FNCA
Forum for Nuclear Cooperation in Asia

FNCA Consolidated Report on Low Level Radioactive Waste Repository (Interim Report)

March 2020

Radiation Safety and Radioactive Waste Management Group, Forum for Nuclear Cooperation in Asia (FNCA)

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PREFACE

The FNCA Radioactive Waste Management Project started in 1995 with the aim of improving the safety of radioactive waste management in the Asian region. Since then, the FNCA member countries have been conducting the activities to exchange and share information/experience gained from radioactive waste management among FNCA member countries. It goes without saying that enhancing radioactive waste management activity ensures and improves the nuclear safety in Asia. With the considerations of growing-up use of radiation and nuclear science/technology in Asian countries, the promoting exchange of knowledge and experience related to radioactive waste management will lead to more effective international cooperation. The workshop activities on radioactive waste management, which has long been implemented between FNCA member countries, has been promoted a favorable development of nuclear safety culture between the participating countries.

As a pioneering project, the results of these activities were compiled in March 2003 in the FNCA RWM Consolidated Report (FNCA RWM-R001): "The Consolidated Report on Radioactive Waste Management in FNCA Countries". Then, in March 2007, the revised version was published as FNCA RWM-R004.

Since then, nearly 20 years have passed, and the progress has been made in the actual site of low-level radioactive waste (LLW) disposal repositories in FNCA countries. In consideration of this, the additional following-up investigations on the LLW disposal repositories were necessary. A comprehensive study was conducted on the current situation of FNCA countries regarding the siting, public acceptance, planning, safety analysis and construction of low-level radioactive waste (LLW) disposal repositories, in taking into account of actual surrounding situations of each participating country.

The study results are summarized in this integrated report. The structure of this report is divided into two parts, one for general matters and for specific matters according to each country report. We are expecting a useful application of this report among the people concerned.

Regarding the formulation of the report, we received various assistance from the persons. We appreciate much these related persons.

March 1, 2020

Project Leader
KOSAKO Toshiso
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Framework of Regional Cooperation under FNCA

1. What is FNCA?

The 1st International Conference for Nuclear Cooperation in Asia (ICNCA) was held by the Atomic Energy Commission in March 1990 to promote cooperation in the field of nuclear energy with neighboring Asian countries more efficiently. Since then, the Atomic Energy Commission of Japan has held many ICNCAs where the ministers in charge of development and utilization of nuclear energy exchanged frank views on how to proceed with regional cooperation, and has carried out practical cooperation on specified subjects as well. At the 10th International Conference for Nuclear Cooperation in Asia held in March 1999, it was agreed to move to a new framework, "Forum for Nuclear Cooperation in Asia" (including Coordinator and Project Leader System) with a view and information to shifting to more effective and organized cooperation activities. Under this framework, view and information exchanges are made on the following fields: (1) Radiation Utilization Development (Industrial Utilization/Environmental Utilization, and Healthcare Utilization), (2) Research Reactor Utilization Development, (3) Nuclear Safety Strengthening, and (4) Nuclear Infrastructure Strengthening.

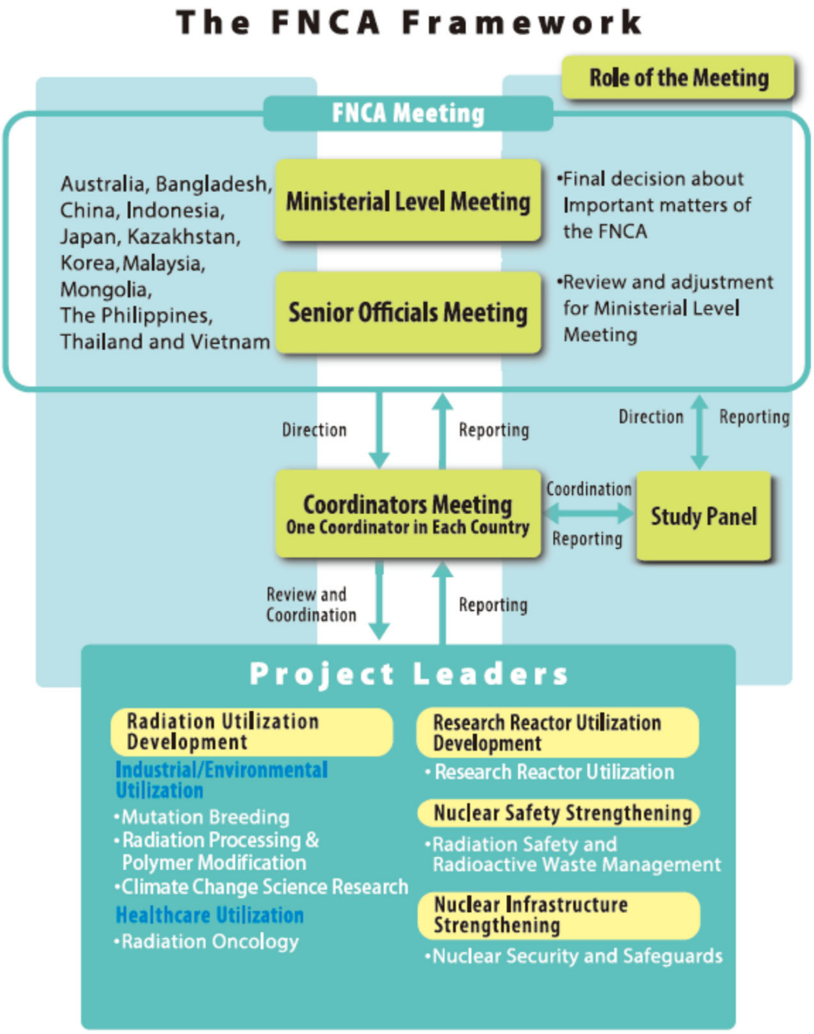
2. Participating Countries

Australia, Bangladesh, China, Indonesia, Japan, Kazakhstan, Republic of Korea, Malaysia, Mongolia, Philippines, Thailand and Vietnam

3. Framework

The basic framework of cooperation consists of the following three (See the figure on the next page). :

- **Forum meeting**
  Discussion on cooperation measures and nuclear-energy policies.
  Forum meeting is comprised of a ministerial level meeting and a senior official level one.
- **Coordinators meeting**
  Discussion on the introduction, revision and abolishment, adjustment, and evaluation of cooperation projects by an appointed coordinator from each country.
- **Cooperation activities for each project**



4. FNCA Radiation Safety and Radioactive Waste Management Project

This project superseded Radioactive Waste Management Project and started in 2008 with the aims of sharing information and experiences in the area of Radiation Safety & Radioactive Waste Management processes and regulatory issues as well as facilitating safety improvement and understanding of RS&RWM to public perception in nuclear society.

In each member country, the use of radiation in industry, agriculture, medical treatment, and various other fields is rapidly increasing, and at the same time, several countries are looking into introducing nuclear power plants. In consideration of such tendency, member countries have been discussing how to promote the standardization (calibration) on personnel dosimeter, focusing on appropriate radiation exposure management.

The accumulated results acquired through these activities over ten years were published as a serried of FNCA Consolidated Report on RWM/RS. These reports are available on the FNCA Website.

[URL: https://www.fnca.mext.go.jp/english/rwm/e_projectreview.html]

AUSTRALIA

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-Part I. General Outline of LLW Repository-

1. General Policy

The aim of Australia's management of radioactive waste is to safely and securely manage Australia's past and future radioactive waste holdings through appropriate processing, containment and eventual disposal. Doing so will reduce, to as low as practicable and justifiable, the associated health, safety, environmental, financial, security and safeguards risks to current and future generations.

The current policy, legislative and regulatory framework for the safe management of radioactive waste in Australia includes each jurisdiction licensing radioactive waste management activities. Radioactive waste management methods must conform to the highest appropriate standards as determined by Commonwealth, state and territory regulators, and requires acceptance by the general public. All radioactive waste management activities will be based on the best available science and technology and conducted in an open and transparent manner.

The Australian Government's approach towards long-term radioactive waste management includes implementing policy to site and establish a centralised, purpose-built National Radioactive Waste Management Facility (NRWMF). This facility will dispose of Australia's domestically produced Low Level Waste (LLW), and store Intermediate Level Waste (ILW) for a period of time sufficient for the Australian Government to establish a permanent ILW disposal facility, consistent with international obligations and best practice. The Australian Government has also implemented policy, legislation and regulations aimed at ensuring Commonwealth waste holders and producers:

- adopt measures for minimising the generation of radioactive waste
- safely manage their waste until it is accepted by a national storage or disposal facility
- dispose or store their waste at the NRWMF or the ILW disposal facility to the maximum extent possible, rather than in other facilities.

The policy for Australia's Low Level Waste repository is to have a facility which can dispose of all Australian generated low level radioactive waste. There will be a National Radioactive Waste Function which is created under the Commonwealth Radioactive Waste Management Act. This Waste Function is then responsible for all operational and future activities dealing with Australia's radioactive waste. The Waste Function will be responsible for purchasing the volunteer site and establishing a builder-operator for the repository. There is an expectation that the States and Territories of Australia will align their definitions of radioactivity with the commonwealth through the National Directory of Radiation Protection and this facility will be used for all national radioactive waste. The Commonwealth will assume all responsibilities for the waste as it is accepted into the facility. The LLW Repository will be licenced and regulated by ARPANSA, the commonwealth radiation regulator.

The Australian Radiation Protection policy is administered and upheld by ARPANSA. The policy objectives are:

- Regulatory activities and performance aligned with international best practice;
  - International best practice shall guide ARPANSA's regulatory activities and decision making. This typically means adapting IAEA documents to become regulatory guides.
- A nationally uniform approach;
  - ARPANSA shall establish partnerships with state and territory regulators. This uniform approach is through the National Directory for Radiation Protection.
- Engagement with government and national bodies;
  - ARPANSA shall establish effective and efficient means of national regulatory collaboration.
- Independence;
  - ARPANSA shall act independently of any other interests in carrying out its regulatory activities.
- Prime responsibility rests with the operator;
  - ARPANSA shall establish and maintain clear demarcation of responsibilities between the regulator and the operator.
- Organisational structure and external advisors;
  - ARPANSA shall optimise its structure and allocation of responsibilities and resources to promote best practicable regulatory performance.
- Multiple and graded approaches to management of radiation risks;
  - ARPANSA's regulatory approach shall be based on understanding hazards, risks and interdependencies, be predictable and strive to eliminate unnecessary regulatory burden.
- Accountability;
  - ARPANSA shall act transparently and engage with stakeholders.

The Australian Department of Environment and Energy designs and implements Australian Government policy and programs to protect and conserve the environment, water and heritage, promote climate action, and provide adequate, reliable and affordable energy. The main piece of legislation to enact this is the Environment Protection and Biodiversity Conservation Act (EPBC) which has the objectives:

- provide for the protection of the environment, especially matters of national environmental significance
- conserve Australian biodiversity
- provide a streamlined national environmental assessment and approvals process
- enhance the protection and management of important natural and cultural places
- control the international movement of plants and animals (wildlife), wildlife specimens and products made or derived from wildlife
- promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources
- recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity
- promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge.

The above objectives are at a Commonwealth level and cover matters of national environmental significance. One of these matters of national environmental significance is protecting the environment from nuclear actions. There are definitions of what are nuclear actions, which includes building, operating, decommissioning a nuclear reactor or nuclear chemical production facility. It also includes the establishment of a radioactive waste facility. This act also bans an action that would create a nuclear fuel fabrication plant; a nuclear power plant; an enrichment plant; or a reprocessing facility.

Again, there are state based environmental regulators which regulate the radioactive industries (hospitals, universities and private industry) which operate within the bounds of the state.

Australia does not have a spent fuel policy. ANSTO has an organisational policy of minimising the amount of waste to be managed, and reprocesses its used fuel in France and the UK, taking back the residues as vitrified containers.

2. Principles and Safety Assessment

Australia uses the IAEA structures and guidance for its regulation and expectations of radioactive licencees. One of the main requirements is to justify the use of radioactivity and demonstrate that the safety of the action to individuals, the community and environment. This demonstration of the safety of the activity is called the Safety Case. This is a suite of documents which are used to thoroughly explain the process, equipment and structures which demonstrate that the required work is safe. The main requirements are on nuclear and radiation safety, although standard work health and safety requirements are also required to be met. The Safety Case also includes information on how the risk assessments are conducted, and the principles on which it is based. The risk assessment process will include specific studies on the environmental impact, community and cultural impacts, heritage impacts and safety impacts. The principles of radiation protection and collation of the national inventory are also explained. The national inventory is the responsibility of the Australian Federal Government and they have used a team of experts to compile the inventory which is being reported in the Joint Convention on Spent Fuel and Radioactive Waste Management.

Following the national radiation protection policy, the regulator follows international best practice by implementing and following the IAEA guidelines. This means that, for example, the IAEA transport of radioactive materials (SSR-6) is exactly copied into the Australian Dangerous Goods Code.

The regulator expects to have stakeholder engagement at all points in the licencing process. This means that as well as radiation protection, there needs to be involvement from security, environmental protection, emergency management, conventional work health and safety and finances. These are the internal stakeholders, and there are external stakeholders such as the public, the other regulators, for commonwealth entities there are the government departments and approval process (financial and environmental).

3. Regulatory and Operational System Preparation

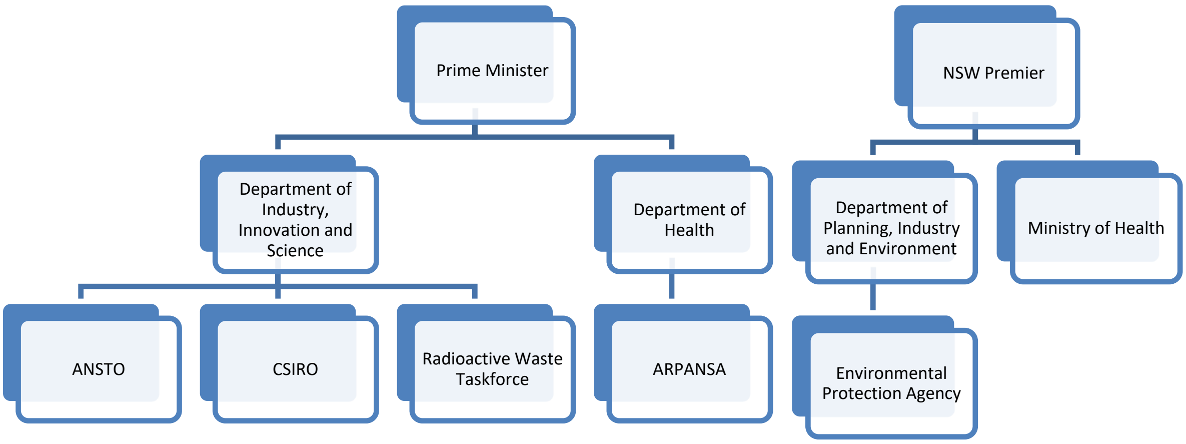
Australia has an independent regulator, the Australian Radiation Protection And Nuclear Safety Agency (ARPANSA) who report to the Department (Minister) of Health at the Commonwealth Level. ARPANSA are the Australian Government's primary authority on radiation protection and nuclear safety. ARPANSA protects the people and the environment from the harmful effects of radiation through research, the services provided and regulation of Commonwealth entities that use radiation. The strategic objectives are to:

- Protect the public, workers and the environment from radiation exposure
- Ensure radiological and nuclear safety and security and emergency preparedness
- Promote the effective use of ionising radiation in medicine
- Ensure effective and proportionate regulation and enforcement activities.

ARPANSA regulates all the Commonwealth Entities that use radiation, which are primarily the Australian Nuclear Science and Technology Organisation (ANSTO), the Commonwealth Scientific Industrial and Research Organisation (CSIRO) and Defence. ANSTO and CSIRO report to the Department (and Minister) of Innovation, Industry and Science, while Defence report to the Department (and Minister) of Defence.

The regulator in Australia has a risk assessed, performance based criteria. This is to make the operator of the nuclear facility (licencee) the person responsible for all safety. The licencee proposes the action and submits the safety case to the regulator who then reviews and assesses the safety case to international standards. The operator uses the national inventory to establish the waste acceptance criteria and design of the facility. This is the physical description of the facility, the waste form and the packages which are used to contain the waste. The operator has to develop the plans which describe how site control, safety, waste, security, emergency and environmental plans and arrangements for the facility will be managed. In Australia the operator of the national facility will be decided upon in 2020. In preparation the federal government has been preparing a generic waste acceptance criteria and a generic facility design. When the facility operator is decided, then the operator will take on the responsibilities for the design, waste acceptance criteria and national inventory of radioactive waste.

At the state level, there are 6 radiation regulators, which sit either under Departments of Health or Environment Departments within their governments. The waste producers in the state areas sit under Health (for hospitals) and Education (for Universities).



Currently there is no central radioactive waste management organisation, although there is an intention to establish one with the establishment NRWMF.

The producer of the waste is considered the owner and has the liability for disposal of the waste. There is the expectation that the waste generator will pay for the disposal of the waste at the LLW repository. The disposal rates will be decided by the LLW Repository Operator. As ANSTO, CSIRO and Defence are all commonwealth government organisations, the liability is owned by the Commonwealth Government and it will pay for the disposal of these wastes. The LLW repository operator will take ownership of the waste once the waste leaves the waste generator sites and is shown to comply with the Waste Acceptance Criteria.

The national inventory will be controlled by the central radioactive waste organisation, but will rely on the information supplied by the waste generators to be accurate. The waste will not be accepted by the LLW repository unless it is on the inventory. The LLW disposal operator will set the Waste Acceptance Criteria as part of the Safety Case for the operations of the NRWMF.

The Waste Acceptance Criteria as written will be approved by the regulator (ARPANSA) and any changes to the Waste Acceptance Criteria will require regulatory approval.

All new radioactive licences, whether they apply to new facilities, decommissioning activities or major changes of use to a facility, require a public consultation process as part of the licencing activities. The Australian public is generally anti-nuclear and there are lots of activist groups who will comment on the submissions for new licences. Questions asked by the public have to be answered to the regulators satisfaction, and all questions and answers are publicly available through the internet. In addition, the large waste producers (ANSTO, CSIRO), the regulators (ARPANSA and EPA) and the LLW Repository Operator have community outreach programs to engage the public and promote positive messages about radiation and the safe handling of radioactive waste.

4. Site Selection:

In Australia the site selection process is an individual volunteer process. This means that when a person with sufficient land can sell it to the government for the national repository. When the process was started there were 28 nominations, which were assessed against a set of criteria. These criteria were decided by an independent advisory panel to the federal government, which included an anti-nuclear campaigner. These criteria related to the physical characteristics of the site, the social issues of the site and the economic viability of the site. Interestingly, facility safety was not rated highly because the assumption is that it will meet all the regulatory requirements and would be equally safe wherever it is sited. Safety would not be a determining factor but a requirement. There is a lengthy report on the criteria and the multi-criteria assessment for all sites has been released to the public. The political and the social factors were much more important in the site selection process. One of the factors which the minister is taking into account is community acceptance of the LLW repository. In practice this will be decided by a local ballot of the communities to determine the level of support in each area. The Government Minister for Resources is the person responsible for making the decision about the site for a LLW repository.

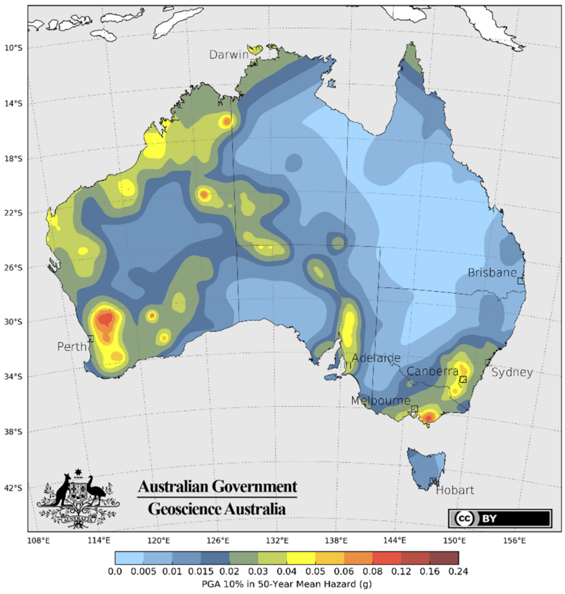


Figure 1: Seismic Map of Australia

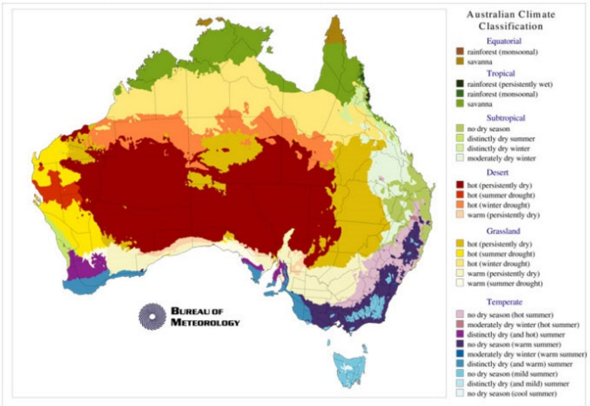


Figure 2: Climate Map of Australia

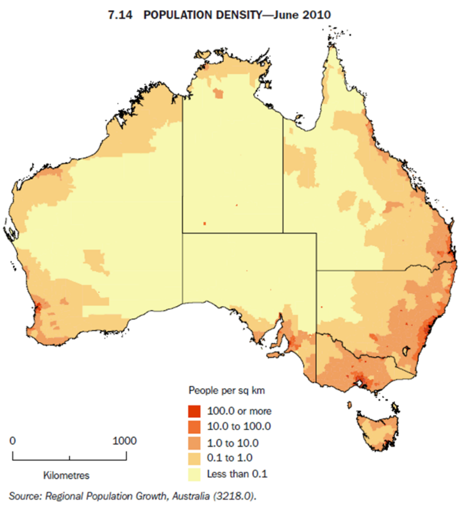


Figure 3: Population Density in Australia

The community consultation process required a large amount of work from the Australian nuclear industry to discuss and communicate the concerns of the public at these locations. The Federal government is responsible for choosing the site and has selected three sites for further consideration. These sites are currently undergoing environmental assessment, heritage surveys and extended community consultation processes. The community which hosts the facility will have a fund provided to improve the community conditions, this fund is larger than the landowner will receive for the land. The environmental impact assessment, site characteristics and criteria assessment will all form part of the safety case for the facility.

5. Design and Construction of disposal Facilities

In Australia the design and construction of disposal facilities for low level solid waste and storage of intermediate level waste is continuing. The federal government will be appointing an entity to be responsible for Radioactive Waste Management Function in Australia; the development of generic waste acceptance criteria and a generic design; and the selection of the site. When the Waste Function is selected, that organisation will assume control of the selected site and can use the specific information to optimize the waste acceptance criteria, the facility design and overall safety case for the disposal site. The detailed design of the facility will lead to detailed waste acceptance criteria, which will lead to detailed package types, which will lead to optimization of the design. This is an iterative process with a large number of variables that need to be continually revised.

