design and carry out dialogue programs on the local public.

There are many communication means for releasing the public concerns. In China, the public are generally introduced with knowledge concerning nuclear and radwaste by using popular tools of media including publication, newspaper, television, broadcast etc. However, the different interests of the public may require different communication means for developing understanding and acceptance.

Table 12 shows the information means in connection with the public of different interests.

In addition to the information programs, public interaction programs are also being implemented in some countries. Such public interaction programs encompass activities that range from simply giving the public information to involving members of the public or special interest groups in the decision making process. At present in China, the public seldom participates in decision-making of nuclear power programs and radwaste management projects. But this does not mean that the public opinion can be neglected. In fact the public opinion appears beginning to affect the implementation of nuclear programs.

At present in China, the issues on nuclear and radwaste management are not so sensitive as in other developed countries. Spoken from the other side, this is factually a favorable condition for developing its nuclear power industry. Even so, for promoting the national nuclear industry, it is necessary to attach importance to the social issues of radwaste management.

To deal with the public concerns, information programs are necessary to be involved in the national strategy of radwaste management. The information strategy should be developed to make use of a mix of publicity, promotions, communications and media for publicizing general knowledge of radwastes and radwaste management as well as maintaining the trust with the public on the safety of radwaste management in China.

Table 12 The public and communication means

(Source: Reference 3; 1- Somewhat useful, 2- Useful, 3- Most appropriate.)

Means \ People	Opinion leaders	News media	Public nationwide	Public local (sites)	Authorities	Environmental groups	Scientific community	International contacts	Employees
News releases (conferences, interviews)		2	2	2				2	
Advertisements			2	2					
Exhibitions			2	2		1			
Information meetings				3	3	2	2	1	2
Visits to facilities	2	3	1	3	3	3	2	2	2
Visits to facilities abroad		3			3	2	2		
Face to face contacts	2	3		2	3	2	2	2	
Brochures, pamphlets	2	2	2	2	2			2	2
Newsletters		1	1	3	2	1	1	1	3
News magazines	2	1			3	1	3	3	2
Technical report		1					3	3	2
Films, videotapes	2	2	3	2	2	2		2	
Public speakers	3			2		2	2		

5. Conclusions

NEA countries have developed strategies of radwaste management, and programs of radwaste management are well in progress. In financing radwaste management, the "polluter pays" is adopted by some countries; in others the responsibilities has been taken over by the Government. The methods of funding waste management activities varies from country to country within several methods --- direct contributions to cover current investment and running costs, payments to specialized waste management bodies, loans the establishment of a fund to cover longer-term commitments.

In China, the exiting structure and enthusiasm of radwaste management can basically satisfy the requirements and are moving forward on the strength of past success with confidence. Wastes are stored safely as long as necessary pending the development of the disposal facility. Aiming at the safe management, the exiting management policy is expected to carry on, and continues to ensure that the necessary research and development are carried out on methods of radwaste management. Much progress has been achieved in the management of radwastes, but there are still improvements to be made. The development of civil nuclear programs represents challenges for radwaste management. From long-term point of view, economics and social issue should be involved in the strategy of radwaste management. A financing system is expected to be created for the long-term management of radwastes. This work provides a platform for further research.

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国際単位系 (SI) と換算表

表 1　SI基本単位および補助単位

量	名　称	記　号
長　さ	メートル	m
質　量	キログラム	kg
時　間	秒	s
電　流	アンペア	A
熱力学温度	ケルビン	K
物質量	モル	mol
光　度	カンデラ	cd
平面角	ラジアン	rad
立体角	ステラジアン	sr

表 2　SIと併用される単位

名　称	記　号
分，時，日	min, h, d
度，分，秒	°, ′, ″
リットル	l, L
トン	t
電子ボルト	eV
原子質量単位	u

$1\ \mathrm{eV}=1.60218\times10^{-19}\ \mathrm{J}$

$1\ \mathrm{u}=1.66054\times10^{-27}\ \mathrm{kg}$

表 5　SI接頭語

倍数	接頭語	記　号
10^{18}	エクサ	E
10^{15}	ペタ	P
10^{12}	テラ	T
10^{9}	ギガ	G
10^{6}	メガ	M
10^{3}	キロ	k
10^{2}	ヘクト	h
10^{1}	デカ	da
10^{-1}	デシ	d
10^{-2}	センチ	c
10^{-3}	ミリ	m
10^{-6}	マイクロ	μ
10^{-9}	ナノ	n
10^{-12}	ピコ	p
10^{-15}	フェムト	f
10^{-18}	アト	a