The detailed design will require an organisational governance structure, organisational chart with all the supporting services (maintenance, human resources, it, security, financial, logistics, etc), utilities (power, transport provisions, water, etc) as well as the design of the facilities.

The Australian design for a waste disposal facility is based on the French and Spanish design of a concrete vault with packaged waste placed inside. This is an engineered barrier to retard water, and when a vault is completed a series of engineered caps will be put over the vault to direct water away from the vault.

There will need to a safety case which will be continually updated to the regulator.

I. The initial safety case will be for the siting of the disposal facility. This is where the site description and initial safety case will be published for public comment. There will be an international review for the regulators decision and international best practice will be followed. Upon successful assessment detailed assessments will begin.

II. The next regulatory review will be on the construction licence, with the updated safety case for review. Upon successful assessment, the construction of the facility will begin, concluding with commissioning of the facility.

III. IAt the completion of the construction and the commissioning, the commissioning reports and operating licence submission will be submitted. This will be the final safety case open for public comment before waste is transported and disposed in the facility.

IV. The safety case will be updated through the life of the facility every 10 years for submission to the regulator.

V. A licence change for closure of the facility will be submitted in 100 years time, with the facility going into the care and maintenance phase. This is a major design change where no waste will be emplaced, vaults closed, the facilities will be decommissioned and all the engineering barriers over the vaults will be constructed and monitored. This monitoring period is called institutional control.

VI. At the end of the institutional control period (at the moment planned to be 300 years, it will depend on the safety case), there will be a licence submission to abandon the licence. The safety case at this point will show that no harm will come to people who accidentally disturb the waste in the vaults.

-Part II. Specific Site Safety Assessment of LLW Repository-

1. General considerations for Safety Assessment

Australian is still in the process of establishing a repository. The Safety assessment has started, and there are generic details about inventory, design and location, however there is yet to be a draft safety assessment completed.

The safety assessment will take information from the inventory, design, environmental assessment, logistics, and organisational structure to create the risk assessment and develop the document. In the description above, we are starting the safety case for point I. This will be based on IAEA guidance SSG-23 - The Safety Case and Safety Assessment for the Disposal of Radioactive Waste.

2. Specific LLW repository planning

The Department of Industry, Innovation and Science has established a taskforce to run the repository project. The scope of the taskforce is to select a site and identify the agency who will become the owner of the radioactive waste liabilities in Australia. This taskforce has then contracted out works to various parties to allow this to happen. There are community consultation groups, surveying groups, environmental impact assessors, logistics assessors and ANSTO as nuclear and radiological expertise for the facility.

The organisational arrangements of the radioactive waste management agency have been identified. The radioactive waste management agency will be the entity responsible for the repository after the site is selected. It will be their internal approval processes which will approve everything. This is the business case, organisational plan, the operational plan, the site design, the facility design, the supporting infrastructure (inside and outside the fence) design, the waste plans, emergency plans, safety management system, environmental management system, quality management system, records management system, the financial forecast, the safety case, and so on. They will be independent of a government department, although the head / chief executive officer / president of the radioactive waste management agency will report to the Minister for the Department of Industry, Innovation and Science. This is the way that ANSTO and CSIRO and other government organisations operate.

Figure 4: Possible location for the NRWMF, Wallerberdina, South Australia

There will be oversight by the regulators, and the regulators will approve the operations, safety case, environmental impact and financial performance of the facility. The waste plan will be decided by the radioactive waste management agency, with the overall safety case approved by ARPANSA. The funding will be asked by the radioactive waste management agency to the Commonwealth Government who will supply the funding.

The design of the repository has been undertaken by ANSTO, who did the nuclear design and operational flows and then utilised a sub-contractor to design the actual buildings and infrastructure required. The initial generic draft of the long term safety case of the repository was contracted to ANSTO, as was the draft generic waste acceptance criteria and national inventory. Essentially, everything within the fence surrounding the repository was contracted to ANSTO to complete. This included the detailed business case which was supplied to the whole of government for funding over the coming years.

The area outside the fence was contracted to AECOM. This included the environmental assessment, the roads, rail, water, communications and other infrastructure which is required to operate the repository. When these are designed, the government will have to improve the roads to take road trains, maybe create a new rail line, supply electricity (either by building new poles and wires or by building a local power supply like a solar panel farm), supply communications and supply water. Water is a big issue in Australia, particularly in the area where the selected sites can be found. There is no reliable surface supply of water, and water extraction from the ground will impact on the local farming communities.

It is expected that staff for the facility will live in the local community and will not be considered as fly-in-fly-out (FIFO) staff. One of the selling points from the local government is that the workers will contribute to the local community. There will also be a strong preference to employ people from the local community. There will be training offered for local workers to become environmental monitoring officers, radiation protection staff, operators moving the waste, admin staff, tour guides and so on. Some positions may at first be filled in by experts coming from other locations, such as risk assessors, safety case experts, engineering support or government liaison officers. However it is expected that the resource planning of the operating agency will build the skills of local staff so that they will be able to take on these roles. There will be an outsourced maintenance model, and local businesses will be much preferred to complete the maintenance of the facility.

There is a strong preference for the operating agency to be an addition to an existing government organisation. This will not affect the number of staff needed to work in the facility, but will reduce the number of people required in the "back office". The larger organisation will have the human resources, quality, information technology, finance, conventional workplace health and safety, security, nuclear safeguards, environmental systems and emergency planning protocols in place which can easily be extended to this facility. These enabling services are required, and it will be cheaper for the Commonwealth if it does not have to create all these new positions.

The logistics will be undertaken by the radioactive waste agency when the location is known. There have been brief discussions with freight companies to ask how it is done, and these have been used in the financial estimates for operations. The transport containers are being designed to fit onto both road and rail transport with no special vehicles needed.

The community have input, but do not get to decide anything. They can question, discuss and make recommendations to the radioactive waste management agency or ARPANSA. These have to be resolved, however the radioactive waste management agency will be the final decision maker in all of these discussions. Due to the Australian government operating philosophy, there will be a lot of consideration given to community concerns, and work will be done to include their ideas.

Emergency preparedness will be organised by the radioactive waste management agency, using local resources (bushfire response, police, guard force and medical support). There may be additional resources required and funded by the repository to ensure that there is adequate emergency response available for the identified accident scenarios.

The regulator will be regularly visiting the site and conducting inspections. These inspections are publicly available on the ARPANSA website and indicate what they have found. If there are any non-compliances with the licences then these are reported to parliament and recorded. The public can also communicate to ARPANSA to raise their concerns.

3. Guidelines for Safety Assessment

Australia will use the IAEA guidelines on safety assessments (SSG-23) as the starting point for developing the safety assessment for the low level waste repository. This will require getting a lot of information from many independent sources to provide the information.

The information will come from independent organisations and from ANSTO expertise. There will be environmental assessments, hydrological assessments, cultural and historical assessments, geological assessments, conducted by independent expert groups. This information will require detailed study of the location, and will require 12 months of data about the site to demonstrate that all seasons of the year are considered and feed into the design of the facility. This information will be compiled into an environmental impact assessment. This will be approved by the environmental regulator which will inform the radiation protection regulator of the outcome.

The national inventory will be supplied by the radioactive waste agency and will be used as the source term for the long term safety case which will use all the location specific environmental information collected by the independent groups. This long term safety case will be used to determine the Waste Acceptance Criteria for the facility.

The long term safety case will also define some of the requirements of the design, such as the quality of the material used in construction, the depth of the waste beneath the surface (whether buried or covered in an engineered barrier) or any external barriers put into place around the waste. The design of the radiological safety components, the long term safety case, the waste acceptance criteria and other requirements around radiation or nuclear safety will be conducted by nuclear experts and reviewed prior to submission to the regulator.

There will be an international review of the safety case, which may use IAEA networks, prior to it being submitted to the radiation protection regulator for approval. The Department of Industry, Innovation and Science has indicated that it is planning to have an ARTEMIS mission by the IAEA review the repository design, safety case and process.

4. Confidence Building

Currently there is significant community consultation going on in the areas around the selected sites. This includes funding someone in the area to act as a local liaison officer and having a committee of local representatives to discuss the repository, how it will affect the town and the way that the town can use the money from the government from hosting the site to better the town. There are lots of meetings and interactions involving brought in experts, drop in centers, discussion booths at local fairs and information fact sheets or leaflets provided to members of the public. There has been a social media presence with facebook accounts, twitter accounts, linkedin accounts and a website with a lot of information on it. This has been happening over a three year period and will continue through the operational period of the repository.

The Commonwealth Government has been issuing lots of information in the lead up to a ballot in the communities asking if they would like to be considered in the next phase of the decision. This ballot is not binding, however the Minister will consider the outcomes in their decision on the siting of the repository. The first location had a ballot which had 62% of the local residents vote in favour of having the disposal facility in their community.

There is funding for the land owner as the government buys the land at four times the prevailing rate. There is a fund (>$12M AUD) for the local community to invest into the town and use as the local committee determines.

ARPANSA has been out to explain the process of licencing to the community, including emphasising that the community gets to make comments on every submission; siting, construction, operation and closure. All documents (except those with security implications) will be available for the public to review, on the ARPANSA website and at the information sessions. The repository owner has to respond to all the questions satisfactorily for the regulator to approve the submission. ARPANSA will be reviewing the safety assessment, the Department for the Environment will be reviewing the Environmental Impact Assessment, the road authorities / marine authorities / air authorities will be reviewing the packaging and the Parliamentary Works Committee will be reviewing and approving the spending of any tax-payers money. There appears to be community acceptance in the regulators for the facility.

The government will be using Australian procurement guidelines to ensure that the contracts for construction and equipment are trackable and free from corruption. The owners and all contractors will have to be certified as ISO9001 compliant. This means there will be an audit program conducted by internal staff members and external staff members. The audit outcomes will not be publicly available, however if an organisation loses ISO9001 accreditation then that organisation can no longer be part of the repository, or support the repository.

5. References:

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IAEA documentation https://www.iaea.org/resources/safety-standards/search
GSG-1 Classification of Radioactive Waste
GSG-3 The Safety Case and Safety Assessment for the Predisposal Management of Radioactive Waste
GSR Part 1 Governmental, Legal and Regulatory Framework for Safety
GSR Part 3 Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards
GSR Part 4 Safety Assessment for Facilities and Activities
GSR Part 5 Predisposal Management of Radioactive Waste
GS-G-3.3 The Management System for the Processing, Handling and Storage of Radioactive Waste
GS-G-3.4 The Management System for the Disposal of Radioactive Waste
GSG-9 Regulatory Control of Radioactive Discharges to the Environment
GS-R-3 The Management System for Facilities and Activities
RS-G-1.7 Application of the Concepts of Exclusion, Exemption and Clearance
SSG-1 Borehole Disposal Facilities for Radioactive Waste
SSG-14 Geological Disposal Facilities for Radioactive Waste
SSG-23 The Safety Case and Safety Assessment for the Disposal of Radioactive Waste
SSG-29 Near Surface Disposal Facilities for Radioactive Waste
SSG-31 Monitoring and Surveillance of Radioactive Waste Disposal Facilities
SSG-35 Site Survey and Site Selection for Nuclear Installations
SSG-40 Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors
SSG-41 Predisposal Management of Radioactive Waste from Nuclear Fuel Cycle Facilities
SSG-41 Predisposal Management of Radioactive Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education
SSR-5 Disposal of Radioactive WasteSSR-6 Regulations for the Safe Transport of

Radioactive Material
TS-G-1.4 The Management System for the Safe Transport of Radioactive Material
WS-G-1.2 Management of Radioactive Waste from the Mining and Milling of Ores
WS-G-2.3 Regulatory Control of Radioactive Discharges to the Environment
WS-G-6.1 Storage of Radioactive Waste

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-Part I. General Outline of LLW Repository-

1. General Policy

In Bangladesh radiation is being utilised in industry, agriculture and medical treatment purposes. The research and development on radiation applications of Bangladesh Atomic Energy Commission (BAEC) covers utilisation of the research reactor, radiation processing and technology, application of radioisotopes, food irradiation etc. Radioactive wastes generated from different stakeholders in the country are safely stored at Central Waste Processing and Storage Facility (CWPSF). No suitable site yet been selected for disposal of radioactive waste in the country. The area survey is underway and site selection procedures will be conducted according IAEA recommendations. Suitable site for waste disposal facility will be finalised on the basis of analysing several data on seismic fault, flood, water table, rainfall, cyclone risk, soil type, surface fault and hydrogelogical characteristics.

The Legal basis for the safe management of radioactive wastes are Bangladesh Atomic Energy Regulatory (BAERA) Act-2012 and Nuclear Safety and Radiation Control (NSRC) Rules-1997 based closely on the BSS apply to regulate activities that involve sources of ionising radiation and management of radioactive waste, to ensure the protection of man and the environment from the hazards of ionising radiations associated with radiation sources and radioactive wastes.

2. Principles and Safety Assessment

According to NSRC rules 1997 chapter X and section no. 87, radioactive waste management practices shall comply with the requirements of the applicable safety series published under IAEA Radwass programme. The activity and volume of any radioactive waste arising from uses of radiation sources shall be kept to the minimum practicable.

For the disposal of radioactive waste the essential protection goal are:

- Long term protection of man and the environment against hazardous effect of the release of harmful substances from RW packages
- Unnecessary radiation exposure or contamination of man and environment must be avoided
- Adequate safety compliance with the regulatory requirements
- Determine guide research and development priorities
- Contribute to confidence of policy makers and scientific community

The protection goals have to be further to be suitable for consideration in the development of the site selection procedure.

Regulatory and Operational System Preparation

BAER act No.19/2012 chapter IV and NSRC rules 1997 describe the general safety requirements. The applicable standards, code and guide for Radioactive Waste Management programme are IAEA Safety series nos. 53, 63, 79, 11-SF, 111-S1, 111-G1.1, G3.1 and other IAEA RADWASS publication.

General standards for the protection of human health and environment are set out in a national in legislation. The regulatory authority develops regulatory requirement specific to disposal facilities on the basis of the national policy.

The regulatory body establish the regulatory requirements for the development of disposal facility for radioactive waste and set out the procedures for meeting the requirements for the various stages of the licensing process. It also set conditions for the development, operation and closure of disposal facility and carry out such activities as are necessary to ensure that the conditions are met.

The regulatory body has to:

- develop regulatory requirements
- provide guidance on the interpretation of the national legislation and regulatory requirements,
- engage in dialogue with waste producers, the operators of the disposal facility and interested parties to ensure that the regulatory requirements are appropriate and practicable
- maintain competent staff, to acquire capabilities for independent assessment and to undertake international co-operation as necessary to fulfill its regulatory functions
- document the procedures that it uses to evaluate the safety of disposal facility
- set out the procedures that a repository operator is expected to follow in demonstrating compliance with the conditions for the development and operation of the disposal facility
- set out the procedures that it follows to assess compliance with the conditions throughout all stages of the development, operation and closure of the disposal facility.

The operator of a radioactive waste disposal facility is responsible for its safety. The operator carries out safety assessment and develop and maintain a safety case, and carries out all the necessary activities for site selection and evaluation, design, construction, operation, closure and, if necessary, surveillance after closure, in accordance with national strategy, in compliance with the regulatory requirements and within the legal and regulatory infrastructure. The operator of disposal facilities responsible for

- conduct or commission the research and development work necessary to ensure that the planned technical operations can be practically and safely accomplished, and to demonstrate this.
- carry out all the necessary investigations of sites and of materials, and has to assess their suitability and obtain all the data necessary for the purposes of safety assessment
- establish technical specifications that are justified by safety assessment, to ensure that the disposal facility is developed in accordance with the safety case (waste acceptance criteria, controls, limits).
- retain all the information relevant to the safety case for the facility, and has to retain the inspection records that demonstrate compliance with regulatory requirements and with the operator’s own specification.
- cooperate with the regulatory body and has to supply all the information that the regulatory body may request.

According to NSRC rules Chapter IV section 17, the safety and fire protection shall be incorporated in all plans, design and layout of building, structures and premises and applicable standards and codes shall be followed for making such plans, design and layout. For installation, commissioning, operation and storing of radioactive material possible risk to health and safety of employees and properties shall have to be anticipated.

3. Site Selection

Currently no specific site has been chosen for waste repository in the country. However, collection of meteorological data, study on Hydro geological characteristics for selecting of appropriate site for waste are being conducted. According to NSRC rules 1997 chapter IV section 17.3 during the site selection process, the factors which affect exposure or potential exposure of radiation workers other employers and members of public for radioactive materials and having the potential for large release into the environment the relevant features (environmental factors and local population) shall take into account. In BAER act 2012 chapter III section 19 describes the relevant act for siting of radioactive waste disposal facility.

Previously, site selection was regarded as primarily a technical process aagreement on, and application of, exclusion and suitability criteria ranking of site attributes, utility analysis. However, currently it is important include more non-technical aspects like public outreach and communication, site volunteers and compensation packages in order to comply with IAEA recommendation. The general criteria for a suitable site for a low level waste repository :

Simple geological-techtonic structure, non-existence of deep aquifers with meteoric water, no recent tectonic activities, rock with low permeability and good retention potential for radionuclide, favourable rock-mechanic properties of the repository formation etc. The geological, techtonic and hydrogeological conditions need to be assessed for determining the site of waste repository. The site selection procedure of waste repository has to be:

- Comply with the legislation of the country
- Acceptable to local and national community
- Geologically stable

4. Design and Construction of Disposal Facilities

Since currently there is no disposal facility available in the country all the processed and unprocessed radioactive wastes are generated in the country from research, medical, industrial and laboratories are safely stored in CWPSF.

In general the operator of a disposal facility is responsible for all necessary activities for design, construction, operation and closure, in compliance with the regulatory requirements and within national legal infrastructure. The operator is responsible for developing and for demonstrating its safety, consistent with the requirements of the regulatory body.

The facility and its engineered barriers need to be designed to provide safety during the operational period. The construction activities have to be carried out in such a way to ensure safety during the operational period.

The disposal facility and its engineered barriers need to be designed

- to contain the waste with its associated hazard,
- to be physically and chemically compatible with the host geological formation and/or surface environment, and
- to provide safety features after closure that complement those features afforded by the host environment.

According to NSRC rules the design reliability, durability and easy manageability and operational suitability, multilayer protection and defense in depth and the requirements of operational environment, human environment related procedural aspects and other human factors are applied. The relevant act for the authorisation process for radioactive wastes disposal facility has been mentioned in BAER Act No. 19/2012.

-Part II. Specific Site Safety Assessment of LLW Repository-

1. General Considerations for Safety Assessment

The safety objective is to site, design, construct, operate and close a disposal facility so that protection after its closure is optimised social and economic factors being taken into account. The general consideration for the safety assessment is to provide radiological safety.

In order to meet the basic safety objective several requirements e.g, general safety requirement, Technical requirement and Management requirement need be complied as described in the NSRC Rules 1997 Chapter X and BAER Act 2012, Chapter IV.

During the operational period
Safety in the operation of radioactive waste disposal facilities has to be achieved by means of a variety of engineered and operational controls.

These include the containment and shielding for the radioactive waste and operational control over time of exposure and proximity to the waste.

Safety after closure: is achieved by developing a disposal system in which the various components work together to provide and to ensure the required level of safety

Protection of the public: by preventing or controlling releases from the facility and by controlling access to the site. A reasonable assurance has to be provided that doses and risks to members of the public in the long term will not exceed the dose constraints or risk constraints that were used as design criteria.

The dose limit for members of the public from all planned exposure situations is an effective dose of 1 mSv in a year and 50 msv occupational dose limit in single year, and this or its risk equivalent are considered criteria not to be exceeded in the future.

Environmental and non-radiological concerns
The scope of safety requirements for disposal of radioactive waste is the protection of the environment against radiological hazards associated with the radioactive material in the disposal facility.

The assessment of conventional environmental impacts such as may occur in the construction and operational period for a disposal facility, e.g. impacts relating to traffic, noise, visual amenity, disturbance of natural habitats, restrictions on land use and social and economic factors, as well as non-radiological toxic hazard also has to be assessed where this is significant.

If non-radioactive materials may affect the release and migration of radioactive contaminants from the radioactive waste, then such interactions have to be considered in the safety assessment.

According to NSRC rules 1997, during the operation, adequate technical capability to support all aspects important for safety, security and safeguard during the whole operational life time shall have to be taken into consideration.

2. Specific LLW Repository site (planning etc.)

At present no waste repository available for disposal of RW in the country. The central waste processing and storage facility is the only licensed facility for performing pre-disposal activities in the country. However, some preliminary work on area survey and study on seismic fault, flood, water table, hydro geological characteristics at different location around the country are being conducted for selecting suitable site for radioactive waste repository.

In general, site characterization is an essential part of the repository development programme that should start as soon as the site has been identified. To gather all the information required to compile a credible safety case. To gain and to demonstrate an understanding of the site so that a convincing case can be used for its safety which is a multi-disciplinary exercise covers a very wide range of activities. For determining the site characteristics that are important to the assessment of the design and safety of a low level waste repository, the following need be considered as a minimum:

- low permeability and high retardation properties
- In environmental settings that would restrict sub-surface and surface radionuclide movement (e.g. low hydraulic gradients or basinal settings)
- In environmental settings where radionuclide releases would result in long travel paths and long travel times back to potential receptors
- Areas away from major population centres
- Close to existing or planned transport infrastructure

The Radioactive waste disposal facility need to be compliance with the stages of authorization procedures of nuclear, radiation and radioactive waste disposal facility BAER Act 12 Chapter III section19.

3. Guidelines for Safety Assessment

Depending on the stage of development of the facility, safety assessment may be used in focusing research, and its results may be used to assess compliance with the safety objective and safety criteria. The requirement of safety assessment of a waste disposal facility need to be compliance with the BAER act 12 and NSRC rules 1997.

Generally safety assessment is the process of systematically analysing the hazards associated with a disposal facility, and the ability of the site and the design of the facility to provide for the fulfilment of safety functions and to meet technical requirements. Safety assessment has to include quantification of the overall level of performance, analysis of the associated uncertainties, and comparison with the relevant design requirements and safety standards. Safety guides provide comprehensive guidance on and international best practices for meeting the requirements of disposal facility Safety assessment of a disposal facilities need to address the following important components:

Characterization of hydro geological parameters:
Requires extensive hydrological investigations: Permeability and hydraulic conductivity, weather, topography, surface storage, infiltration, evapotranspiration, soil storage, lateral drainage, leakage through linear and geo-membrane etc.

- Specification of the assessment context
- Description of the waste disposal system
- Development and justification of the scenarios
- Formulation and implementation of models
- Analysis of results and building of confidence

4. Confidence Building

An appropriate management system will contribute to confidence that the relevant requirements and criteria for site selection and evaluation, design, construction, operation, closure and safety after closure are met. The management system for waste disposal facility provides for the preparation and retention of documentary evidence to illustrate that the necessary quality of data has been achieved. The management system also ensures the collation of all the information that is important to safety and that is recorded at all steps of the development and operation of the facility, and the preservation of that information. The safety of the disposal facility needs to be assessed periodically until termination of the licence. During this period, the safety shall also be assessed when a safety significant modification is planned or in the event of changes with regard to the conditions of the authorization. In the event that any requirements set down in the Safety Requirements publication are not met, measures shall be put in place to upgrade the safety of the facility, economic and social factors being taken into account. During the review of operator's quality assurance programme by regulatory authority the following component taken into account:

- Maintain and produce waste inventory
- Site plans, engineering drawings, specifications and process description
- Safety and environmental assessment methods and computer codes
- Environmental monitoring programme
- Result of safety and environmental assessments
- Effluent and environmental impact monitoring results

Measures of surveillance and control of the disposal facilities include:

- restrictions on access by people and by animals;
- inspection of physical conditions;
- retention of appropriate maintenance capabilities;

According to NSRC rules chapter IX section 56. The following monitoring programme is required:

- Assessment of external radiation level at all appropriate location
- Assessment of levels of radioactive contamination at all appropriate locations
- Assessment of radiation risks associated with the accident and emergency situation
- The review of the monitoring progamme carry out periodically and also in the event of any major modification carried out to the installation or practices
- Surveillance of the Environment: According to NSRC rules 1997 section: 57: Surveillance for the environment include:
- Compliance with the authorized limit
- Assessment of potential exposure of members of the public from the source under consideration
- Evaluation of trends of exposure levels in the environment
- Monitoring of , environmental pathways and the critical group and the pre operational studies
- Appropriate maintenance of the record of the measurements of external exposure and radioactive contamination and the estimate of doses received by the populations

To verify compliance with quality assurance programme independent audit may be carried out which have been mentioned in the BAER Act 12, Chapter IV section 30.

CHINA

CHINA

-Part I. General Outline of LLW Repository-

1. General Policy

The task of shallow ground disposal is to limit the radionuclides in the waste to the disposal site within the time frame (generally 300a to 500a) in which the waste may pose an unacceptable risk to humans. Preventing the spread of radionuclides to the environment at unacceptable concentrations or quantities and protecting the human safety.

2. Principles and Safety Assessment

Solid radioactive waste shall be disposed of in accordance with their classification. Solid LILW shall be disposed of in near-surface or intermediate depth disposal facilities. Solid HLW waste shall be disposed of in a centralized deep geological disposal repository. Wastes arising from uranium (thorium) mining and milling tend to be in relatively-centralized in-situ landfill.

In order to estimate the functions of the LLW repository, safety analysis and environmental impact assessment must be performed when selecting a plan, determining the site, designing, operating, and shutting down the site.

The effective annual dose of radionuclides released to the environment through various routes to representative individuals in the public does not exceed 0.25 mSv. Provide protection for individuals who unintentionally break into the disposal site or come into contact with waste at any time after the organized control of the disposal site is stipulated. The annual effective dose of unintentional intruders who are continuously exposed does not exceed 1 mSv, and the effective dose for a single acute exposure does not more than 5 mSv.

Requirements for siting

The safety analysis report and the environmental impact report must be included in the approval documents for the declaration of the site. The report shall include the following main contents: (1) the implementation of the safety requirements involved in relevant national standards, existing problems and measures should be taken; (2) analyzing of the quantity and probability that radionuclides may be transferred from the repository to the human and environment, the mechanism, pathway and rate of radionuclides to human body, initially estimating the personal dose equivalent and collective dose equivalent of the public in the normal state, natural and man-made events, and making safety assessments; (3) pre-analyzing and evaluating the environmental impact of the LLW repository at various stages, such as construction, operation and shutdown, and the impact that the surrounding environment may have on the LLW repository.

Requirements for designing

The preliminary design stage of the LLW repository shall have design documents of safety analysis and environmental protection, which shall include two main contents: (1) discussing the engineering measures should be taken and their reliability to achieve the standard requirements; (2) further demonstrating the contents of the safety analysis report and environmental impact report at the siting stage, the dose equivalents of the public and workers during the operational phase and the dose equivalents received by the public of post-closure should be estimated based on the design parameters, and consideration and evaluation of harms to the environment and humans also should be taken when natural and man-made events occurred.

Requirements for operation and shutdown phases

Before the operation and shutdown of LLW repository, the approval procedures must be performed in accordance with national regulations.

The division of the three stages of “closure”, “semi-closure” and “open” during the post-closure of the LLW repository shall be subject to safety analysis and evaluation, and may only be implemented after approval by the national environmental protection department.

During the operation, closure, and semi-closure phases of the LLW repository, the environmental quality shall be evaluated periodically according to the data of environmental monitoring. Since anomalies caused by man-made or natural events affect the expected function of the LLW repository, they should be analyzed and evaluated in a timely manner, and reported to the national and local environmental protection departments.

3. Regulatory and Operational System Preparation

Legal framework

A legal framework comprised of national laws, administrative regulations, departmental rules (national standards), management guides and reference legal instruments governing radioactive waste management has been established and maintained in China. Implementation of these instruments can provide the protection of individuals, society and the environment. These documents were developed and issued after stringent review by relevant authorities including regulatory control department. These set out the specific requirements for every step in radioactive waste management and criteria for protection of the public, the workers and the environment in respect of several main links in waste management (including the disposal of solid radioactive waste and the release of radioactive effluents), which are basically consistent with internationally endorsed standards and criteria. The MEE/NNSA, alongside with the competent authorities of nuclear facilities, shall conduct regulatory control and supervisory monitoring of compliance of such facilities with standards.

Waste acceptance requirements

"*Safety requirement for near surface disposal of low and medium level radioactive solid waste*" (GB 9132-2018) stipulate the generanl requirements of waste form, waste package and acceptance. The filling of LILW waste package, package container, surface radiation level, surface contamination, transportation, disposal, emergency plan and quality assurance were also regulated in "*Standard of safety for low and intermediate level solid radioactive waste packages*" (GB12711-2018)

4. Site Selection

Siting of solid radioactive waste disposal facilities

China attaches high priority to the siting of radioactive waste management facilities, with the relevant regulations and standards being developed to guide the siting of different radioactive waste management facilities.

The site-related factors were evaluated during the siting of solid radioactive waste disposal facility, involving earthquake, regional stability, geological structure and lithology, engineering geology, hydrogeology, mineral resources, natural and cultural resources, population density, surface water and drinking water, urban, airports, and the distance away from the inflammable and explosive dangerous goods warehouse etc.

The impacts of such facilities on individual, the society and the public were evaluated, with account taken of the post-closure evolution of the site condition. Under our national standards, analyses were made, in the process of siting, of amounts and probability of migration of radionuclides into human environment, associated mechanisms, pathway, and velocity of radionuclide into human body, together with estimating initially the individual dose equivalent and collective dose equivalent under normal conditions, natural and artificial events, and also preliminarily analyzing and evaluating the environmental impacts of disposal facilities during construction, operation and post closure, and the possible impacts of the surrounding environment on disposal facilities.

Public Communication and Information Publicity

Prior to submitting the environmental impact statement to the Ministry of Ecology and Environmental/National Nuclear Safety Administration (MEE/NNSA), the applicants of construction projects, including the projects of radioactive waste management facility, should legally disclose the full text of information. Having accepted the said environmental impact statement, the MEE/NNSA should make the full text of information available to the public legally and should make its comment public on either approving or disapproving the environmental impact statement. After having approved such project, the MEE/NNSA shall open to the society the licensing process.

The MEE/NNSA issued in 2015 the Work Program on Public Communication of Nuclear and Radiation Safety and the Work Guidance on Public Communication of Nuclear Technology Application (trial), with a view to enhancing popular science dissemination, information disclosure and public involvement. Science 2015, MEE/NNSA, National Energy Administration (NEA) and China Atomic Energy Authority (CAEA) provide every year the periodic guidance on the activity of nuclear industry Open Days.

The building of information publicity channel is underway. The major platforms are the MEE/NNSA's information website and CAEA's and NEA's websites. Additional channels include China Environmental Status Bulletin, China Environmental Yearbook, NNSA's Annual Report, Annual Report on Environmental Radiation Monitoring, China Environmental Paper, radio and television, network website, as well as other media and channels.

5. Design and Construction of Disposal Facilities

Design and Construction of LILW Disposal Site

To limit possible radiological impacts to individuals, the society and the environment, the following measures were mainly considered and taken in the design and construction of LILW disposal sites:

(1) multiple barriers, consisting of engineering barrier (waste forms, container, disposal structure, and backfilling materials) and natural barrier, are developed and provided;

(2) proper waterproof and drainage systems are set; the engineering barrier is set to prevent the infiltration of groundwater and surface water in such a way as to minimize the contact of waste with water; waterproof design is focused on preventing surface water and rainwater from infiltration into disposal units; permeability and absorbability of rocks, surface runoff and ground water table and other site characteristics are considered in design of site waterproof; the design of drainage system can ensure the timely drainage of impounded water on the ground at site and in disposal units;

(3) in addition to drainage and waterproof, the design of disposal site also involves unit backfilling, overburden structure, surface treatment, and plantation; the holes and channels to monitor groundwater are installed in the vicinity of disposal units and proper locations onsite;

(4) disposal units are arranged in line with the overall plan, including access, walkways, contaminated area and non-contaminated area;

(5) waste acceptance zones are equipped with detection instrumentations for measuring dose rate, surface contamination, cargo certificate of vehicle and cask; inspection device for unloaded waste drum (box); radiation monitoring and warning systems; installations to treat

damaged containers: devices for transportation equipment decontamination, and facility to treat waste generated from decontamination; and

(6) laboratories are established for conducting routine analysis of water, soils, air and plant samples; individual decontamination, individual and environmental monitoring, instrumentation and equipment maintenance, and equipment decontamination.

The LILW treatment facilities currently in operation have been provided in design phase with technical preparation measures to enable such facilities to be closed. These includes buffer areas between disposal unit and disposal site boundary, underwater monitoring wells set in an appropriate location in buffer areas, on-site laboratories for analysis of samples from water, soils, air, animal and plant. In so doing, the analysis of on-site and ambient environmental safety may become available. Additionally, in accordance with design requirements, the enough distance should be left between the top level of disposed waste and disposal facility overburden layer. If necessary, anti-intrusion barrier needs to be established where protection can be provided to an unintentional intruder within institutional controls period. Overburden layer shall be designed so as to control water seepage to as low as practically feasible and as to lead infiltrated or surface water to the outside of disposal unit and to protect them from erosion due to geological process and biological activities.

Operation of LILW Disposal Site

The basic principles

The operation of the disposal site shall ensure that the radiation dose of its workers is lower than the national standard, and other safety shall also comply with national regulations.

The processing of volume reduction and solidification of wastes should, in principle, be completed before being sent to the disposal site.

Waste acceptance and handling

After the waste is transported to the disposal site, it must be inspected to confirm that the waste package meets the packaging requirements, is not damaged during transportation, and is fully consistent with the contents of the waste card being filled. The format of the waste card should be approved by the waste receiving department. The waste card is filled out by the waste generation unit and is responsible for its content.

The disposal site should have suitable handling equipment and appliances, such as cranes, forklifts, remote control hooks, etc. These equipment and appliances should be compatible with the handling and transportation methods.

Operation of waste disposal

The operator of the disposal site must abide by the provisions in the operating permit and formulate corresponding operating procedures as required.

Disposal operations for waste include the handling, placement of the waste, and the closure of disposal units. The safety of the workers and the public should be ensured throughout the disposal operation.

The placement of the waste should facilitate the closure of the disposal unit and should not adversely affect the safety isolation.

The operation file of waste disposal should include the date and location of the waste disposal, as well as the basic data of the waste, such as the serial number of the waste barrel or tank, the origin, the main radionuclide in the waste, the total activity and activity concentration, the radiation level, the volume and weight of the waste, and the problems with the disposal operation. The operator of the disposal site shall be responsible for the safekeeping of the operational files, and copies of them shall be deposited with the relevant departments as required.

A permanent sign shall be established at the appropriate location near the waste disposal site and disposal unit to indicate where the waste is buried and related matters.

Supervision of operation

The operator of the disposal site shall be responsible for the daily monitoring of the on-site environment, which shall include: (1) measurement of surface contamination; (2) measuring and analyzing the groundwater samples; and (3) measuring and analyzing the surface and a certain depth of the rock and soil sample; 4) measuring and analyzing the plant samples; (5) measuring and analyzing the air samples; (6) radiation monitoring; (7) periodic inspection of the integrity of the top cover of the disposal unit.

The external environmental monitoring plan of the disposal site shall be implemented independently by the local environmental protection department and the disposal site operator.

The results of environmental monitoring should be reported regularly to national and local environmental protection agencies. If abnormal conditions are found, they should be reported immediately and truthfully. The operator shall regularly evaluate the monitoring results and report them according to regulations.

Abnormal situation

The disposal site shall have emergency measures and remedies to deal with the following abnormal conditions, such as unclear waste cards, unqualified or broken waste packaging, scattered waste, and abnormal release of radioactive materials, preventing or minimizing the diffusion of pollution.

In the event of an accident that may cause pollution, the operator of the disposal site shall determine the location, nuclide, level, scope and process of the pollution as soon as possible so as to determine the remedial measures should be taken. If the accident is so serious that the disposal unit must be opened, a careful plan should be made in advance and necessary measures should be taken to limit the spread of pollution (including air pollution, water pollution and material contamination).

If there is evidence that the environment has been contaminated, the operator should be responsible for completing the entire pollution abatement action under the supervision of the national and local environmental protection departments, and investigate the cause of the pollution.

The conditions of closure

The disposal site shall be normally closed when the amount of waste allowed to be disposed of by the operating permit or the total radioactive limit has been reached.

When it is found that the design of the disposal system or siting has uncorrectable errors, or serious accidents occurred, or unforeseen natural disasters making the disposal site no longer suitable for disposal of radioactive waste, the disposal site should be closed abnormally. Unusual closures should be planned in advance. The implementation of abnormal closure must be approved by the national environmental protection department.

Post-closure phase

After the disposal site is closed, control shall still be carried out within the prescribed control period of the site to ensure that it meets the radiation protection requirements and has no adverse impact on the environment, and that no intrusion to the disposal site occurs during this period.

After the disposal site is closed, it generally goes through three stages:

(1) The closed phase. The disposal site that has just been closed should maintaining closed status and can only enter the site for supervision work;

(2) Semi-closed stage. When it is proved that the hazard of the waste is very small, and the covering of the waste is intact, it is allowed to enter the site, but excavation or drilling is not allowed;

(3) Open stage. After reaching the specified site control period, the radioactivity of the waste has dropped to a level that does not require radiation protection, and it has been verified that the site can be fully opened.

National and local environmental protection agencies should agree with the relevant departments to manage and implement the tasks after the closure of the disposal site.

The cost of maintenance, monitoring and emergency measures after the closure of the disposal site shall be budgeted prior to the operation of the disposal site and shall be drawn from a certain percentage of the charges for disposal of the waste. In order to accommodate the various changes that may be encountered, the cost should be re-estimated from time to time and necessary adjustments also should be made.

Supervision

Supervision after the closure of the disposal site, such as environmental monitoring, restricted access, facility maintenance, archival preservation, and possible emergency actions, should be carried out with the participation of national and local environmental protection agencies.

-Part II. Specific Site Safety Assessment of LLW Repository-

1. General Considerations for Safety Assessment

Solid radioactive waste shall be disposed of in accordance with their classification. Solid low- and intermediate-level radioactive waste (LILW) shall be disposed of in near-surface or intermediate depth disposal facilities. Solid high level radioactive waste (HLW) waste shall be disposed of in a centralized deep geological disposal repository. Wastes arising from uranium (thorium) mining and milling tend to be in relatively-centralized in-situ landfill.

In order to estimate the functions of the LILW repository, safety analysis and environmental impact assessment must be performed when selecting a plan, determining the site, designing, operating, and shutting down the site.

Requirements for siting

The safety analysis report and the environmental impact report must be included in the approval documents for the declaration of the site. The report shall include the following main contents: (1) the implementation of the safety requirements involved in relevant national standards, existing problems and measures should be taken; (2) analyzing of the quantity and probability that radionuclides may be transferred from the repository to the human and environment, the mechanism, pathway and rate of radionuclides to human body, initially estimating the personal dose equivalent and collective dose equivalent of the public in the normal state, natural and man-made events, and making safety assessments; (3) pre-analyzing and evaluating the environmental impact of the LILW repository at various stages, such as construction, operation and shutdown, and the impact that the surrounding environment may have on the LILW repository.

Requirements for designing

The preliminary design stage of the LILW repository shall have design documents of safety analysis and environmental protection, which shall include two main contents: (1) discussing the engineering measures should be taken and their reliability to achieve the standard requirements; (2) further demonstrating the contents of the safety analysis report and environmental impact report at the siting stage, the dose equivalents of the public and workers during the operational phase and the dose equivalents received by the public of post-closure should be estimated based on the design parameters, and consideration and evaluation of harms to the environment and humans also should be taken when natural and man-made events occurred.

Requirements for operation and shutdown phases

Before the operation and shutdown of LILW repository, the approval procedures must be performed in accordance with national regulations.

The division of the three stages of “closure”, “semi-closure” and “open” during the post-closure of the LILW repository shall be subject to safety analysis and evaluation, and may only be implemented after approval by the national environmental protection department.

During the operation, closure, and semi-closure phases of the LILW repository, the environmental quality shall be evaluated periodically according to the data of environmental monitoring. Since anomalies caused by man-made or natural events affect the expected function of the LILW repository, they should be analyzed and evaluated in a timely manner, and reported to the national and local environmental protection departments.

2. Specific LILW Repository site (planning etc.)

There are currently two solid LILW disposal sites in operation in China. The following table is an introduction to the Guangdong Beilong disposal site.

Name	Capacity (m^3)	Operation Period (year)	Total Radioactivity (Bq)	Land Area (m^2)
Guangdong Beilong Disposal Site	80,000	40	5.4×10^{15}	205,000

It mainly disposes solid LILW waste generated by the operation of nuclear power plants in Daya Bay Nuclear Power Station Base, Guangdong Province and adjacent areas of Guangdong, as well as urban radioactive waste.

A total of 70 disposal units were designed at the Beilong disposal site. The size of each unit was 17×17×7 m, the space utilization rate was 57.2%, and each unit could dispose of 1157m^3 waste.

The disposal unit is a reinforced concrete structure with a base plate thickness of 700 mm, the side wall thickness is 400 mm, the top plate thickness is 500-1000 mm, and the strength grade is C40. The stainless steel drain pipe is embedded in the center of the bottom of the repository and connected to the drain pipe of gallery below, which can effectively exclude the water entering into the repository. After the disposal repository is full with waste, the top plate is covered with a 5m thick multi-layer structure covering, which have the functions of waterproof, preventing animal holes and deep root plants and unintentional intrusion. There are monitoring wells around the repository, and a sampling port for the dialysis water is arranged in the underground pipe gallery, which can timely monitor whether the repository has leakage and the impact of leakage on the environment.

The location of Beilong disposal site is mainly composed of weathering products of light gray thick layer metamorphic medium-fine sandstone fine-thin metamorphic argillaceous sandstone with poor water permeability. There are small-scale inactive faults near the site, but generally the filling is better and the water conductivity is poor, it does not have a significant impact on the nuclides resisting capacity of the disposal site.

According to the design data, the occupational exposure of each type of work under the normal operation of the disposal site does not exceed 5 mSv/a, and the annual collective dose does not exceed 4.7×10^{-2} people▪Sv.

If a accident of transportation vehicle fires and explodes is occurred during the operation of the disposal site, the maximum immersion radiation of the residents may not exceed 2.6×10^{-12} Sv, the maximum internal exposure of inhalation shall not exceed 2.8×10^{-10} Sv, and the external radiation of the surface deposition shall not exceed 1.3×10^{-12} Sv.

At the post-closure phase of disposal site, under normal conditions, only ^{3}H and ^{14}C in 500a can pass through the unsaturated zone to enter groundwater and streams. The maximum dose of drinking water for children is no more than 4.5×10^{-7} Sv/a, and the maximum dose of ingested seafood is not more than 2.0×10^{-11} Sv/a. The other nuclides can be blocked in the unsaturated zone. If the engineering barrier fails, the drainage facilities and the blind ditch are blocked, the radionuclides are soaked in the groundwater for one month when the maximum release concentration of the radionuclides are at the bottom of the repository. The maximum dose of drinking water for children is no more than 5.2×10^{-7} Sv/a. The maximum dose of seafood does not exceed 2.8×10^{-11} Sv/a, and the main contributing nuclides are ^{3}H and ^{14}C.

After the disposal site is closed for 100 years, the public's unintentional intrusion into the disposal site for constructing houses will not exceed 1.8×10^{-5} Sv/a, and the main contribution is ^{137}Cs. The total of external exposure of the borehole and the inhalation of the internal radiation shall not exceed 3.6×10^{-6} Sv/a, and the main contribution is ^{137}Cs and ^{239}Pu. After drilling, the external dose of polluted soil, the inhalation of suspended materials, the ingestion of contaminated vegetables, and the total external dose of housing construction do not exceed 7.9×10^{-5} Sv/a. The maximum dose of well drinking does not exceed 2.2×10^{-7} Sv/a.

After a large number of tests, simulations and calculations, the results show that in the normal operation of the Beilong disposal site, only a small amount of radionuclides will be released into the environment, and the resulting public additional dose equivalent is far lower than the national limits and the management target values determined by the disposal site, so the disposal site will not have an unacceptable impact on the environment.

3. Guidelines for Safety Assessment

Data acquisition program

Data acquisition mainly includes environmental data of site, disposal site data and the status of environmental quality data.

Environmental data of site includes geographic location data, population distribution data, land use and resource profile data, meteorological data, hydrological data, geological and geomorphological data, and hydrogeological condition data.

Disposal site data includes disposal objects, disposal site planning and layout, waste disposal related data, and auxiliary facility data.

The status of environmental quality data includes the background value of radiation environment and the non-radioactive environment of the disposal site and nearby areas, and the environmental impact data of the nuclear power plant on the disposal site nearby.

Pre-operational, operational and post-closure monitoring

After the design of the disposal site is completed, at least one systematic environmental monitoring of the site should be carried out before the operation of disposal. The specific monitoring items include groundwater level, environmental radiation level of gamma, soil, groundwater, surface water, seawater, sediment, crops and air. In addition to environmental radiation level of gamma, the gamma spectrum analysis of aerosol; analysis of ^{3}H and ^{14}C for gas sample; analysis of ^{60}Co, ^{90}Sr, ^{137}Cs, ^{14}C, ^{63}Ni, ^{3}H, $^{239+240}Pu$ for water sample; soil, sediment, crops, seawater and seafood gamma spectrum and analysis for ^{90}Sr and ^{137}Cs also should be carried out.

The monitors of radioactivity for the site, buffer zone and surrounding environment should be carried out during the operation period of disposal site. The monitoring items are groundwater level, gamma radiation level of environment, groundwater, repository drainage, surface water, air, soil, sediment, crops and seafood. The monitoring focuses on external drainage and groundwater, and the key nuclides are ^{3}H and ^{90}Sr.