表 3　固有の名称をもつSI組立単位

量	名　称	記号	他のSI単位による表現
周波数	ヘルツ	Hz	s^{-1}
力	ニュートン	N	$m\cdot kg/s^2$
圧力，応力	パスカル	Pa	N/m^2
ｴﾈﾙｷﾞｰ, 仕事, 熱量	ジュール	J	N·m
工率，放射束	ワット	W	J/s
電気量，電荷	クーロン	C	A·s
電位，電圧，起電力	ボルト	V	W/A
静電容量	ファラド	F	C/V
電気抵抗	オーム	Ω	V/A
コンダクタンス	ジーメンス	S	A/V
磁束	ウェーバ	Wb	V·s
磁束密度	テスラ	T	Wb/m^2
インダクタンス	ヘンリー	H	Wb/A
セルシウス温度	セルシウス度	℃	
光束	ルーメン	lm	cd·sr
照度	ルクス	lx	lm/m^2
放射能	ベクレル	Bq	s^{-1}
吸収線量	グレイ	Gy	J/kg
線量当量	シーベルト	Sv	J/kg

表 4　SIと共に暫定的に維持される単位

名　称	記　号
オングストローム	Å
バーン	b
バール	bar
ガル	Gal
キュリー	Ci
レントゲン	R
ラド	rad
レム	rem

$1\ \text{Å}=0.1\ \mathrm{nm}=10^{-10}\ \mathrm{m}$

$1\ \mathrm{b}=100\ \mathrm{fm}^2=10^{-28}\ \mathrm{m}^2$

$1\ \mathrm{bar}=0.1\ \mathrm{MPa}=10^5\ \mathrm{Pa}$

$1\ \mathrm{Gal}=1\ \mathrm{cm/s^2}=10^{-2}\ \mathrm{m/s^2}$

$1\ \mathrm{Ci}=3.7\times10^{10}\ \mathrm{Bq}$

$1\ \mathrm{R}=2.58\times10^{-4}\ \mathrm{C/kg}$

$1\ \mathrm{rad}=1\ \mathrm{cGy}=10^{-2}\ \mathrm{Gy}$

$1\ \mathrm{rem}=1\ \mathrm{cSv}=10^{-2}\ \mathrm{Sv}$

(注)

1. 表1－5は「国際単位系」第5版，国際度量衡局 1985年刊行による。ただし，1 eV および1 uの値はCODATAの1986年推奨値によった。
2. 表4には海里，ノット，アール，ヘクタールも含まれているが日常の単位なのでここでは省略した。
3. bar は，JISでは流体の圧力を表わす場合に限り表2のカテゴリーに分類されている。
4. EC閣僚理事会指令では bar，barn および「血圧の単位」mmHg を表2のカテゴリーに入れている。

換　算　表

力	$N(=10^5\,dyn)$	kgf	lbf
	1	0.101972	0.224809
	9.80665	1	2.20462
	4.44822	0.453592	1

粘　度　$1\ \mathrm{Pa\cdot s(N\cdot s/m^2)}=10\ \mathrm{P}$(ポアズ)$(\mathrm{g/(cm\cdot s)})$

動粘度　$1\ \mathrm{m^2/s}=10^4\,\mathrm{St}$(ストークス)$(\mathrm{cm^2/s})$

圧力	MPa(=10 bar)	kgf/cm^2	atm	mmHg(Torr)	lbf/in^2(psi)
	1	10.1972	9.86923	7.50062×10^3	145.038
	0.0980665	1	0.967841	735.559	14.2233
	0.101325	1.03323	1	760	14.6959
	1.33322×10^{-4}	1.35951×10^{-3}	1.31579×10^{-3}	1	1.93368×10^{-2}
	6.89476×10^{-3}	7.03070×10^{-2}	6.80460×10^{-2}	51.7149	1

エネルギー・仕事・熱量	$J(=10^7\,erg)$	kgf·m	kW·h	cal(計量法)	Btu	ft·lbf	eV
	1	0.101972	2.77778×10^{-7}	0.238889	9.47813×10^{-4}	0.737562	6.24150×10^{18}
	9.80665	1	2.72407×10^{-6}	2.34270	9.29487×10^{-3}	7.23301	6.12082×10^{19}
	3.6×10^6	3.67098×10^5	1	8.59999×10^5	3412.13	2.65522×10^6	2.24694×10^{25}
	4.18605	0.426858	1.16279×10^{-6}	1	3.96759×10^{-3}	3.08747	2.61272×10^{19}
	1055.06	107.586	2.93072×10^{-4}	252.042	1	778.172	6.58515×10^{21}
	1.35582	0.138255	3.76616×10^{-7}	0.323890	1.28506×10^{-3}	1	8.46233×10^{18}
	1.60218×10^{-19}	1.63377×10^{-20}	4.45050×10^{-26}	3.82743×10^{-20}	1.51857×10^{-22}	1.18171×10^{-19}	1

1 cal = 4.18605 J (計量法)

= 4.184 J　(熱化学)

= 4.1855 J　(15 °C)

= 4.1868 J (国際蒸気表)

仕事率　1 PS (仏馬力)

= 75 kgf·m/s

= 735.499 W

放射能	Bq	Ci
	1	2.70270×10^{-11}
	3.7×10^{10}	1

吸収線量	Gy	rad
	1	100
	0.01	1

照射線量	C/kg	R
	1	3876
	2.58×10^{-4}	1

線量当量	Sv	rem
	1	100
	0.01	1

(86年12月26日現在)

ANALYSIS ON LONG-TERM STRATEGY FOR RADWASTE MANAGEMENT IN CHINA