The post-closure monitoring of disposal site is divided into two phases. In the first phase, the monitoring plan is basically the same with operation phase, the monitoring time is 5-10a, and the monitoring purpose is to evaluate the stability of the waste form, the reliability of the disposal facility and the effectiveness of the shutdown measures. The focus of the monitoring is on the drainage of the disposal unit and the groundwater in the site. The second phase continues until the end of the active monitoring period. The purpose of the monitoring is to determine the long-term impact of the disposal site and to verify whether the environmental impact of the disposal of the radioactive waste complies with national regulations. The monitoring content is mainly ^{3}H and ^{90}Sr in the early stage, and ^{14}C and ^{137}Cs in the later stage. Long-term monitoring can identify problems that may arise in the disposal system in a timely manner in order to take appropriate remedial measures. If the monitoring results indicate that the disposal facility is stable and reliable, the monitoring plan can be appropriately adjusted to gradually reduce the frequency of monitoring and sampling points.

Scenario analysis, pathways

According to the environment and the design of the disposal site, the release of radionuclides and possible unintentional intrusion into the Beilong disposal site during normal operation, accidents, shutdown, and long-term isolation after shutdown of the disposal site are calculated and predicted. The impact that may be on the staff, the public and the environment is also calculated and predicted.

Under normal operating conditions, the disposal site will produce occupational exposure to workers during the process of waste receiving inspection, hoisting and stacking, monitoring, backfilling and equipment maintenance.

There are two main types of accidents that may occur during the operation of the disposal site. A vehicle that transports waste fires or explodes and a waste container falls into an unsealed disposal unit during the lifting process.

After the disposal site is closed, it is considered that the performance of the artificial barrier will gradually deteriorate with the passage of time. Due to the infiltration of water, the nuclides will be leached from the waste form, and then released to the bottom of repository through the package, the backfill material and the bottom of the disposal unit, thereafter carried by groundwater, surface water, and finally to the bay.

The scenarios of unintentional intrusion after the monitoring period are mainly based on the residential scenario, the drilling scenario, the post-drilling scenario and the well-drinking scenario.

Each of the above scenarios has its own specific pathway of radionuclide transmission. Due to the many transmission routes, only the post-drilling scenario is taken as an example. The cores drilled by the drilling make the radioactive wastes distributed within a certain range, so that the intruders are affected irradiation. The irradiation route includes internal irradiation of inhalation by re-suspended contaminated soil, direct external irradiation of contaminated soil, internal irradiation caused by vegetables grown on contaminated soil, and external irradiation of building houses on contaminated soil.

Conceptual and mathematical model

Specific conceptual and mathematical models should be considered for each scenario. The following is a description of the conceptual and mathematical models of a vehicle that transports waste during a fire or explosion scenario during operation.

Conceptual model

The fire or explosion accident of vehicles transporting waste is characterized by suddenness and short duration. When calculating the time integral air concentration, as a more safety consideration, the radioactive release during the accident is regarded as a series of puff release. The composition is treated according to the release of the ground source, and the puff release period is 30s. Assuming an accident time of 20 minutes, a total of 40 puffs are released during the accident. The quasi-static wind state model and the wind model were used to calculate the nuclide concentrations at 1 m, 20 m and 5000 m, respectively.

Mathematical model

For the calculation points leaving the release point distance x=1 m and 20 m, the quasi-static wind state is adopted, and the static wind puff mode with uniform distribution of omnidirectional concentration is adopted:

$$C_i(\mathrm{x},\mathrm{t}) = \frac{2Q_i\Delta t}{(2\pi)^{3/2}xV^{*}\sigma_z(t)}$$

For residential areas at x=5000m, treat them in a windy puff mode:

$$C_i(x,t-t') = \frac{Q_i\Delta t}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z} exp\left\{-\frac{[x-(t-t_i')u]^2}{2\sigma_x^2}\right\}$$

<u>Consequence analysis</u>

The external exposure dose and the inhalation internal dose according to the calculated nuclide concentration of the mathematical model should be evaluated, and then comparing with the nationally specified limits, and finally the conclusions of safety analysis and environmental assessment should be given. The problems in the facility and the corresponding measures that should be taken to improve the quality of safety should also be pointed out.

4. Confidence Building

<u>Verification, calibration and validation of models</u>

Taking a fire or explosion scenario of a vehicle transporting waste as an example, the results calculated by the wind tunnel experiment and the mathematical model are compared and analyzed to verify the accuracy of the model.

<u>Quality assurance</u>

The operators all prepared and have been implementing respective QA programs in siting, designing, construction and operation of the disposal sites, with representation of the QA inclusions and requirements for closure and post-closure institutional control period.

The MEE/NNSA review and accept the QA programs and other types of safety related important documents, including their important revisions, as required of QA, safety regulations and other types of safety related guides; supervise the implementation of the QA program with respect to nuclear safety; selecting control points of the related quality plans in respect of the safety and quality-related major activities and overseeing them on-site; organizing technical review and demonstration of the results of such activities; organize technical review of major non-conformance and oversee effectively the process of addressing such non-conformance.

Peer review of safety assessments

The reports of safety analysis and environmental impact assessment are subject to expert review prior to submission to the regulatory body to ensure the accuracy of the reports.

INDONESIA

INDONESIA

-Part I. General Outline of LLW Repository-

1. General Policy

1) Legal Framework

Indonesia has issued the Act of the Republic of Indonesia No. 10/1997 on Nuclear Energy Since April 1997, issued. This law covers various arrangements, including the establishment of Nuclear Energy Regulatory Agency (NERA) by the Presidential Decree No. 76/1998 in May 1998, the basic principles of the regulation practices in the application of nuclear energy, the basic arrangement of waste management and the liability of nuclear damage. The Act No. 10/1997 on Nuclear Energy consists of 10 chapters with 48 articles. The provision on the waste management consists of 6 articles. With regard to the waste management, the Act clearly stipulates that no part of the Indonesian territory could be used as sites for any foreign or other country radioactive waste repository.

As stated earlier, the Act No. 10/1997 on Nuclear Energy also stipulates some basic arrangements for waste management. The basic arrangement is accommodated in Chapter VI in 6 articles. It stipulates *inter alia*:

a) The radioactive waste management shall be conducted to mitigate radiation hazards to the workers, the public and the environment (Article 22(1))
b) The Executing Body (in this case BATAN) shall accomplish the radioactive waste management, for doing which it may designate a state or private company or cooperative to conduct commercial waste management activity (Article 23)
c) The user generating low and intermediate level of radioactive waste shall obligate to collect, segregate, or treat and temporarily store the waste before being transferred to the Executing Body (Article 24 (1)).
d) The radioactive waste storage in the premise of the Executing Body shall be subjected for fee and the amount of which will be stipulated in a Degree of The Minister of Finance (Article 26)
e) The transportation and storage of radioactive waste shall consider the safety of workers, public and environment (Article 27 (1))
f) The provisions on radioactive waste management including the waste transportation and disposal shall be further implemented in Government Regulation (Article 27 (2))

With respect to high level radioactive waste (HLW) management, the Act sets forth the following provisions:

a) Nuclear material consists of nuclear ores, nuclear fuel, and spent fuel. Spent fuel is considered as HLW (Article 2 (1) and its elucidation)
b) The user generating HLW shall be obligated to temporarily store those wastes during the period not less than the life time of the nuclear reactor before being transferred to the Executing Body (Article 24 (2))

Government Regulation No. 61/2013 on Radioactive Waste Management states that:

a) BATAN carries out the disposal of disused sealed radioactive material that has been determined as radioactive waste as referred to in Article 12 paragraph (3) letter c.
b) Disposal as referred to in paragraph (1) is carried out at:
   - near surface disposal; or
   - medium depth disposal.
c) Construction, operation and closure of disposal facilities as referred to in paragraph (2) must have permission from the Chairman of BAPETEN.

2) Safety Objective

Radioactive waste is potentially hazardous and it must be managed in ways that ensure the protection of the public and the environment for as long as it remains hazardous. Two basic objectives of safe waste disposal should be taken into consideration, namely:

a) To protect human being and his environment from harmful effect of radioactive waste
b) To dispose of the waste in such a way that the transfer of responsibility of waste management to the future generations is minimized.

3) Disposal Strategy

As stated in Government Regulation No.61/2013, BATAN carries out the disposal of disused sealed radioactive material that has been determined as radioactive waste. Disposal is carried out by near surface disposal or medium depth disposal. BATAN has designed the near surface disposal for the radioactive waste level near to clearance level. BATAN also has a plan to design a borehole disposal for DSRS. Based on the elucidation of Act No.10/1997 on Nuclear Energy, it is prohibited the use of any the use of any part of Indonesian territory for any foreign or other country radioactive waste repository.

Indonesia conducts the disposal study for near surface and deep geological facilities since 1989. Site investigation has been done, and two universities were involved in the preliminary study. The locations for this activity include some uninhabited islands with the characteristic of basaltic rock, andesitic rock that suitable for the high level waste, and in Java with the characteristic of volcanic host rock, clay host rock. Some locations have been considered as the suitable media for isolating the waste; however some more studies, especially on demography change, socio-economical impact, and also political trend must be reviewed.

4) Radioactive Waste Management Plan

The main principles of management of low and intermediate level radioactive wastes are summarized as: minimization of wastes, collection of waste conforming the categories, volume reduction, solidification and stabilization, reliable packaging, *in-situ* interim storage, safe transportation, and final disposal.

The radioactive waste produced by Bandung and Yogyakarta Nuclear Research Centers is small in quantity with low level activity and mostly contain short-life radionuclides. The treatment of aqueous waste in Bandung and Yogyakarta Nuclear Research Center is simple, i.e., by collection of wastes in the hold-up tank for further decay, down to insignificant activity and allowed to be discharged into a river. The solid and organic liquid wastes are collected in the containers, kept and stored in storage facilities for radioactivity to decay.

The Serpong Nuclear Research Complex which is comprising some waste generating facilities belonging to the Multipurpose Reactor Center, Nuclear Fuel Technology Center, Radioactive Waste Technology Center, Radioisotopes and Radiopharmaceuticals Center, generates a larger quantity of low and medium level waste. To deal with these wastes, the the Radioactive Waste Management Station (RWMS) was established in Serpong and started its operation in 1989. The RWMS is under the management of the Center for Radioactive Waste Technology (CRWT). The Center is assigned responsible for the ultimate management of radioactive waste generated from the whole territory of the Republic of Indonesia.

The radioactive wastes from outside of BATAN are mostly resulted from activities in nuclear medicine/hospital (spent sources, liquid waste), industrial application (spent sources for radiography, logging and gauging, lightning protection devices), and research institute.

The basic policy of waste management in Indonesia is as follows:

a) Radioactive waste generation from the use of nuclear energy should be as minimum as possible.
b) Any discharge of liquid effluent and gas effluent to the environment should be as low as possible.
c) Handling, treatment and disposal of radioactive wastes should be carried out by taking into account the environment protection consideration.
d) Conditioning wastes should be emplaced at nuclear site and specially constructed for this purpose.
e) Research and development in radioactive waste management should be carried out to support the safety aspect of present and future nuclear energy program.

2. Principles and Safety Assessment

1) Fundamental safety principles

The safety objective and the fundamental safety principles established in IAEA Safety Fundamental apply for all facilities and activities in which radioactive waste is generated or managed, and for the entire lifetime of such facilities, including planning, siting, design, manufacturing, construction, commissioning, operation, shutdown and decommissioning. This includes the associated transport of radioactive material and the management of radioactive waste.

In controlling the radiological and non-radiological hazards associated with radioactive waste, the following aspects have also to be considered: conventional health and safety issues, radiation risks that may transcend national borders, and the potential impacts and burdens on future generations arising from long periods of storage of radioactive waste.

The safety requirements for the protection of human health and the environment apply to the management of radioactive waste generated in medicine, industry and research and other activities. Waste is required to be managed so as to protect human health and the environment now and in the future without imposing undue burdens on future generations. Public exposures that arise from materials removed from controlled environments, from the discharge of effluents containing radionuclides, from accidental releases and from the transport of radioactive waste in the public domain are also required to be controlled.

2) Safety Criteria

Based on the Government Regulation No. 33/2007 on Safety of Ionizing Radiation and Security of Radioactive Sources, the dose limit in Indonesia as in Table 1. Dose constraint in the facility could be decided by the permit holder with the approval of Nuclear Energy Regulatory Agency (BAPETEN).

Table 1. Dose Limits in Indonesia

Type of Dose Limit	Limit on Dose from Occupational Exposure	Limit on Dose from Public Exposure
Effective Dose	*20 mSv per year,* averaged over defined periods of 5 years, with no single year exceeding 50 mSv	*1 mSv in a year*. a higher value could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year
Equivalent Dose to the Lens of the Eye	20 mSv per year, averaged over defined periods of 5 years, with no single year	15 mSv in a year

	exceeding 50 mSv	
Equivalent Dose to the Skin (Averaged over 1 cm^2 of skin regardless of the area exposed)	500 mSv in a year	50 mSv in a year
Equivalent Dose to the Hands and Feet	500 mSv in a year	

3) Formulation Safety Assessment

A safety assessment has to be carried out at the design stage for a new facility or activity, or as early as possible in the lifetime of an existing facility or activity. For facilities and activities that continue over long periods of time, the safety assessment needs to be updated as necessary through the stages of the lifetime of the facility or activity, so as to take into account possible changes in circumstances (such as the application of new standards or new scientific and technological developments), changes in site characteristics, and modifications to the design or operation, and also the effects of ageing.

The safety assessment has to address all radiation risks that arise from normal operation (that is, when the facility is operating normally or the activity is being carried out normally) and from anticipated operational occurrences and accident conditions (in which failures or internal or external events have occurred that challenge the safety of the facility or activity). The safety assessment for anticipated operational occurrences and accident conditions also has to address failures that might occur and the consequences of any failures.

The safety assessment has to include a safety analysis, which consists of a set of different quantitative analyses for evaluating and assessing challenges to safety in various operational states, anticipated operational occurrences and accident conditions, by means of deterministic and also probabilistic methods.

4) Long term safety of RW repository

The safety assessment has to address radiation risks in the present and in the long term. This is particularly important for activities such as the management of radioactive waste, the effects of which could span many generations.

To ensure of human and environmental safety against potential radiological impacts in operation and post-closure of disposal facilities, the quality of the treated waste must meet the chemical, physical, mechanical and radiation requirements or criteria. This requirement is necessary for treated, conditioned and packaged waste to ensure that the waste will be resistant in the long term period, so that, they will not damaged, cracked, or broken. In addition, the site characteristic as a natural barrier, and engineered barrier of disposal facility are part of the design that must be evaluated to ensure the safety.

5) Monitoring and Institutional Control

Institutional control is an important safety component for surface disposal facilities or near surface disposal facilities for preventing human intrusion for a certain period of time. Institutional control is usually required for achieving the safety objective and should remain in place as long as the waste remains potentially hazardous (e.g. 300 years). Waste containing appreciable amounts of long lived radionuclides should be disposed of at greater depths.

Institutional control should be seen as a component of the overall system of protection against the hazards of radioactive waste. This is consistent with the general defence in depth concept, as it adds a layer of protection to the natural and engineered barriers of the facility. However, the presence of institutional control should not be used to justify a reduction in the level of design performance of the containment and isolation system.

3. Regulatory and Operational System Preparation

1) Existing of regulatory framework for Radioactive Waste Repository

a) Act Number 10/1997 on Nuclear Energy
b) Act Number 32/2009 on Protection and Management of the Environment
c) Government Regulation No. 61/2013 on Radioactive Waste Management
d) Government Regulation No. 33/2007 on Safety of Ionizing Radiation and Security of Radioactive Sources
e) Government Regulation No. 2/2014 on the Licensing of Nuclear Installation and the Utilization of Nuclear Materials
f) Government Regulation No. 54/2012 on the Safety and Security of Nuclear Installations;
g) Government Regulation No. 26/2002 on the Transport Safety of Radioactive Materials;
h) Government Regulation No. 27/2012 on Environmental Permit;
i) Government Regulation No. 101/2014 on Management of Hazardous and Toxic Material Waste;
j) Decree of the Chairman of the Nuclear Energy Regulatory Agency No.07/2017 on Radioactivity Limit in the Environment;
k) Decree of the Chairman of the Nuclear Energy Regulatory Agency No.09/2009 on Intervention of Exposure from TENORM;
l) Decree of the Minister of Forestry and Environment No. P.38/2019 on Types of Business Plan and/or Activities that must have Analysis of the Impact of the Environment;
m) Decree of the Minister of Forestry and Environment No. P.63/2016 on Requirement and Procedures for Storage of Hazardous and Toxic Material Waste in Final Disposal Facility.

2) Responsibility to Construct and Develop and Operate of Waste Repository

Based on the Government Regulation No. 61/2013 on Radioactive Waste Management, the radioactive disposal carries out by BATAN. The disposal types as referred to this Government Regulation are near surface disposal and medium depth disposal. Construction, operation and closure of disposal facilities must have permission from the Chairman of BAPETEN.

4. Site Selection

1) Site screening

At the stage of site investigation and site selection, the safety case should support the process leading to the identification of one or more potential disposal sites and should assist in the progression to the next step of development. The safety case and its content will evolve as the project develops in terms of engineering and in terms of characterization of the different natural and engineered components of the disposal system. At this stage, the safety assessment is initially generic in nature, but will evolve as the design develops and the level of detail of the site characterization increases. Criteria for rejecting a site and desirable characteristics for a site would be determined at this stage; the site characterization should be such that it is possible to verify whether the desirable characteristics are present or to determine whether the site should be rejected when compared to the criteria.

Selection of potential sites have been conducted in Indonesia based on IAEA Safety Series No. 111-G-3.1. There are 4 steps for selecting the potential site, i.e.: 1) Conceptual and Planning Stage, 2) Survey Area Stage, 3) Site Characterization Stage, and 4) Site Confirmation Stage. Aspects of the study were considered in the selection of potential sites including topography, hydrology, geology, mineral resources, and land use/spatial planning. The method used in the selection of potential sites is buffering, scoring and overlay techniques. For disposal concepts that can be applied (near surface disposal and deep geological disposal) in igneous rocks such as granite, granodiorite and adamelite. Based on the R&D programs, BATAN has conducted the investigation to obtain some potential sites in several area: Bangka Island, Banten Region (Serpong and Serang), West Java Region (Karawang - Sumedang), Central-East Java Region, Genting Island, and Masalembo Island.

2) Site Criteria

a) Capable of Being Characterized

The ability of a site to provide long-term isolation of waste should be demonstrated by using models and other analyses based on the characteristics of the site.

b) Population Distribution and Land Use

The candidate site should be located in an area of low population density where the potential for future population growth is estimated to be quite limited.

c) Natural Resources
   Published or open file information on natural resources should be evaluated to determine the potential impact on the site if natural resources were to be exploited.
d) Site Must Be Well Drained
   A 100-year floodplain, coastal high-hazard areas, wetlands, or areas where flood velocities could cause damage to the disposal facility are not suitable for waste disposal.
e) Depth to Water Table
   Areas with a known or suspected high water table should be avoided. A disposal site should be sufficiently above the water table so that ground-water intrusion, perennial or otherwise, into the waste will not occur. Waste disposal should not be permitted in the zone of fluctuation of the water table.
f) Ground-Water Discharge
   Areas are not suitable for LLW disposal if groundwater discharge features such as springs, seeps, swamps, or bogs are present.
g) Tectonic and Geomorphic Processes
   A site in a tectonically active area may have unfavorable conditions. Volcanism and hydrothermal activity may be unfavorable.
h) Adverse Impacts from Nearby Facilities
   A candidate site should not be located near any facilities or activities that could adversely affect the ability of the site to meet the performance objective. In addition, a candidate site should not be located near facilities that could mask the site monitoring program.

3) Societal and political acceptability

Radioactive waste disposal should be accepted by the public near the disposal and also the public where far from the site. Societal and political acceptability would be conducted in order to find Environmental Permit via process of Environmental Impact Analysis. EIA would be done in national level, not local or regional level.

5. Design and Construction of Disposal Facilities

1) Funding

Since many of the activities associated with long term management of radioactive waste will take place several decades (more) into the future (possibly after the generators of the waste have gone out of business), it is prudent to collect the financial resources that will be needed for future operations while the waste generators are still in operation. There are various financial systems in the world to ensure the long term availability of financial resources for their disposal programs. Funds and reserves are the two most common financing systems. In the former, the financial resources are usually maintained by organizations independent from the waste generators. In the Russian Federation, financing is obtained from the national budget.

The annual fees that are widely used to obtain the resources kept in the funds are generally calculated and determined based on the amount of electricity or waste generated in a certain year (i.e. on the basis of the future liability associated with the waste generated in that year). The costs of dealing with the radioactive waste are built into electricity tariffs. For instance, in the USA, consumers pay 0.1 cents per kilowatt-hour, which utilities pay into a special fund.

For Indonesia case the establishment for the radioactive waste funding system is necessary after the government agree to build the NPP. Otherwise for non NPP, the funding for disposal would be come from the national budget system.

2) Conceptual Design

The conceptual design phase of a near surface disposal project consists of a technical, economic and safety evaluation of various disposal options. At this stage, a disposal site may or may not have been selected. It is expected that the evaluation should show near surface disposal is the most viable option, taking account of factors such as: safety (e.g. compliance with the established safety principles and licensing requirements); environmental impact (e.g. compatibility with the characteristics of available sites or of generic sites); technical issues (e.g. ability to handle the amount and general characteristics of wastes that will be produced); social and economic factors; and cost. The evaluation describes the intended disposal technical options including the descriptions and functions of the waste package, buffer and barrier materials proposed to be used, and the intended performance and safety functions assigned to each of the components that comprise the multi-barrier system.

To carry out the conceptual design work, the following data are required:

a) estimated waste inventory, general characteristics, and their places of origin;
b) site characteristics (generic or specific), and data (geology, hydrology, hydrogeology, geochemistry, climate, soil condition, etc.); and
c) safety and regulatory criteria (operational and long term).

At this stage in the design process, there is generally a lack of specific information regarding the site and/or the waste characteristics. At the conceptual phase of design, the safety assessment often therefore has to use estimated waste inventory and characteristics, and generic site characteristics. Sensitivity studies from the conceptual performance assessment can be helpful in identifying information needed from site characterisation and from research programmes on waste characteristics and engineered barriers.

3) Basic Engineering Design

The main objective of the basic engineering design phase is to confirm that the disposal option selected from the conceptual design phase could become a licensable, operational option. This is done by demonstrating that the disposal system meets all safety and design criteria and that it can be constructed and operated in a safe and cost efficient manner. The results of the basic engineering design phase are used in the safety assessment that, in many cases, is used, in this phase, in the licensing process.

The overall disposal system design normally includes basic design details for the following:

a) location of the disposal site;
b) facility layout;
c) site preparation (excavation, drainage, earthwork, roads, etc.);
d) access and service roads, parking areas, fences;
e) run-off and disposal system drainage, collection point design and treatment of collected
f) liquids if warranted;
g) disposal system (engineered structures, pits, etc.);
h) definition of backfilling and capping systems (materials and description of emplacement techniques);
i) radiation protection and monitoring systems;
j) power, heating, ventilation, communication and other support systems; and
k) fire protection and security system.

In addition to the disposal system, auxiliary buildings and services need to be considered for reception of waste, interim storage, conditioning or repackaging of waste, and preparation and storage of buffer, barrier, and construction materials. Additional buildings and services that may be required and need consideration in the design include those with radioactive zone restrictions (such as chemical and radiochemical laboratories, control room, liquid effluent treatment facility, and decontamination facility) and without such restrictions (such as personnel rooms (shower, toilets, etc.), administration buildings, visitors' centre, truck, railway or boat terminal, shops, stores, and garages).

4) Detail Engineering Design

The main object of the detailed engineering design phase is to prepare for the construction phase and the operational and closure phases. These phases confirm that the disposal facility can be operated and closed safely and efficiently. Detailed design is completed to the satisfaction of the relevant regulatory/licensing authorities.

Additional objectives are:

a) to include any additional requirements from regulatory authorities introduced following their review of and comments on the basic design;
b) to further develop the basic design taking into account more detailed information on site and environment and waste packages;
c) to finalise details of the design for the overall disposal system and ancillary and auxiliary facilities and produce associated drawings and other design documents;
d) to finalise specifications for construction, equipment procurement and commissioning of the facility;
e) to finalise cost estimates for facility construction, operation and closure;
f) to complete the development of facility specific waste acceptance criteria;
g) to provide information to support the safety assessment undertaken for licencing purposes;
h) to define environmental surveillance and radiological monitoring programmes to be conducted during operations and after closure of the disposal facility;
i) to define operations personnel and staff training and support requirements;
j) to provide to all concerned parties with the information requirements for final closure of the facility;
k) to finalise QA programmes for construction, operation, commissioning, and closure; and to prepare operational procedures, specifications and manuals.

5) Implementation

BATAN has a detail design of the near surface disposal at Serpong Nuclear Establishment that will be projected for storing the low level waste. But, the construction and operation of the near surface disposal facility has been postponed by the Government. The near surface disposal would be constructed if the budget available.

-Part II. Specific Site Safety Assessment of LLW Repository-

1. General Considerations for Safety Assessment

1) Regulatory requirement

The planning of construction and operation of near surface disposal (NSD) facility for low level radioactive waste need a safety assessment. In order to provide assurance that radioactive waste disposal system is functioning properly it is necessary to predict the individual dose as a part of safety assessment. In the Article 23 of BAPETEN Chairman Regulation No. 4/2013 is mentioned that dose constraint value for public is 1 mSv/year.

2) Time Frame of assessment

Waste disposal must guarantee reasonable protection for both current and future generations, with a greater certainty balance for shorter periods and greater degrees of uncertainty as time goes on. The timeframes normally considered in safety assessments include: a) from the closure of disposal facilities to the end of the institutional control period, b) from the end of the institutional control period to 10,000 years, and c) the period after 10,000 years. In the safety assessment of Near Surface Disposal at Serpong Nuclear Area is determined that the time frame between 0 to 1000 years.

3) Purpose of safety assessment

Basically, the purpose of safety assessment is to provide a reasonable scientific assurance that disposal system will provide an adequate level of safety and meet the requirements to protect human health and the environment.

Other purposes are :

a. Demonstrating compliance with regulatory requirements.
b. Knowledge and experience development.
c. Site characterization and disposal facility design.
d. Supporting public trust.
e. Supporting the confidence of decision makers.

2. Specific LLW Repository site (planning etc.)

1) Identifying Infrastructure

- ✓ The site of NSD for demonstration disposal is located in association with the Radioactive Waste Installation (RWI) and the Interim Storage (IS) located in the Nuclear Serpong Area (NSA). So that the infrastructures are included to the in that zone.
- ✓ The candidate of NSD facility is located in the NSA, PUSPIPTEK Area, Serpong, Banten (Figure 1).

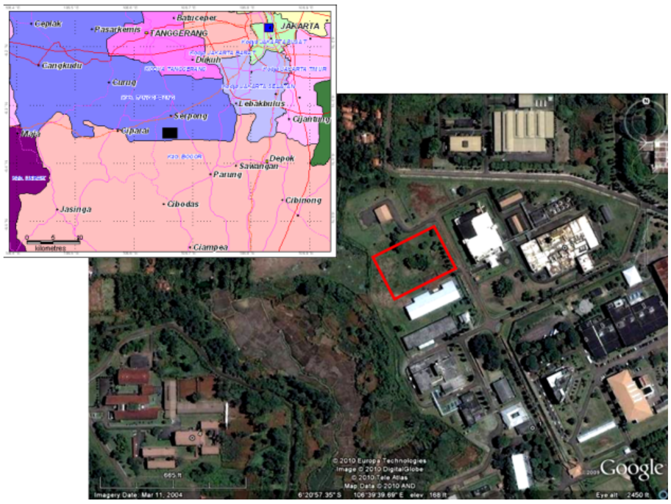


Figure 1. Map of NSD location at Serpong Nuclear Area, PUSPIPTEK, Serpong Banten

2) Capacity of repository

The NSD facility is vault type in 20.2 x 20.2 m size with a depth of 2.6 m from the ground surface (4.43 m above the highest ground water level).

The facility was designed to accommodate waste packaged in 200 l drum and 950 l concrete shell. The capacity of the disposal will be 1,350 drums and 144 concrete shells.

General layout of the proposed facility can be seen at Figure 2.

The assumption based on the calculation of total activity of Co-60 is 301,032 Bq and Cs-137 is 5,857,920 Bq.

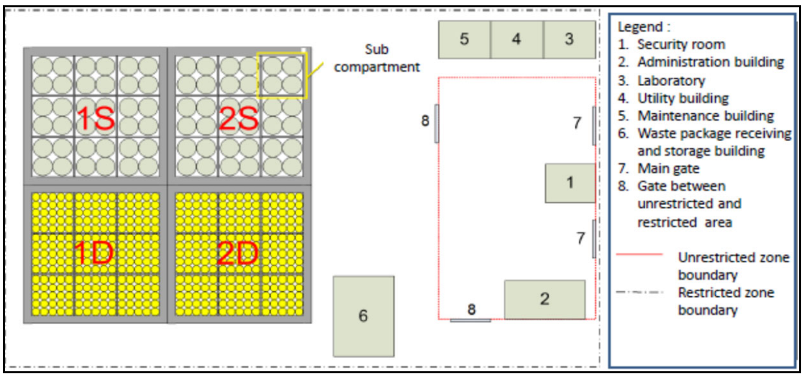


Figure 2. Layout design of proposed NSD

3) Waste acceptance criteria

The NSD type has been chosen based on the suitability with the waste and site characteristic.

The purpose of construction and operation of NSD is to dispose the accumulated low level radioactive waste that have been immobilized and packaged since 1988 at Radioactive Waste

Installation (RWI) and stored at Interim Storage (IS) located in the Nuclear Serpong Area (NSA).

The NSD facility in NSA is dedicated also for Demonstration Plant of Radioactive Waste Disposal (DP-RWD) to demonstrate the safety and durability of the disposal system, so that, the public acceptance will also increase.

The radionuclides contained in the waste that was considered in the study were radionuclides which dominantly contain in the packaged waste and as reference for the safety assessment with short half life less than or equal to about 30 years, namely Co-60 and Cs-137.

4) Areas away from major population centres
The site is not so far from the population centre, but the impact of the disposal had been considered based on the result of safety assessment.

5) Close to existing or planned transport infrastructure
As mentioned above that the site of NSD for demonstration disposal is located in association with the Radioactive Waste Installation (RWI) and the Interim Storage (IS) located in the Nuclear Serpong Area (NSA). So that the transport infrastructure are included to the in that zone.

6) Societal change in future
Societal change in future is considered relatively not so significant based on the limited land for development.

3. Guidelines for Safety Assessment

1) Base line data
Base line data concerning to climate, hydrogeology, biota etc., were obtained from Environmental Impact Assessment Report, and also completed with routine monitoring from 2011 to now.

2) Detailed site specific parameters
Detailed site specific parameters were obtained from engineering geology and hydro-geological investigation in 2010, and updated data until now.

Input data used in the software is the primary data obtained from field investigation on engineering geology and hydrogeology, climate data, secondary data and some assumption data about site, conceptual design of the NSD facility and data of radioactive waste that will be disposed off.

3) Description of the system (near field, far field)
The disposal system generally consists of the following components:

- Near field, including waste, disposal area, artificial barrier and disturbed zone around the disposal area.
- The geosphere, including rocks and materials that exist between the near-field and the biosphere, includes the unsaturated and water-saturated zones.
- Biosphere, part of the atmosphere, hydrosphere and soil where humans move.

The disposal system description should contain the following information:

- Near field, including origin, condition, characteristics and quantity of waste, radionuclide inventory, artificial barrier (waste packaging, disposal unit, disposal cover), and the distribution and disturbed zone characteristics.
- Geosphere, including geological, hydrogeological, geochemical, tectonic and seismic conditions.
- Biosphere, including climate and atmosphere, water bodies, human activities, biota, lithostratigraphy near the surface, topography, geographic distribution and location.

The description developed must include qualitative and quantitative aspects of the system components. The description of the disposal system must be made in accordance with the predetermined assessment context (which includes objectives, end-points, philosophy and timeframe), and the level of detail must meet the context under consideration. And what is also important to note and document is the existence of two sources of uncertainty, namely uncertainties related to the characterization of the system; and uncertainties related to the future evolution of the disposal system.

4) Develop and justify scenario

When conducting a safety assessment, the assessment of the performance of the disposal system both present and future (including events that are expected to occur) is important. This means that several different factors (such as conceptual models and parameter uncertainties, long-term periods, changes in human behavior and climate) must be taken into account and evaluated. This can often be achieved through the development and analysis of a scenario.

A scenario can be defined as a member of a set of features, events and processes (FEP) that are determined for predicting the future behavior of a disposal system in a safety assessment. The scenarios chosen together will provide a comprehensive picture of the evolutionary system and critical path that might occur based on the context of the study and description of the system. There are several methods that can be used to develop scenarios, but none of them can be claimed as the most correct. The relevant methods for near surface disposal are now being reviewed in the ISAM program. These methods include expert judgment, fault tree analysis and event tree analysis.

One common element in various approaches to developing scenarios is the preparation of a FEP list that can directly or indirectly affect the radionuclide disposal and migration system. The FEP is usually identified from the disposal system description. The FEP list should be compiled and documented in a systematic manner. The relative importance of each FEP is reviewed, generally using expert judgment. From the FEP review and judgment process will be taken to the screening process, which in turn there will be a FEP that is wasted and there are those that need further consideration in the safety analysis. FEP filtering can be assisted with calculations.

Selected FEP lists are used together with system descriptions to develop scenarios. Then a scenario scenario will be used to analyze the assessment. The selected scenarios depend on the purpose of the assessment (the context of the assessment). From these scenarios, the evolution of future conditions, critical issues and system strength will be illustrated.

5) Formulate and implement Model

The process of formulating and implementing the model consists of the following stages:

- Development of conceptual models from the disposal system;
- Presentation of conceptual models and processes related to mathematical models;
- Implementation of mathematical models in computer tools.

Conceptual Models

After the scenario is developed, the consequences for the assessment context must be analyzed. For some scenarios it might be sufficient to use a qualitative assessment approach (if quantitative data are not available). For scenarios that are studied quantitatively, they must be organized in a form that allows them to be presented mathematically. A package of assumptions for the model (dimensions, boundary conditions, FEP, interrelations between FEP and others) is needed for each scenario, which is then used to form a conceptual model. More than one conceptual model that may be consistent with information obtained for a scenario.

A conceptual model must at least contain a description of:

- Basic FEP of the model;
- Linkages between FEPs;
- The scope of the application model in the dimensions of space and time.

The model should be sufficiently detailed so that the mathematical model can be developed to explain the behavior of the system and its components which are sufficient to estimate the performance of the system in the specified time frame.

Mathematical Model

Conceptual models for each scenario are then expressed in mathematical form as an algebraic and / or differential equation, with boundary and initial conditions which then need to find a solution. In practice, the mathematical representation of the disposal system will often be based on an empirical understanding of the system's level of detail. An example is the uptake of pollutants into biota, which are specifically represented by bioaccumulation factors. It is important to recognize where a certain mathematical model, which might have been explained in terms of a single empirical factor, in fact turns out to represent a different combination of FEPs that might have been identified in the conceptual model. Therefore it is necessary to be careful to avoid double-counting the effects of certain processes, or vice versa, instead ignoring potential relevant FEPs.

Computer Tools

Mathematical model solutions are usually implemented by one or more computer devices with analytic or numerical methods. The device may already be available and or the device is specifically developed for certain mathematical models. If there are only a few conceptual models and mathematical models, it is possible to use only one computer device.

Safety assessment of NSD facility in Serpong Nuclear Area uses Prediction of Radiation Effects from Shallow Trench Operation – Environmental Protection Agency – Critical Population Group/ General Population (PRESTO-EPA-CPG/POP) software version 4.2, issued by the U.S. Environmental Protection Agency (US-EPA).

Mathematical models for calculating radiological dose:

Many equations are used as mathematical models for calculating the parameters of safety, but due to space limitations will be presented only a simple formula to calculate the annual dose received by population.

$$D_{ijl}\ (k) = (K_j E_{ij}(k).DF_{ijl})/P(k)$$

K_j	:	Numerical factor introduced by units Eij(k),
$E_{ij}(k)$	:	Exposure of radionuclide i in the exposure path j,
DF_{ijl}	:	dose rate factor of radionuclide i exposure pathways j and organ l,
P(K)	:	population on location k.

6) Run analysis

If scenarios and conceptual models and computer models have been developed and implemented in software with structured data, then calculations can be carried out to assess the impact of disposal facilities.

7) Interpret results

The results are then arranged, analyzed and presented. Interpretation of the results of the assessment will provide analysts with the first opportunity to test quantitative results from scenario models.

Also important to look after and pay attention to is the presentation of results. Various methods can be used to present results. Many alternative representations are possible to present the results both for the output of deterministic models and probabilistic models. For example, the dosage curve over time showing a significant dose contribution from radionuclides has been widely used. And it is vital to guarantee that the form of presentation used can satisfy the audience.

The interpretation, analysis and presentation of results are followed by the decision making process. It is multi-faceted and often many competing factors must be involved together and combined to reach a decision.

8) Compare against assessment criteria

The results are compared with the criteria applied in the context of the assessment. The context of the assessment will include regulatory criteria and possibly other indicators.

In analyzing the results of an assessment, it must not be forgotten that there are a number of uncertainties associated with quantitative safety assessments.

4. Confidence Building

1) Management of uncertainties (Scenario, input data and model)

According to the IAEA, the uncertainty is considered to originate from three sources, namely:

- Uncertainty due to the evolution of the disposal system in the time frame of the assessment (scenario uncertainty);
- Uncertainty in data and parameters used as input in modeling.
- Uncertainty in the conceptual, mathematical and computer models used for simulating the behavior and evolution of the disposal system (for example: the inability of the model to be able to represent the system as a whole, estimates used in solving model equations, and coding errors);

2) Sensitivity analysis

The analytical skills in safety assessment need to be improved because this analysis is vital and as a capital for decision making.

<u>Scenario analysis, pathways</u>

Scenarios selected in this safety assessment is the scenario of the migration of radionuclides through the groundwater pathway.

The main sources of water, which led to the leaching of radionuclides from contaminants matrix, is precipitation.

Precipitation water at the site will infiltrates into the soil, flows over the surface of the ground, or evaporated into the atmosphere.

Transport of radionuclides from the site may occur due to water infiltration or runoff.

A dynamic model, which calculates evaporative water loss and water transport based on the dynamic equations, is used to calculate the rate of infiltration.

The water that infiltrate into the zone of contamination will leach the radionuclide of the zone.

Contaminated water that flows as runoff or infiltrate into the site as a percolation flow, eventually will enter the aquifer.

Radionuclides that eventually reach the aquifer generally will be transported at speed slower than or equal to the speed of water flow in the aquifer.

Retardation as the interaction of radionuclides with the solid media in the aquifer, known as the effect of sorption (uptake).

When radionuclides are transported in the aquifer of the wells water, it will be consumed by residents in the site and/or off-site area through the drinking water, irrigation, and livestock feed.

Radionuclide remaining in the aquifer is considered transported further and causing a general population health impacts on downstream areas.

Water contaminated at the site would be accumulated if the infiltration rate exceeds the ex-filtration rate out of the contaminated zone.

When the volume of water that accumulates in the waste exceeds the cavity /total porosity, contaminated water will overflow to the land surface.

Radionuclides in the contaminated water would then be mixed with surface waterflow and subsequent to the flow (river) nearby.

Potentially, contaminated water will be consumed byl ocal residents and residents who live downstream through drinking water, irrigation, livestock feed and aquaculture.

Consequence analysis (example)

- ✓ The concentration of Co-60 in well water is $4.0x10^{-10}Bq/m^3$in the year of 200 after closure and the concentration tend to decrease until $3.0x10^{-15}Bq/m^3$ in the year of 300 after closure of the NSD.
- ✓ The concentration of Co-60 in well water is still far below the boundary value that has been defined in regulation.
- ✓ The maximum concentration of Co-60 in surface water is $1.52x10^{-3}Bq/m^3$ in the first year after closure and tend to decrease until $9.44x10^{-26}Bq/m^3$ in the year of 401 after closure of the NSD, so that, the concentration of radionuclide Co-60 in well water is far below the boundary value.
- ✓ The maximum concentration of Cs-137 in surface water is 1.84 Bq/m^3 in the 101 year after closure and the concentration tend to decrease until $3.31x10^{-29}Bq/m^3$ in the year of 2901 after closure of the NSD, so the concentration of Cs-137 in well water is still far below the boundary value.
- ✓ The total contribution of its largest individual dose is Cs-137 with a peak value at the beginning of the year amounting to15.0x10-7μSv/year and the smallest value of $15.0x10^{-13}$μSv/year in the year 500 after post-closure of NSD.
- ✓ The total value of annual dose tend to decrease from year to year with a peak value of $5.0x10^{-9}$μSv/year in the early and the smallest dose is $5.0x10^{-38}$μSv/year in the year of 2600 post-closure, this value indicate that the total dose caused from post closure of the NSD is still too far below the dose constraint value for public (1 mSv/year).

3) Public Involvement

Publics were involved primarily in the form as communication, socialization, consultation and coordination when the environmental impact assessment report was developed. Besides that at the initial stage of the site selection, site characterization, etc. some public involvement has been started.

Processes and results of safety assessment should be peer reviewed by all stakeholder components to assure the objectivity, systematically and integrity.

4) Documentation and preservation and availability of document

Presentation of results is usually already available in the safety assessment software, so all that remains is to choose a good and convincing presentation technique.

JAPAN

JAPAN

-Part I. General Outline of LLW Repository-

1. General Policy

(1) Protection of Human Health and Environment

In processing and disposing of radioactive waste, it is essential to recognize that the disposal of the radioactive waste should not be left to future generations; it is the responsibility of the current generation who have enjoyed the benefits of nuclear energy use.

It is known that some nuclear industry and R&D institutions are running short of waste storage capacity. To ensure the smooth implementation of full-scale decommissioning in the years ahead, it will be necessary to secure suitable waste disposal sites and to expand their capacity by means of clearance process. A pressing challenge here is securing of the understanding of the general public and local residents that is a prerequisite for these steps.

To suitably address this challenge, the nuclear industry that has generated the radioactive waste needs to take more prominent and active role in accordance with the "polluter pays principle." If nuclear industry has apprehensions, they should actively engage in exchange of views with the regulatory agency. At the same time, the National Government needs to strengthen its overall progress management.

If it is considered more effective and efficient to process and dispose of the waste centrally in accordance with the properties of the waste, without arguing the generator or source of the waste, it is desirable for the National Government or nuclear industry to examine the necessary measures to be taken. (Japan Atomic Energy Commission, *Basic Policy for Nuclear Energy*, pp15-16, 20 July 2017)

(2) Environmental Impact Assessment

Article 2 of the Atomic Energy Basic Act, which is a higher level law of both the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors, and Act on Prevention of Radiation Hazards due to Radioisotopes, etc., describes environmental impact assessment as follows:

- Article 2 The research, development and utilization of nuclear energy shall be limited to peaceful purposes, shall aim at ensuring safety, and shall be performed independently under democratic administration, and the results obtained shall be made public so as to actively contribute to international cooperation.

- 2 Safety assurance described in the preceding paragraph shall be performed based on the established international criteria, aiming at contributing to protection of people's lives, health and properties, and preservation of environment, as well as security of our country.

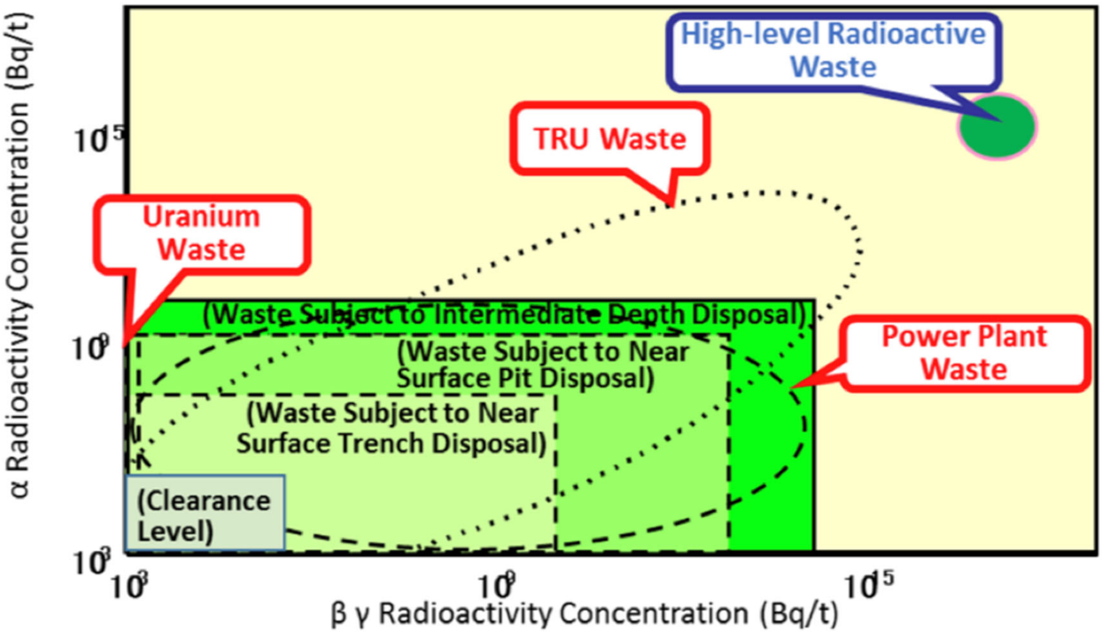
(3) Principles and Safety Assessment

1) General Considerations for Safety Assessment

Radioactive wastes are generated from the use of radiation and nuclear energy in such as nuclear power plants, nuclear fuel cycle facilities, universities, laboratories, and medical institutions, related research and development, and decommissioning of these facilities. It is important to process and dispose these radioactive wastes as a vital aspect of the use of radiation and nuclear energy so as not to significantly affect the human health and the living environment.

There are varieties of radioactive wastes in terms of physical and chemical forms, types of radioactive materials, and the radioactive concentration. Thus, the radioactive wastes should be appropriately processed according to the characteristics, classified according to the radioactive concentration (see Fig. 1), and then reasonably disposed of (see Fig. 2).

In Basic Policy for Nuclear Energy decided by the Cabinet of Japan in April 2014, the following policies were set for the processing and disposal of radioactive wastes; (i) enforcement of measures for achieving solutions and promotions concerning the management of high-level radioactive wastes under the responsibility of the current generation, and (ii) promotion of disposal of low-level radioactive wastes generated from activities such as the decommissioning. In line with these policies, objectives for the processing and disposal for the radioactive wastes have been discussed in Japan according to the classification of the radioactive wastes, and the framework for safety regulations has been improved. Furthermore, there have been activities on the mutual understanding among national and local people as well as the research and development for necessary technologies.



(NOTES)

High-level Radioactive Waste:
High-levels radioactive liquid waste generated after separating and recovering uranium and plutonium from spent fuel. In Japan, it is mixed with glass and solidified.

Low-level Radioactive Waste:
Power Plant Waste: Radioactive waste generated at nuclear power plants
TRU Waste: Long half life low exothermic radioactive waste. Radioactive waste generated at reprocessing facilities and MOX fuel processing facilities.
Uranium Waste: Radioactive waste generated at uranium enrichment facilities and uranium fuel processing facilities.
Research facility Waste etc.: Radioactive waste generated at R&D facilities and medical facilities. Part of TRU waste and uranium waste is also included.

Fig. 1. Image of radioactive waste classification in Japan (source: White Paper on Nuclear Energy, 2016. Atomic Energy Commission of Japan. Summary report available at: http://www.aec.go.jp/jicst/NC/about/hakusho/hakusho2016/gaiyo_1_e.pdf）

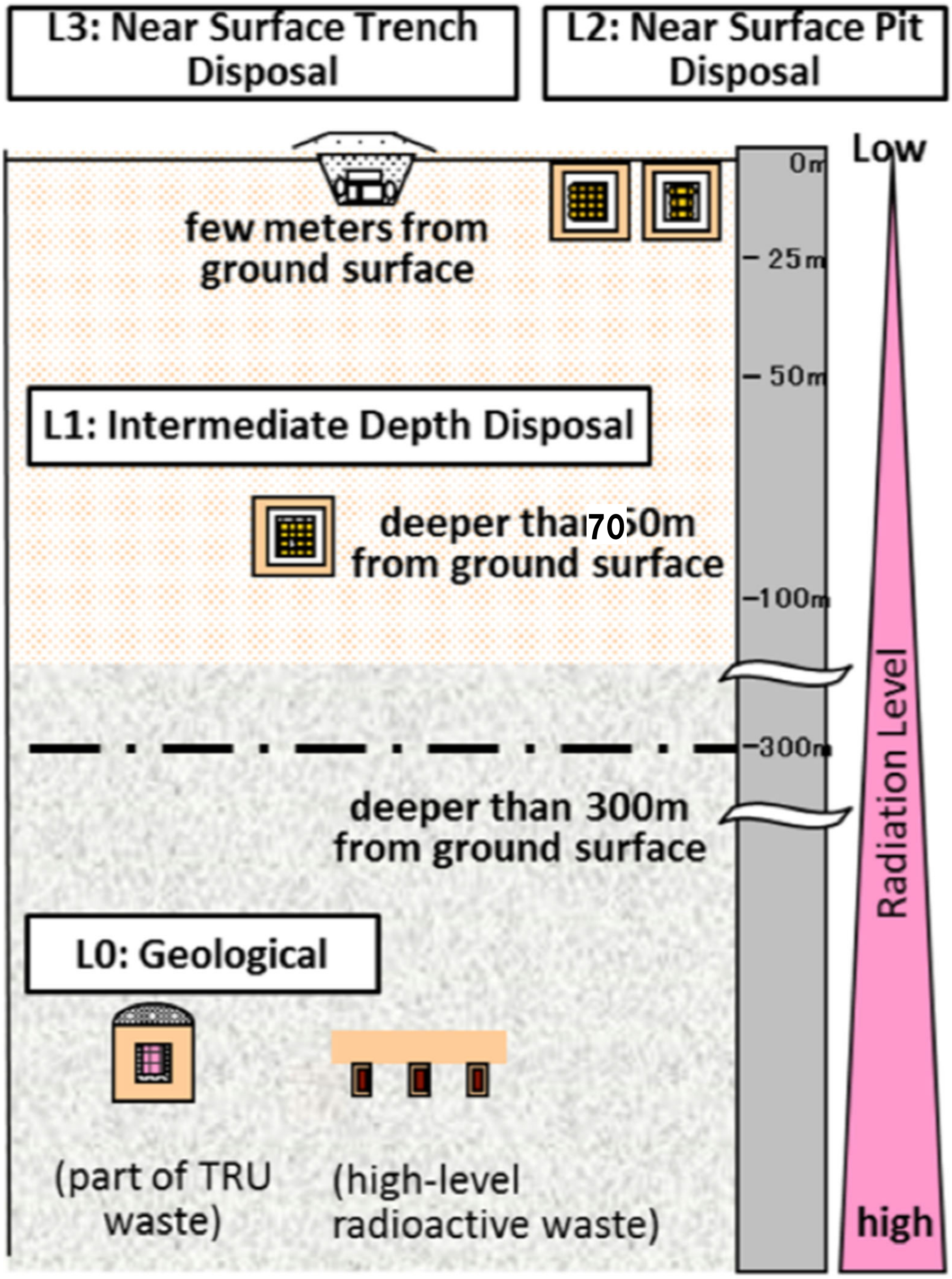


Fig. 2. Image of radioactive waste disposal method in Japan (source: White Paper on Nuclear Energy, 2016. Atomic Energy Commission of Japan. Summary report available at: http://www.aec.go.jp/jicst/NC/about/hakusho/hakusho2016/gaiyo_1_e.pdf)

2) Radiation and Environmental Protection Principles

A) Safety Assessment of Public Exposure

(Reference: Interpretation of Regulations of Criteria for Site, Structure and Equipment of Category 2 Waste Disposal Facility)

Public dose, due to direct and skyshine radiation from radioactive waste disposal facilities under normal conditions, including those due to leakage and transfer of radioactive materials from the facilities, and due to release of radioactive materials to environment from the facilities, shall not exceed the dose limit ordinated by regulations, and shall not exceed 50μSv/y of effective dose considering with the principle of As Low As Reasonable Achievable (ALARA).

Radiation dose to people staying outside of the control area, where people come in and out, shall not exceed the public dose limit.

Public dose in case of an accident or emergency shall be 5mSv or less, and shall take into consideration followings:

i. Scattering of radioactive materials due to falling of radioactive solid waste caused by operational errors, etc.
ii. Influence of fire and explosion in the relevant waste disposal facility
iii. The other abnormal leakage of radioactive materials from the perspective of public exposure due to breakdown of equipment, equipment failure, operational errors, etc.

Demonstrate the prospect of transition to a state required no activities on the conservation of the waste disposal facility by closure.

For this purpose, concerning the basic design and its policy of waste disposal facility, influence of radioactive materials on environment induced by radioactive wastes buried after the commencement of decommissioning shall be designed based on the knowledge at the time of designing the facility to meet the standards shown below

a) Natural Process Scenario: Scenario with natural process in consideration with radioactive material leakage, transport through natural barriers, to rivers, etc., and general land use (except for activities with excavation of waste disposal site) , shall be assessed as follows;

・Public exposure shall not excess 300 μSv/y in the scenario with the severest combination of the conditions of artificial / natural barrier and the pathways to public, within scientifically reasonable range.

・Public exposure shall not excess 10 μSv/y in assessment under the most likely parameters that make up the combination of artificial / natural barrier conditions and pathways to public within scientifically reasonable range.

・Public exposure shall be assessed in consideration with superposition effect, if multiple disposal facilities have planned of installation at the same site.

b) Human Intrusion Scenario: Public exposure caused on radioactive material leakage, transport through natural barriers, to rivers, etc., and general land use with excavation of waste disposal facility, shall not excess 300 μSv/y due to trench disposal, and shall not excess 1 mSv/y due to pit disposal or trench disposal with the equipment of resistance against excavation (equivalent to surrounding partition) .

These scenarios shall be assessed in consideration with natural phenomena and human activities of land use that affect artificial barriers and natural barriers*, based on past records, the latest scientific and technical knowledge of the site of the waste disposal facility and its surroundings, such as on-site surveys.

The period to be evaluated after the commencement of decommissioning is the period until the maximum value of the value evaluated as the dose received by the public for each scenario appears.

B) Radioactivity Concentration Criteria for Radioactive Waste

i. Trench Disposal (Reference: Regulations of Category 2 Waste Disposal Project of Nuclear Fuel Material or Material Contaminated by Nuclear Fuel Material, Appendix 2)

- Co-60 10 GBq/t
- Sr-90 10 MBq/t
- Cs-137 100 MBq/t

ii. Pit Disposal (Reference: Regulations of Category 2 Waste Disposal Project of Nuclear Fuel Material or Material Contaminated by Nuclear Fuel Material, Appendix 1)

- C-14 100 GBq/t
- Co-60 1 PBq/t

- Ni-63 10 TBq/t
- Sr-90 10 GBq/t
- Tc-99 1 GBq/t
- Cs-137 100 TBq/t
- α emitters 10 GBq/t

iii. Intermediate depth disposal (Reference: Enforcement Order for the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors, Article 31)

- C-14 10 PBq/t
- Cl-36 10 TBq/t
- Tc-99 100 TBq/t
- I-129 1 TBq/t
- α emitters 100 GBq/t

iv. Geological disposal

- No provision of upper limit of radioactive nuclide and radioactivity concentration

(4) Regulatory and Operational System Preparation

1) Regulatory Regime for Licensing the Low Level Radioactive Waste Repositories as Disposal Project

- Defined by the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors, Article 51-2 to 51-34.
- Defined by the Enforcement Order for the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors, Article 30 to Article 37.
- Defined by the Regulations of Category 2 Waste Disposal Project of Nuclear Fuel Material or Material Contaminated by Nuclear Fuel Material.
- Defined by the Regulations of Criteria for Site, Structure and Equipment of Category 2 Waste Disposal Facility
- Defined by the Announcement that prescribes technical details of Measures for Category 2 Waste Disposal of Nuclear Fuel Material.
- Interpretation of Regulations of Criteria for Site, Structure and Equipment of Category 2 Waste Disposal Facility was Decided by Nuclear Regulation Authority

2) Organizations

- Operator:

- Japan Nuclear Fuel Limited (concerning wastes of Electric Power Companies and commercial use)
- Japan Atomic Energy Agency (concerning wastes of Research Institute and Hospital)

● Promoter (Government):

- Japan Atomic Energy Commission
- Agency for Natural Resources and Energy
- Ministry of Education, Culture, Sports, Science and Technology

● Regulator (Government):

- Nuclear Regulation Authority※1

3) Verification of Wastes

Refer to the verification items provided in “Regulations Concerning the Activities of Category 2 Radioactive Waste Disposal Nuclear Source Material, Nuclear Fuel Material and their Contaminated Material, Article 8, Paragraph 2. Followings are the technical standards specified by this regulation.

A) Packaged waste (waste form for intermediate depth disposal and pit disposal)

i. Packaged waste of liquids or ion exchange resins, incineration ashes, filter sludge, particulate matter or molded powder shall be solidified in containers.

ii. Packaged waste of solids shall be sealed or solidified in containers.

iii. Packaged waste shall not excess the maximum radioactive concentration listed on the documents for application,

iv. Packaged waste shall avoid the risk of damage on integrity of package by its containing materials until settlement on disposal facility.

v. Packaged waste shall keep robustness to withstand its risk of overload until termination of disposal.

vi. Packaged waste shall keep minimize the scattering or leakage of radioactive material due to falling from the assumed maximum height until settlement on disposal facility.

vii. Packaged waste shall be labelled the marks of radioactive waste on the surface of the waste package with clear and hard to erased, supported notification to verification the items listed in the application.

※1 Ministry of Health, Labor and Welfare regulates wastes from hospital, Ministry of Agriculture, Forestry and Fisheries regulates wastes from veterinary service

viii. Packaged waste shall be attached with the document of the specifications below:

- Assurance for the compliance with the technical standards above
- Elaborations of the package of the waste sealed or solidified
- Strength of the package and its measurement method
- Radioactive materials the waste contains, and the measurement method

B) Concrete-like waste (waste form for pit disposal and trench disposal)

i. Concrete-like waste shall not excess the maximum radioactive concentration listed on the documents for application,

ii. Concrete-like waste shall avoid the risk of damage on integrity of the disposal facility by its containing materials.

iii. Concrete-like waste shall be supported notification to verification the items listed in the application.

iv. Concrete-like waste shall be attached with the document of the specifications below:

- Assurance for the compliance with the technical standards above
- Radioactive materials the waste contains, and the measurement method

(5) Site Selection (An Example from the Plan of JAEA Disposal Facility)

(Reference: Plan for Implementation of Disposal (Radioactive Waste of Research Institutes etc.), November 2019 Approval on Change)

1) Characteristics of Acceptable Site

A) Conformity Assessment Items

i. Assessment Index of Safety

Take into consideration and assess the natural environment, namely “Volcano”, ”Tsunami”, “Depression”, “Landslide”, “Cataract”, “Fault (Active Fault)” (ground with no displacement hazard), and confirm that the candidate site has no safety problems with these items.

ii. Assessment Index of Environmental Preservation

Take into consideration and assess the “Restriction and Plan for Land Use” and “Preservation of Cultural Assets” which are based on the legal provisions such as Natural Conservation Law and the Law for the Protection of Cultural

Properties, and confirm that the usage of candidate site is not limited and extremely difficult in terms of environmental preservation of the candidate site.

iii. Others

Confirm that the candidate site can secure adequate area for disposal. Details are separately prescribed and provided by JAEA.

B) Comparative Assessment Items

Take into consideration and assess the ease of securing a certain scale of disposal site, and the convenience of transportation of waste in terms of economic efficiency and convenience, and confirm that the disposal can be smoothly conducted. Details are separately prescribed and provided by JAEA based on the socioeconomic circumstances.

2) Design and Construction of Disposal Facilities

A) Technical Standards of the Approval of the Design and Construction Method

Followings are the technical items prescribed based on the Regulations of Criteria for Site, Structure and Equipment of Category 2 Waste Disposal Facility, and on the Interpretation of Regulations of Criteria for Site, Structure and Equipment of Category 2 Waste Disposal Facility.

- Ground of the waste disposal facility
- Prevention of damage by earthquake
- Prevention of damage by tsunami
- Prevention of damage by external shock (possible natural phenomena and unintended human intrusion)
- Prevention of damage by fire etc. (fire detection, fire extinction, impact reduction measures)
- Shielding etc. (dose rate reduction around the place of activity, prevention measures for the scattering of radioactive materials)
- Prevention of radiation hazards in case of emergency (public protection around the site during the period from start of waste acceptance to decommissioning, and prospects that disposal site would transition into a maintenance-free state during the period of above mentioned)
- Waste disposal site (having abnormal leakage prevention function, having enclosure function until the end of disposal in case of pit disposal, not losing safety due to chemical materials contained in the wastes)
- Radiation control facility (establishment of dose monitoring and control facility for workers and the site boundary etc.)

- Waste facility (installation of facilities with capability of reduction processing of radioactivity concentration in air and water at the supervised area boundary)
- Monitoring facility of ground water level etc.
- Power reserve
- Telecommunication facilities etc.

B) Development of Operational Safety Programs

Followings are the items to be confirmed concerning the examination standards of safety program listed in the "Provisions of Category 2 Waste Disposal Project of Nuclear Fuel Material or Material Contaminated by Nuclear Fuel Material" and "Enactment of Examination Standards of Safety Program in Disposal Facilities Related to the Category 2 Waste Disposal Project"

- System for compliance with related laws and safety programs
- System for promoting safety culture
- Quality assurance of waste disposal facility
- Duties and organization of persons in management of waste disposal facilities
- Scope of duties of the chief engineer of radioactive waste etc.
- Operational safety education
- Measures taken for the operational safety of Category 2 waste disposal in accordance with the attenuation of radioactivity
- Setting of control area, supervised area and disposal maintenance area etc.
- Emissions monitoring facility and wastewater monitoring facility
- Dose, dose equivalent rate, decontamination etc.
- Monitoring of waste disposal site and its surrounding circumstances
- Patrol and inspection of waste disposal facilities
- Transport and disposal of radioactive waste etc.
- Measures to be taken in case of emergency
- Record and report
- Periodic assessment of waste disposal facility etc.
- Technical information sharing
- Information disclosure in case of nonconformance
- Other necessary items

C) Closure criteria

Closure shall be conducted within 300-400 years after disposal in case of pit disposal, and within about 50 years in case of trench disposal.

The item that "prospects shall be obtained that disposal site would transition into a maintenance-free state" within above mentioned period indicates that the expected influence of radioactive materials on environment induced by the radioactive wastes buried after the commencement of decommissioning shall be designed based on the knowledge at the time of designing the waste disposal facility to meet the standards concerning basic design and its policy of waste disposal facility (cf. 1. (3) 2) A) Safety Assessment of Public Exposure).

i. **Natural Process Scenario:** Scenario with natural process shall be assessed as follows;
   - Not excess **300μSv/y in the scenario with the severest combination** of the conditions of artificial / natural barrier and the pathways to public, within scientifically reasonable range.
   - Not excess **10μSv/y in assessment under the most likely parameters**

ii. **Human Intrusion Scenario:** Public exposure caused on land use with excavation of waste disposal facility
   - Not excess **300μSv/y due to trench disposal**, and shall not excess **1 mSv/y due to pit disposal or trench disposal with the equipment of resistance against excavation** (equivalent to surrounding partition) .

D) Control after Closure

- In the case of pit disposal and trench disposal, it shall be indicated that "prospects shall be obtained that disposal site would transition into a maintenance-free state".
- Intermediate depth disposal is under consideration of Nuclear Regulation Authority as of January 2019.

3) Recording and Quality Assurance (Reference: Enactment of Examination Standards of Safety Program in Disposal Facilities Related to the Category 2 Waste Disposal Project)

Examination standards on application for development of safety program concerning the disposal facilities related to the activities of Category 2 waste disposal is open for public, and description on quality assurance is as follows as of January 2019.

- Quality assurance plan shall be established based on JEAC 4011-2009 or an equivalent standard that are approved in the Provisions of Category 2 Waste Disposal Project of Nuclear Fuel Material or Material Contaminated by Nuclear Fuel Material, Article 20, paragraph 1, item 3, "Quality Assurance of Waste

Disposal Facility", Provisions of Nuclear Fuel Material Processing Project, Article 7-2-2 to Article 7-8, Provisions of Spent Nuclear Fuel Reprocessing Project, Article 8-3 to Article 8-9

- Description on quality assurance shall be based on the "About description of quality assurance mentioned in safety programs of waste disposal facility related to the Category 2 waste disposal project" (12 February 2009, NISA No. 6 (2 March 2009, NISA192a-09-1)
- With regards to the positioning of operation procedures in safety programs, to comply with the manuals, operational procedures and other safety related documents prescribed in the Provisions of Category 2 Waste Disposal Project of Nuclear Fuel Material or Material Contaminated by Nuclear Fuel Material, Article 13, paragraph 10, positioning of those documents shall be clearly defined according to their importance in the hierarchical system of quality assurance documents such as safety programs and its secondary document and tertiary document.

-Part II. Specific Site Safety Assessment of LLW Repository-

1. General Considerations for Safety Assessment (Reference: Regulations of Criteria for Site, Structure and Equipment of Category 2 Waste Disposal Facility)

(1) Policy, Public Acceptance, etc.

Operate final disposal in an appropriate way according to the type of the nuclear fuel material or material contaminated by nuclear fuel material based on the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors.

Specifically, after the intermediate depth disposal of radioactive solid wastes from nuclear facilities, control radiation exposure giving consideration to the possible public exposure level, and make a proper disposal until it is recognized that the disposal site no longer requires management in terms of exposure control due to reductions in radioactivity.

Radioactive wastes are classified into trench disposal, pit disposal, etc. according to their radioactivity level by types of radioactive materials.

Prospects shall be obtained that disposal site would transition into a maintenance-free state by the end of disposal facility management period (which is about 300-400 years after disposal for pit disposal, and 50 years for trench disposal). (Regulations of Criteria for Site, Structure and Equipment of Category 2 Waste Disposal Facility, Article 9, paragraph 1, item 2)

1) **Safety Assessment: Dose Standards** (cf. 1. (3) 2) A) Safety Assessment of Public Exposure)

   i. **Natural Process Scenario:** Scenario with natural process shall be assessed as follows;
      - Not excess **300μSv/y in the scenario with the severest combination** of the conditions of artificial / natural barrier and the pathways to public, within scientifically reasonable range.
      - Not excess **10μSv/y in assessment under the most likely parameters**

   ii. **Human Intrusion Scenario:** Public exposure caused on land use with excavation of waste disposal facility
      - Not excess **300μSv/y due to trench disposal**, and shall not excess **1 mSv/y due to pit disposal or trench disposal with the equipment of resistance against excavation** (equivalent to surrounding partition)

2) **Safety Assessment: Other Technical Standards**

   Disposal Facility Design: Basic Functions and Design Requirements and Management Requirements Related to Waste Disposal Site

A) **Shielding Function** (Pit-disposal, Trench Disposal, in Operation)

<Purpose> Not to exceed the dose limit (50μSv/y) to the public on supervised area.

Not to exceed the emergency dose limit (5mSv/y) to the public in emergency case as follows:

i. Scattering of radioactive materials due to falling of radioactive solid waste caused by operational errors, etc.
ii. Influence of fire and explosion in the relevant waste disposal facility
iii. The other abnormal leakage of radioactive materials from the perspective of public exposure due to breakdown of equipment, equipment failure, operational errors, etc.

<Design Requirements> Design to monitor dose equivalent rate in supervised area.

<Management Requirements> Monitor dose equivalent rate related to direct and skyshine radiation in supervised area.

B) **Confinement Function** (Pit Disposal)

<Purpose> No leakage from the limited area of the disposal facility

<Design Requirements> Installation of surrounding partition or equivalent equipment. Designed to monitor leakage from the limited area of the disposal facility.

<Management Requirements> Measure radioactive materials leaked from engineered barriers.

C) **Controlling Radionuclide Migration Function** (pit disposal and trench disposal)

<Purpose> Function of controlling radionuclide migration works properly

<Design Requirements> Designed to monitor the leakage of radioactive materials

<Management Requirements> Measure ground water level, leakage of dose and activity concentration.

3) Others (Management Requirements)

A) Limited access to the supervised area.
B) Inspection, and prohibition and constraints of certain activities in disposal conservation district.
C) Other safety measures: design requirements against natural phenomena.

<Design Requirements> Not to affect safety against fire, explosion, earthquake, tsunami, external shock (possible natural phenomena (excluding earthquake and tsunami) etc.), etc.

(2) Specific LLW Repository Site (1) JAEA Demonstration Test of Trench Disposal

1) Specification of the Repository.

A) Name: Waste Disposal Facility (Demonstration Test of Waste Disposal), Nuclear Science Research Institute, Japan Atomic Energy Agency (JAEA)
B) Location: Tokai-mura, Naka-gun, Ibaraki, Japan
C) Type of Waste and Project Activities: Disposal of wastes such as contaminated concrete produced with dismantling of JPDR (Japan Power Demonstration Reactor), which is not solidified in container.
D) Maximum Disposal Capacity: 2,520 cubic meters approx...

2) History of JAEA Demonstration Test of Trench Disposal

A) Data Acquisition Program (Reference: "Decommissioning Techniques", issues 15, May 1996)

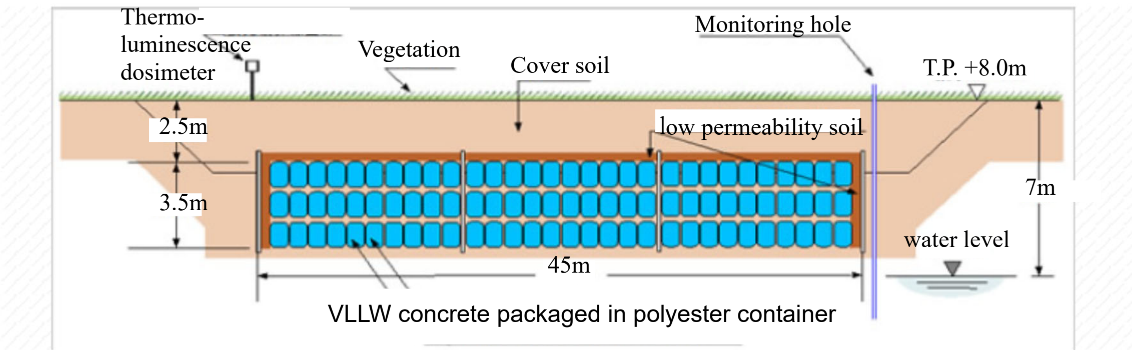
- October 1993: Disposal license application
- June 1995: Application approved
- October 1995: Operational safety programs approved
    i. Radioactivity of each disposed radioactive materials shall not exceed the value specified in the license application. (Specify radioactivity level and weight by disposal unit, and calculate cumulative radioactivity after all wastes are disposed.
    ii. Removal of pooled water in the disposal district and prevention of rain water intrusion during disposal activities. (Installation of protective tent)
    iii. Prevention measures for the scattering of radioactive materials (enclosure in flexible containers, packing in plastic sheets)
    iv. Measures not to leave airgaps after disposal (filling up of the gaps between wastes with dirt, and implementation of intermediate cover)
    v. Prohibition of disposal of hazardous or explosive materials. (implementation of work management for dirt and cover)
    vi. Implementation of cover to prevent permeability from becoming higher than that of surrounding soils. (implementation of soil compaction, implementation of hydraulic test)

B) Pre-operational, Operational and Post-Closure Monitoring

- Disposal Phase (period of stationary work on waste, and period till the confirmation of upper cover stabilization: 1.5 to 2 years approx...)
  i. Setting control area
  ii. Setting supervised area
  iii. Environmental monitoring
  iv. Ambient dose equivalent measurement
  v. Ground water observations
  vi. Regular observation of radioactivity level in ground water and ambient soil
  vii. Release control area after completion of soil cover constructions, and set disposal conservation district and start observation of stability of upper cover.
  viii. Inspection and maintenance of waste disposal site

- Conservation Phase (for 28 years after the disposal phase is concluded)
  i. Continuation of disposal conservation district (release of supervised area)
  ii. Observation of radioactivity level in ground water and soil as necessary
  iii. Inspection and maintenance of waste disposal site
  iv. Restriction or prohibition of certain activities including drilling and residence within disposal conservation district.

C) Scenario analysis, pathways



Concrete waste packaged in polyester container

Outlook of trench disposal facility and penetration inhibitor cover

- Assessment during the period of disposal phase and conservation phase
  1. External exposure (skyshine radiation) from the wastes to be disposed of (unsolidified concrete etc.).
  2. Internal exposure through intake of marine products contaminated by the radioactive materials which were leaked from wastes to be disposed of and discharged into the ocean via ground water.

  Critical pathway is ”i. External exposure” 1.2 x 10^{-2}μSv/y

- Assessment after the conservation phase is concluded (simulate unlimited release for site reuse)

  [General Events]
  1. Internal exposure through intake of marine products contaminated by the radioactive materials which were leaked from wastes to be disposed of and discharged into the ocean via ground water.
  2. External and internal exposure of the construction workers who are engaged in drilling the old nuclear installation site partially, by direct radiation and through dust inhalation respectively.
  3. External and internal exposure of residents living in the house built on the excavated soil of the partially drilled old nuclear installation site, by direct radiation and through dust inhalation respectively.

  Critical pathway is ”iii. External exposure of residents” 6.2 x 10^{-1}μSv/y

- [Infrequent Events]
  1. External and internal exposure of the construction workers who are engaged in drilling the whole old nuclear installation site, by direct radiation and through dust inhalation respectively.
  2. External and internal exposure of residents living in the house built on the excavated soil of the fully drilled old nuclear installation site, by direct radiation and through dust inhalation respectively.

iii. Internal exposure through drinking ground water from the well placed just near the disposal site.

Critical pathway is ”iii. Internal exposure through drinking ground water” 6.2 μSv/y

(3) Specific LLW Repository Site (2) Rokkasho Low-level Radioactive Waste Disposal Center

1) Specification of the Repository.

A) History of Rokkasho Low-level Radioactive Waste Disposal Center

As of the end of March 2016, the total amounts of low-level radioactive wastes generated and stored in the domestic nuclear power plants are approximately 680,000 of 200-liter waste drums. A part of these low-level radioactive wastes has been transported to and disposed of at the Low-level Radioactive Waste Disposal Center operated by Japan Nuclear Fuel Limited (JNFL) in Rokkasho village of Aomori Prefecture (see Fig. 3) of which land area is approximately 3,400,000 m^3).

Currently, the Low-level Radioactive Waste Disposal Center has two facilities in operation at the same disposal site. One is designed to dispose of drums containing homogeneous and solidified wastes such as condensed liquid wastes, used resin and fly ash, that were packed by cement, asphalt, and plastic. The acceptance of such low-level radioactive wastes in this first facility (i.e., No. 1 Disposal Facility) has started since December 1992. The other (i.e., No. 2 Disposal Facility) is designed to dispose of drums containing other solid wastes such as metals, plastics, thermal insulation materials, and filters, that were packed by cement-based fillers (i.e., mortar), and the acceptance has started since October 2000. The capacity of each disposal facility is 40,000 m^3, which is equivalent to 200,000 of 200-liter drums. As of the end of March 2018, the total amounts of drums that have been disposed of are 148,147 at the No.1 Disposal Facility and 148,872 at the No.2 Disposal Facility, respectively.

Given the situation that the No. 2 Disposal Facility will be fully occupied by the waste drums expected to be transported from each nuclear power plant in Japan in coming years, the JNFL has submitted an application to the Nuclear Regulation Authority of Japan in August 2018 to ask a new construction of a disposal facility (i.e., No. 3 Disposal Facility) at the same site and also to make use of the existing disposal facilities.

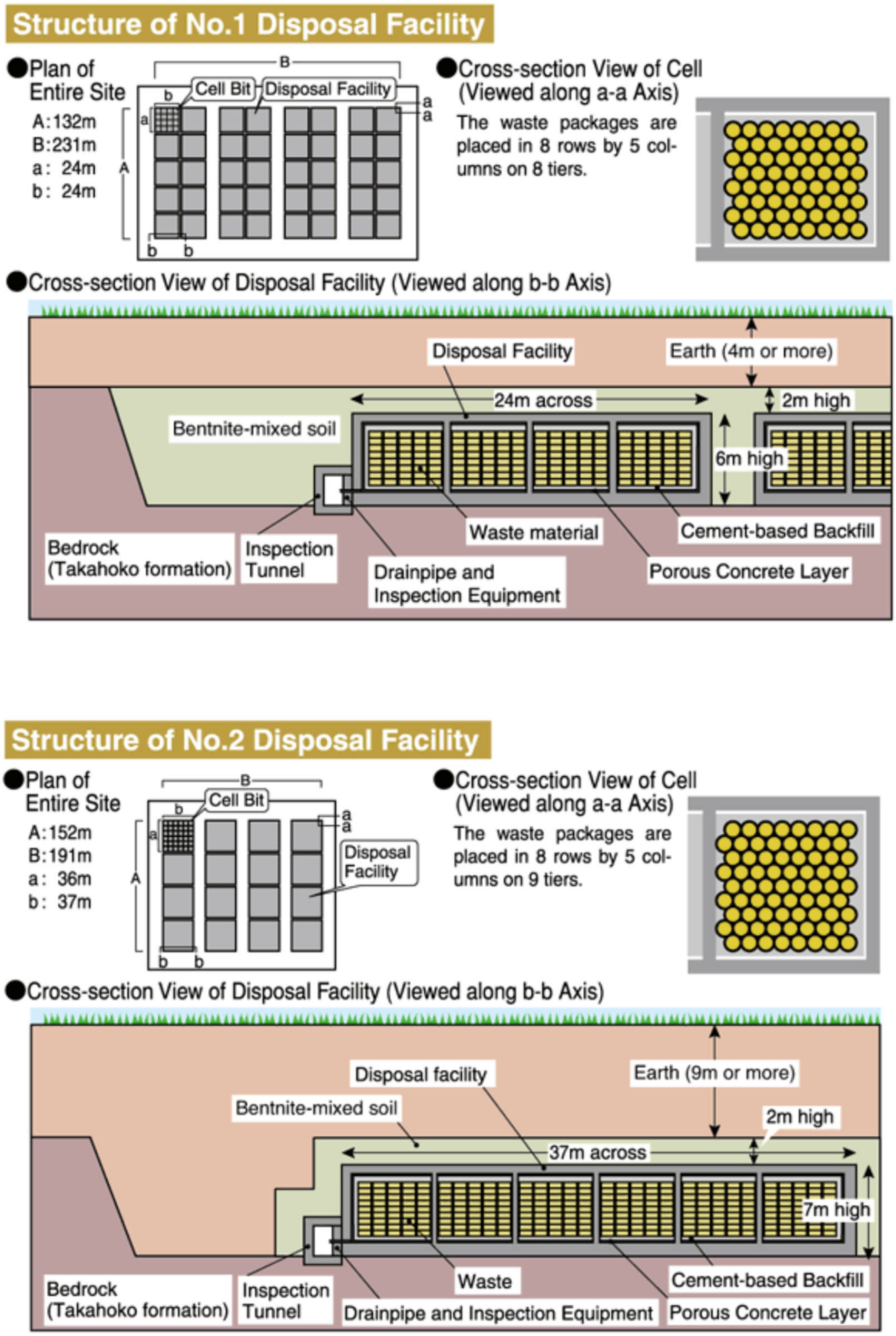


Fig. 3. Concept for pit disposal at Rokkasho Low-level Radioactive Waste Disposal Center (Source: Japan Nuclear Fuel Limited. Available at https://www.jnfl.co.jp/en/business/llw/).

B) Guidelines for Safety Assessment

Safety requirements for the radioactive waste disposal facility are given in laws such as “Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors”. The basic objective is to ensure the safety by confining radioactive materials using passive facilities and equipment, by securing the safety function regarding the migration suppression and radiation shielding, and by appropriately combining these functions. In addition, by securing an appropriate safety margin, it is designed to prevent the occurrence of an abnormal situation, and even if the abnormal situation arises, it is designed not to significantly impact the public around the installation in terms of the exposure dose to ionizing radiation.

The dose limit of 1 mSv per year is defined for the public outside of the peripheral monitoring area by “Rule of Disposal for Second Kind Waste of Nuclear Source Material or Material Contaminated by Nuclear Source Material”, and it is required to design the waste disposal facility so that the dose to the public becomes far below this dose limit even in the case of loss of safety function. For the period from the acceptance of radioactive wastes for the disposal at the facility to the beginning of the decommissioning of the facility, it is required to design the facility, in addition to the compliance with the aforementioned public dose limit defined by the related notice, so that the public dose during the normal operation from the exposure to radiation leaked from the facility, the migration of radionuclides, direct exposure to gamma ray emitted from the facility, gamma ray from the sky shine, and the discharges of radioactive materials into the environment, is controlled as low as reasonably achieved and becomes lower than 0.05 mSv per year. Furthermore, it is required to ensure that the public dose becomes lower than 1 mSv per an accident or incident even in the case of accidental and abnormal situations.

As for the land to be used for the waste disposal, it is designed to ensure that a perspective can be obtained that it can proceed to a condition in which countermeasures regarding the preservation of waste disposal are not necessary after the decommissioning phase starts. Here, the condition in which countermeasures regarding the preservation are not necessary means that the disposal facility is designed to ensure that there are enough possibilities that the pubic dose becomes lower than 0.01 mSv (10 μSv) per year in the basic scenario, and does not exceed 0.3 mSv (300 μSv) per year in the less-likely scenario and 1 mSv per year in natural event and artificial event except the basic and less-likely scenarios. The basic scenario is to be assessed using parameters that are considered to be scientifically most probable under scientifically most probable conditions in consideration of series of changes that are considered to be most probable based on characteristics of the disposal facility, geological environment in surrounding areas, and exposure pathways. The less-likely scenario is to be assessed by most conservative settings that are considered to be scientifically reasonable under the settings of conditions in comprehensive consideration of uncertainties of the basic scenario.

C) Activities for Building Trust for Safety

An example of confidence building in Japan includes an activity to develop private standards to be endorsed by the regulatory body. In this respect, the Standards Committee has been established in the Atomic Energy Society of Japan (AESJ) in order to ensure the safety and reliability of nuclear facilities, and to maintain and develop the technological level in Japan. Four Technical Committee have been established under the Standards Committee for each topic, namely, System Safety, Risk Assessment, Nuclear Fuel Cycle, and Advanced and Fundamental Systems.

The AESJ Standards are the agreed documents regarding technologies to be achieved in activities such as the design of nuclear facility, construction, operation, and decommissioning, based on the latest experience and knowledge of providers of nuclear technologies, users, and experts. The Standards are developed through the process of discussions in compliance with the justice, fairness, and openness, hearing opinions of stakeholders that may be affected through the public consultation.

With respect to methodologies to be applied for a safety assessment of the low-level radioactive wastes, the following Standards have been developed under the Technical Committee on Nuclear Fuel Cycle depending on the types of disposal facility (see Fig. 2).

- Trench disposal of L3 waste (2006): methodology for safety assessment of radioactive waste disposal of the extremely low-level radioactivity (AESJ-SC-F007)
- Pit disposal of L2 waste (2012): methodology for safety assessment of pit disposal in the near surface (AESJ-SC-F023).
- Intermediate depth disposal of L1 waste (2008): methodology for safety assessment of depth disposal (AESJ-SC-F012)

Note that the Standards are to be revised in every five years in principle and widely open to opinions, on the basis of the understanding that the value of its use can be maintained by appropriately revising the Standards reflecting the development of new technologies and the latest experience and knowledge.

Processing of soil and other wastes containing radionuclides released due to the accident at the Fukushima Daiichi nuclear power plant.

1. Basic policy for radioactive contamination in Fukushima Prefecture

Soil and other wastes were widely contaminated with the radioactive materials released into the environment due to the accident at the Fukushima Daiichi nuclear power plant following the Great East Japan Earthquake in March 2011. "The Act on Special Measures concerning the Handling of Radioactive Pollution" was promulgated on 30 August 2011, to reduce the effects of the contaminated materials to the human health and the living environment. On 11 November of the same year, the basic policy providing the following particulars was indicated.

A) Monitoring and measurement for grasping the situation of the environment contaminated by the radioactive materials released due to the accident:

Monitoring and measurement should be periodically conducted in cooperation among the national and local governments and the Nuclear Operators, to grasp the situation of the contaminated environment as well as the effectiveness of the implemented waste processing and decontamination. The results and/or information obtained should be publicly available.

B) Processing of the wastes contaminated by the radioactive materials released due to the accident:

Wastes interfering with the peripheral residents' life, e.g. removal soil by decontamination and disaster wastes generated near the living environment, should be given priority to be processed. Separation between flammable and non-flammable wastes, volume reduction by intermediate processing and recycling should be implemented while securing safety. An additional dose of the peripheral residents due to waste processing should not be exceeded 1 mSv/y and the living environment should be conserved. Before the eventual close of the collected waste management, the additional dose should be ensured not to be exceeded 10 μSv/y[2] based on the assumption of the scientifically reasonable exposure scenario.

C) Measures for decontamination of soil and other wastes:

Because of the wide coverage of decontamination (soil, road, river, lake, coast, harbor, agricultural land, forest, etc.), an operational plan should be preferentially developed for key areas in terms of human health protection, e.g. the living environment for children who have high radiosensitivity, to implement the necessary measures

[2] According to ICRP Publ. 104, the order of magnitude of 10-100 μSv/y is considered to be small in comparison with the variation in natural background radiation and could be regarded as the trivial level of individual effective dose.

according to the dose level. The aims of decontamination are:

- to reduce the area where the effective dose exceeds 20 mSv/y (as an additional dose except for exposure due to natural radiation and medical exposure) in a phased and an expeditious manner; and
- to achieve 1 mSv/y in the long term[3] for the area where the effective dose is less than 20 mSv/y.

D) Collection, transportation, storage and disposal of removal soil:

Measures to prevent from scattering and escaping, to implement monitoring and to keep records (information on how much and where the removal soil was transported) should be carried out whenever collection, transportation, storage or disposal of the removal soil was conducted. The volume of the soil should be reduced as much as possible during the process of storage and disposal, and the low-level contaminated soil should be recycled while ensuring safety.

Removal soil, sludge and vegetation containing radionuclides generated by decontamination were stored in temporary storage sites established by each municipality in Fukushima Prefecture for about three years, then transported to an intermediate storage facility and will be stored intensively for 30 years at the maximum. Radioactive wastes which were not able to be recycled within 30 years will be also transported to a final disposal site established outside of the Fukushima Prefecture in the future although the scale and place of the final disposal site are still under consideration.

2. Temporary disposal site established in the Fukushima Prefecture

(1) Safety measures at temporary disposal site

Temporary disposal sites were established at a place far away from the residential area enough to secure safety with the following measures.

A) Scattering prevention of removal soil:

Removal soil should be put into flexible container bags or sandbags.

B) Intrusion prevention of rainwater and spill prevention of radioactive materials:

Temporary disposal sites should be covered entirely by a waterproof sheet even including the bottom face to avoid contamination of the land itself under the sites.

C) Radiation shielding:

Sandbags should be arranged around removal soil for shielding. 98% of

[3] According to ICRP Publ. 111, the lower part of the 1-20 mSv/y band was recommended to be selected as the reference level for the optimization of protection for the people living in contaminated areas, and 1 mSv/y was given as a typical value used for constraining the optimization process in long-term post-accident situations.

radiation could be shielded by a sandbag layer with the thickness of 30cm.

(2) Attitude of the residents for establishment of temporary disposal sites

Local residents were critical of establishment of temporary disposal sites, both from the concern about increase of radiation level by gathering radioactive wastes in one place and from their perspective as victims of the nuclear accident. In Date City, Fukushima Prefecture, as results of the repeated dialogues between city officials and local residents, the first temporary disposal site was established in October 2011. Continuous efforts to encourage the residents to confirm the limited radiation level around the actual temporary disposal sites enabled to proceed further establishments of temporary disposal sites. Date City has held as many as 83 times of dialogues until December 2011 under the technical supports of radiation protection experts. These dialogues led to building the trust relationship with the local residents and strengthening information sharing among the residents. The passive attitude of the residents who wished to steer the temporary disposal sites away from the living environment to the mountains was gradually changed to the active attitude rather to manage it closely and to implement the necessary measures in terms of radiation protection especially for children.

(3) Transportation status from the temporal disposal sites to the intermediate storage facility

1,300 temporal disposal sites have been established in Fukushima Prefecture. At least at 350 sites, removal soil has been completely transported to the intermediate storage facility by 2018; 250 sites out of them have been restored. By the end of 2019, further removal soil at about 450 sites will have been transported and more than 250 sites out of them are estimated to be restored. Removal soil at all the sites is expected to be finally transported to the intermediate storage facility by March 2021.

3. Intermediate storage facility established around Fukushima Daiichi nuclear power plant

(1) Safety design of the intermediate storage facility

The intermediate storage facility straddling Okuma and Futaba Town was established around the Fukushima Daiichi nuclear power plant and put into full-scale operation in October 2017. The waste volume needs to be transported to the intermediate storage facility is estimated to be 14,000,000 m^3 and about 2,000,000 m^3 of the wastes has been already transported by January 2019. More than 90% of the wastes are removal soil generated by decontamination and 80% of the soil contains less than 8,000 Bq/kg of radiocaesium. The intermediate storage facility has soil storage facilities (Type I and Type II) and waste storage facilities, and the following safety measures were taken for each facility.

A) Soil storage facility (Type I): A facility that stores removal soil containing 8,000 Bq/kg or less of radiocaesium and being unlikely to contaminate groundwater.
   - To transport gradually while preventing from scattering and spill of radiocaesium by soil/sheet covering.
   - To prevent from scattering, spill and external exposure by soil covering after transportation.
   - To store the soil in a facility with water shielding function, if it is likely to contaminate groundwater due to inclusion of a certain level of organic substances.

B) Soil storage facility (Type II): A facility that stores removal soil containing more than 8,000 Bq/kg of radiocaesium.
   - To implement the same measures as Type I.
   - To remove radioactive materials contained in leachate at a water treatment facility before its releasing into the river.

C) Waste storage facility: A facility that stores wastes containing more than 100,000 Bq/kg of radiocaesium.
   - To seal off the wastes into a container and prevent from scattering and spill.
   - To store the containers in the building which has the shielding effect to prevent from external exposure.
   - To establish the facility on hilly area or upland with hard soil which could withstand the maximum scale of an earthquake and a tsunami estimated based on the Great East Japan Earthquake occurred in March 2011.

The results of environmental monitoring around the intermediate storage facility, i.e. air dose rate and radiocaesium concentration of groundwater, are publicly available via its website.

(2) Efforts for final disposal outside of Fukushima Prefecture

It was agreed that final disposal of the radioactive wastes stored in the intermediate storage facility will be completed outside of Fukushima Prefecture within 30 years. The needs of further efforts are recognized on:

- development of volume reduction and recycling techniques;
- promotion of recycling;
- consideration of final disposal scenarios; and
- fostering of nationwide understanding.

The criteria for recycling of the radioactive wastes is currently estimated 8,000-4,000 Bq/kg, corresponding to the annual dose of 1 mSv or less according to the intended use. Although most of radioactive wastes could be recycled scientifically because radiocaesium concentration will be decreased to about 40% after a storage period of 30 years in the intermediate storage facility, it is essential to foster the nationwide understanding and trust for realization.

KAZAKHSTAN

KAZAKHSTAN

-Part I. General Outline of LLW Repository-

1. General Policy

The objective of the national policy of the Republic of Kazakhstan for radioactive waste management is to create and provide for effective functioning of comprehensive radioactive waste management system that allows to achieve safe management (including disposal) with radioactive wastes of all types and categories which were accumulated in previous years, are available at present and will be generated in the future, with the rational use of financial, technical, and human resources, taking into account international experience.

The basic principles of the national policy for radioactive waste management are the following:

- Radioactive wastes produced at the territory of the Republic of Kazakhstan should be disposed in such a way to ensure radiation protection of public and environment for the whole period of potential hazard of the wastes;
- Individuals and legal entities engaged in nuclear energy use activities leading to the generation of radioactive wastes are obliged to take measures for waste minimization;
- Safe storage/disposal of radioactive wastes should be provided for by design and operational documentation as a mandatory step of any type of activity leading to the generation of radioactive wastes;
- Radioactive waste and spent nuclear fuel management activity is carried out based on license;
- Radioactive waste management has to fulfil requirements of nuclear and radiation safety and security in accordance with legislation of the Republic of Kazakhstan in the field of nuclear energy use as well as international treaties ratified by the Republic of Kazakhstan.

1.1. Legal Framework: Acts & Regulations

The following legal acts regulate the relations in the field of radioactive wastes management in the Republic of Kazakhstan:

- Law of the Republic of Kazakhstan as of February 3, 2010 No. 246-IV on “Ratification of the “Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Wastes Management”;
- Law of the Republic of Kazakhstan as of February 10, 2011, No. 405-IV on “Ratification of the “Vienna Convention on Civil Liability for Nuclear Damage”;
- Law of the Republic of Kazakhstan on February 3, 2010 No. 245-IV on “Ratification of the “Convention on Nuclear Safety”;
- Code of the Republic of Kazakhstan as of January 9, 2007 No. 212-III “Environmental Code of the Republic of Kazakhstan”;

- Law of the Republic of Kazakhstan as of January 12, 2016 No.442-V "On Use of Nuclear Energy";
- Law of the Republic of Kazakhstan as of April 23, 1998 No.219-I "On Radiation Safety of Population";
- Code of the Republic of Kazakhstan as of December 27, 2017 No.125-VI "On Subsoil and Subsoil Use";
- Law of the Republic of Kazakhstan as of May 16, 2014 No.202-V "On Permissions and Notifications";
- Law of the Republic of Kazakhstan as of April 11, 2014 No.188-V "On Civil Protection".

Also these relations are regulated by a number of regulative legal acts:

- The Order of Minister of Energy of the Republic of Kazakhstan as of February 20, 2017 No.58 on "Approval of Technical Regulation "Nuclear and Radiation Safety";
- The Order of Minister of Energy of the Republic of Kazakhstan as of February 20, 2017 No.59 on "Approval of Technical Regulation "Nuclear and Radiation Safety of Research Nuclear Facilities";
- The Order of Minister of Energy of the Republic of Kazakhstan as of February 20, 2017 No.60 on "Approval of Technical Regulation "Nuclear and Radiation Safety of Nuclear Power Plants";
- The Order of the Minister of Energy of the Republic of Kazakhstan as of February 8, 2016 No.39 on "Approval of Rules for Collection, Storage and Disposal of Radioactive Wastes and Spent Nuclear Fuel";
- The Resolution of Government of the Republic of Kazakhstan as of May 24, 2016 No. 301 on "Approval of Rules for Siting of Nuclear Facilities and Disposal Facilities ";
- The Order of Minister of Energy of the Republic of Kazakhstan as of February 22, 2016 No.75 on "Approval of Rules for Transportation of Radioactive Substances and Radioactive Wastes";
- The Order of Minister of Energy of the Republic of Kazakhstan as of February 22, 2016, No.76 on "Approval of Rules for Transportation of Nuclear Materials";
- The Order of Minister of Energy of the Republic of Kazakhstan as of February 9, 2016, No.49 on "Approval of Rules for Radionuclide Sources Management";
- The Order of Acting Minister of Energy of the Republic of Kazakhstan as of February 12, 2016, No.59 on "Approval of Rules for State Accounting of Ionizing Radiation Sources";
- The Order of Minister of Energy of the Republic of Kazakhstan as of February 9, 2016 No.44 on "Approval of Rules for State Accounting of Nuclear Materials";
- The Order of Minister of Energy of the Republic of Kazakhstan as of February 9, 2016, No.51 on "Approval of Rules on Approval of Designs of Transport Packaging";
- The Resolution of Government of the Republic of Kazakhstan as of May 12, 2016, No. 287 on "Approval of Rules for Decommissioning of Nuclear and Radiation Facilities";

- The Order of Acting Minister on Investments and Development of the Republic of Kazakhstan as of December 26, 2014, No. 297 on “Approval of Rules for Ensuring Industrial Safety in Geological Exploration, Mining and Processing of Uranium”;

- The Order of Acting Minister on Investments and Development of the Republic of Kazakhstan as of December 26, 2014, No.301 on “Approval of Rules for Ensuring Industrial Safety in Ionizing Radiation Sources Management”;

- The Order of Minister of Healthcare System of the Republic of Kazakhstan as of June 26, 2019, No. KR DSM-97 on “Approval of Sanitary Rules “Sanitary-Epidemiological Requirements to Ensure Radiation Safety”;

- The Order of Acting Minister of the National Economy of the Republic of Kazakhstan as March 27, 2015, No. 260 “Sanitary Rules “Sanitary and Epidemiological Requirements for Radiation Hazardous Facilities”;

- The Order of Minister of the National Economy of the Republic of Kazakhstan as of February 27, 2015, No. 155 “Hygienic Standards “Sanitary and Epidemiological Requirements to Ensure Radiation Safety”;

- The Order of Chairman of CAE MEMR RK No.66 as of July 17, 2008. “Safety Guidelines on Near Surface Disposal of Radioactive Wastes”.

1.2. Safety Objective

The main objective of radiation safety is to protect health of population, including personnel from harmful effects of ionizing radiation by observing the basic principles and standards of radiation safety without unreasonable restrictions of useful activity using radiation in various fields of economy, science and medicine.

1.3. Disposal Strategy

The most elaborated conception in regulatory documents and repeatedly implemented in Kazakhstan concerning final isolation of low and medium-level wastes is their near surface long-term storage (and disposal in the future) – i.e. disposition of such wastes in engineering structures at the surface of the land and/or at a depth of several tens meters.

The objective of disposition and isolation of RW in this way is to eliminate unacceptable risks to human health and long-term hazard for the environment both during the operation of storage facility (in case of disposal – repository facility) and after its closure.

To achieve this objective, the complex of near surface long-term storage of wastes should ensure:

- Reliable isolation of wastes from the environment;
- Penetration protection;
- Control of potential release of radionuclides into the environment;
- Limitation of any beyond-design discharges to the environment;
- Continuing supervision of site during the established monitoring period after the closure

of complex.

1.4. National RWM Strategy/Plan

At the present moment, Kazakhstan does not have any developed and adopted at the government level National Strategy (or Plan) for radioactive wastes management. However, preliminary work on creation of such type document is underway – several years ago a concept of the strategy was developed. At this concept, the implementation of strategy in several stages is under consideration.

During the first stage lasting 10-15 years, it would be reasonable to carry out the following measures:

- To compile a complete inventory of RW available in the country, especially: to carry out full inventory of all RW storage sites; to assess the hazard of all available storage sites, including those storage sites formed during the USSR period, to classify them in accordance with the hazard level, the time reserves to prevent radionuclides distribution and to take a decision on further management with them (for example, concentrated redisposal and localization at the one disposal site or local RW isolation); to conduct zoning of the territory according to the hazard level and determine priorities; to establish centralized and continuous accounting of RW, based on annual inventory;

- To adopt the Law on Radioactive Wastes in which it is necessary to clearly define the state policy on RW management and approve the national program on nuclear wastes, to regulate state regulation and responsibility / functional duties of the participants in the implementation of the radioactive waste management strategy;

- To improve Legal Acts, Standards and Rules in the field of Radioactive wastes management;

- To establish a National Organization on the radioactive waste management, including their long-term storage and disposal;

- To create effective financial mechanism for radioactive waste management;

- To ensure safe operation of the existing RW storages;

- To start removal and conditioning of operational radioactive wastes from storages of BN-350, NNC RK, Ulba Metallurgical Plant, ICMP;

- To construct facilities for processing, conditioning and packaging of radioactive wastes according to preliminary criteria of radioactive wastes acceptance for storage and disposal;

- To create park of transport vehicles for radioactive wastes transportation;

- To start operations on projection, construction, and commissioning of disposal sites for very low-active wastes, short-lived low and medium active wastes as well as centralized storage for interim storage of high-active and long-lived low and medium active wastes;

- To adopt a decision on the feasibility of disposal site construction in deep geological formations when the development program for Kazakhstan's nuclear energy is approved, involving new NPP construction in the country; and, if the decision is positive, to start work on site selection for the construction of a facility for the disposal of highly active and long-lived low- and medium-active wastes in stable deep geological formations.

At the second stage (lasting 35-40 years) the following can be supposedly realized:

- Conduction of territories rehabilitation contaminated with wastes from uranium mining and oil and gas industry;
- Development of technologies, equipment and work performance on rehabilitation of territories contaminated in the result of nuclear explosions in Kazakhstan;
- Completion of operations on elimination of hazardous storages of radioactive wastes including those which were formed during USSR period before the introduction of RW regulation in Kazakhstan;
- Completion of works on removal and conditioning of operational radioactive wastes from the storages of BN-350, NNC RK, Ulba Metallurgical Plant, ICMP and their transfer for disposal;
- Disposal of all accumulated very low-active RW, long-lived and medium-active wastes;
- Implementation of safe interim storage of high-active and long-lived low and medium active wastes;
- In case of decision making on the feasibility of constructing a disposal site in deep geological formations, the design, construction and commissioning of storage for disposal of high-active and long-lived low and medium-active wastes in stable deep geological formations should be carried out.

It is supposed at the third stage (lasting 10-15 years):

- to carry out operation of conditioning facility and packaging of all types and categories wastes;
- to carry out operation of disposal facilities for radioactive wastes of all types and categories available in the country;
- to implement measures on rehabilitation of radioactively contaminated territories.

2. Principles and Safety Assessment

2.1. Fundamental safety principles

The basic principles of ensuring long-term safety of near surface storage/disposal facilities of RW are:

- the principle of applying several levels of protection, including: form and stability of the waste itself; reliability of their packaging; natural barriers of the storage / disposal site; engineering barriers (structures) of the storage/repository; storage / repository operation method and control methods;

- the principle of non-exceeding radiation dose quotas established by radiation safety standards for the population from storage/disposal of RW;

- the principle of minimizing operational costs for long-term monitoring and control of the safety of storage/disposal.

2.2. Safety Criteria (Dose limit/ Dose constraint for Occupational Worker and Public)

The basic document regulating the requirements of the Law of the Republic of Kazakhstan "On Radiation Safety for Population" is "Sanitary-Epidemiological Requirements to Ensure Radiation Safety".

This document establishes three classes of standards for all categories of exposed persons (personnel of group "A", personnel of group "B" and population):

- Main dose limits

- Permissible levels of monofactor exposure (for a single radionuclide, for a one route of entry, or for one type of external exposure) that are derived from the main dose limits: annual intake limit, allowable average annual volumetric activity, average annual specific activity, equivalent dose rate;

- Control levels (doses, levels, activities, flux densities). Their values take into account the level of radiation safety achieved in the organization and provide conditions under which the radiation exposure will be below the permissible level.

The main limits of radiation doses do not include doses from natural and medical exposure, as well as doses due to radiation accidents. There are special restrictions on these types of exposure.

The effective dose for personnel should not exceed over the period of occupational activity (50 years) – 1000 mSv, for public over the period of live (70 years) – 70 mSv.

The annual effective exposure dose for personnel due to normal operation from technogenic sources of ionizing radiation should not exceed the values of doses limits presented in Table 1.

The annual effective dose refers to the sum of effective external exposure dose received in a calendar year and the expected effective internal exposure dose due to the intake of radionuclides to the body for the same year.

Permissible levels of ionizing radiation exposure and other requirements to limit human exposure are determined from dose limits taken equal to 20 mSv per year for personnel and 1 mSv per year for the population.

Table 1 – Basic Dose Limits

Normative values	Dose Limits	
	Personnel of Group A	Population
Effective Dose	20 mSv per year in average for any subsequent 5 years, but not more than 50 mSv per year	1 mSv per year in average for any subsequent 5 years, but not more than 5 mSv per year
Equivalent dose per year in:		

lens	20 mSv	15 mSv
skin	500 mSv	50 mSv
hands and feet	500 mSv	50 mSv

Note:

- Simultaneous irradiation to the specified limits is allowed for all normative values;
- Main dose limits, like all other permissible exposure levels for B group personnel are 1/4 of the values for A group personnel.

2.3. Common formulation of safety assessment

Construction of any RW management facilities (including facilities for long-term storage and/or disposal) is preceded by development and approval of design documentation, including safety analysis report (SAR), as one of the compulsory elements on safety analysis, presenting justification of safety at normal operation and at normal operation failure, including accidents occurrence. SAR includes systematic, complete and non-contradictory safety justification, exercised by doing deterministic and (in some cases) probabilistic safety analysis.

On the basis of conducted analysis, design basis is created for systems, affecting the safety, and the compliance with established safety criteria is confirmed.

2.4. Long term safety of RW repository

Safety analysis is a procedure for assessing functional indicators of long-term storage/disposal facility and, in particular, its potential radiological consequences for human health and environment.

Special attention during analysis is paid to assessing the different methods and mechanisms that may lead to human exposure during facility operation and its closure.

Safety analysis includes quantitative assessment of radiation consequences for worst-case scenarios that could occur during operation and after closure of long-term storage/disposal facility, as well as impact assessment in case of unintended penetration after completion of specified monitoring and control period.

Since facility and its closure may represent a potential threat for human health, a prediction of expected impact is made during safety analysis preparation and safety measures are developed with the purpose to protect the future generation. Considering the most probable ways of long-term storage/disposal facility evolution after its closure, the design documentation provides for that predicted dose value for population would not exceed 0.1 of dose limit norms established for radiation safety, and collective annual dose for critical group of population would not exceed 1 man-sieverts (man-Zv).

Considering the issues on long-term protection of environment, any non-radiation impacts beside radiation factors are considered as well, such as chemical contamination or native habitat change.

2.5. Monitoring and Institutional Control

The design documentation shall provide for sanitary protection zone around the storage/disposal facility and creation of environment monitoring system for the period of operation and during the specified monitoring period. Measures and means of monitoring shall not imperil the long-term functional specifications of the whole storage/disposal facility. Size of sanitary-protection zone is set in accordance with the existing sanitary rules.

Radiation monitoring procedure, dosimetry control execution procedure in area of increased radiation hazard, description of individual protection gears and alarm, list and policy on the maintenance and retention of accounting records, personnel training program and other organizational and technical measures are reflected in Radiation Protection Plan (or instructions). The plan is a subject for periodic revision and re-approval within the time limit and in manner prescribed by authorized agency.

After storage/disposal facility closure, population access to the site or its alternate use is forbidden during the specified monitoring and control period.

The duration of specified monitoring and control period is substantiated on design stage of storage/disposal facility, considering composition and nature of waste, its specific and total activity, as well as predicted activity within disposal facility in the future and existing experience on information storage. In accordance with RK rules the monitoring period established shall not exceed 100 years.

Organization is assigned for the specified monitoring and control period that would be responsible for application of active and/or passive surveillance measures over environment state.

2.6. Safety assessment during entire life cycle of the repository

Storage/disposal facility construction can be started only at availability of approved and agreed-on facility design documentation reviewed by State supervision and monitoring bodies in legal manner.

At pre-construction phase the operating organization shall submit the preliminary safety analysis report for storage/disposal facility to authorized agency. A positive conclusion on results of preliminary SAR review is considered as the official permit for construction gained from authorized agency.

At the post-construction phase the operating organization shall submit to authorized agency a final SAR, that includes all amendments inserted into design during the construction and commissioning storage/disposal facility. Positive conclusion on results of final SAR review is a compulsory condition for operating license issue on storage/disposal facility operation.

Internal commission shall be appointed regularly (no less once a year) by the management of storage/disposal facility for radiation safety inspection at the facility.

When commissioning, periodically (no less once per 3 years), as well as when reconstructing (modernization) that would affect design basis of storage/disposal facility, the authorized agency shall execute independent inspection on control over compliance with technical regulations requirements and safety rules.

3. Regulatory and Operational System Preparation

3.1. Existence of Regulatory Frame for Radioactive Waste Repository

Basic documents in RK, referring to storage/disposal facilities, are as follows:

- Law of the Republic of Kazakhstan dated January 12, 2016 # 442-V "On Use of Nuclear Energy";

- Decree of the Ministry of Energy of the Republic of Kazakhstan dated February 8, 2016 # 39 "On Approving the Rules for Collection, Storage and Disposal of Radioactive Wastes and Spent Nuclear Fuel";

- Decree of the Chairman of KAE MEMR RK # 66 dated July 17, 2008 on "Radioactive Waste Near Surface Disposal Safety Manual".

3.2. Responsibility to Develop, Construct and Operate of Waste Repository

Construction, operation and decommissioning of long-term storage/disposal facilities is permitted to be exercised only by legal persons. Such legal persons are under obligation to have a license for the appropriate type of activity in the field of nuclear power.

Operating organization is responsible facility operational safety assurance and: executes safety and environmental impact assessment; provides necessary level of personnel, population and environmental safety; establishes required organizational structure; executes personnel recruitment and training; purchases necessary quantity of qualitative equipment; develops and implements quality assurance program on RW management; executes surveillance and monitoring of technological process.

Long-term storage/disposal facility decommissioning is carried out basing on facility' management decision, agreed with an authorized agency and in accordance with the final Facility Decommissioning Plan.

Decision on disposal facility closure is taken by the Government of the Republic of Kazakhstan upon proposal submitted by the authorized agency after corresponding activities completion. The proposal is based on the disposal facility closure activities, performed by operating organization, involving:

- remediation of the territory, contaminated due to disposal facility operation;

- measurements of radiation environment at disposal facility;

- preparation of documentation for archiving accompanied with complete description of radioactive wastes disposed, disposition facility structure, geotectonic, geological and geophysical characteristics of disposal facility positioning.

Operating organization is responsible for disposal facility safety up to all work completion on its closure, provided by the design documentation, including territory remediation.

3.3. Knowledge management system (Inventory, Waste characterization, Data management [site selection]

The operating organization is primarily responsible for creation of an information collection and storage system of RW receipt, storing and disposal.

The operating organization develops a system of collection and keeping:

- the whole design documentation of the storage/disposal facility,
- accounting records of wastes inventories, accepted or existed in RW storage/disposal facility,
- data on operation, radiation monitoring results, dosimetry control, incidents occurred,
- information on the impacts on personnel, population and environment.

The operating organization designates a person, responsible for RW accounting and storing, who regulates RW receipt upon established sanitary rules. This person makes schematic map on RW placement within storage facility. All RW received are registered in the accounting log book. The current accounting log book is kept on constant basis. Copies of RW technical passports (certificates) are kept by the person, responsible for RW accounting and storing. Organization management provides preservation of the accompanying documents during the whole operating period. Table 2 presents example of radioactive wastes accounting form.

Table 2 – Radioactive Wastes Accounting Log Book

#	RW Description	Receipt Date	Radioactive waste types (solid, liquid radioactive wastes)	Type and # of storage tank, package, container	pH medium	Quantity of radioactive wastes (kg or l)	Radionuclide composition and types of radiation	Specific activity	Total activity	Full name and signature of a delivering side	Full name and signature of receiving side	Description and # of transportation container
1	2	3	4	5	6	7	8	9	10	11	12	13

Annually, during storage/repository filling, the Commission, designated by organization management, carries out RW inventory (checks the correctness of RW accounting procedure) delivered for long-term storage/disposal. Inventory commission involves people responsible for accounting, storing, as well as management and accounting department representatives.

Inventory commission checks:

- presence of accompanying documents for RW (passports, certificates);
- conformance of RW radiation source characterizing records in accounting log books with data specified in accompanying documents (passports, certificates);
- RW physical verification at storage facilities and compliance of obtained data with records in accounting log books and accountancy data;
- correctness of accountancy and accuracy of records in accounting log books when RW receiving and transferring;
- conformance of schematic map with RW actual placement in storage/repository. In case of non-conformity the schematic maps shall be amended.

Upon inventory results of radiation sources, the commission prepares Inventory Act that is a subject for signing by all members of inventory commission and approval by organization manager and stamping.

All documentation shall be kept in operating organization, and transferred to the state (regional) archive after facility closure and kept up to the expiration of specified monitoring and control period.

After the expiry of specified monitoring and control period any proposals on alternative use of the territory shall be a subject of ecological expertise and assessment under applicable law. The corresponding warning signs and reminders on the previous use of the territory shall be reflected in the land use documents and kept for 300 years.

4. Site Selection

4.1. Area/site screening

Decision on construction and location of long-term storage/disposal facilities is made by the Government of the Republic of Kazakhstan upon agreement with the local representative bodies within the territory of which it is planning to construct these facilities, considering:

- needs in them to solve economic targets of the country and separate regions;
- availability of certain conditions for location of the facilities, meeting the requirements of the RK legislation in the sphere of nuclear power use;
- zero threat for the facilities' safety from nearly located civil and military objects;
- requirements, established by ecological legislation of the Republic of Kazakhstan;
- possible social and economic consequences from the objects location affecting the industrial, agricultural and social development of the region.

Practice of such a decision making in RK involves:

- issue of Governmental decree on Working Group establishment, that would be responsible for site selection;
- criteria development for regions and site selection;
- preliminary selection of regions and possible construction sites within these regions;

- visiting regions and possible construction sites by Working Group;

- preparation of the analysis report upon characteristics, advantages and disadvantages of site location regions and possible construction sites;

- issue of an act on selection of region and possible construction sites.

After decision making on construction and region, operations are conducted on specific site selection out of alternative ones (not less than three).

Site is selected considering:

- possible external impact of natural and (or) technogenic character;

- possible transfer of radioactive substances;

- possibility to prevent population and environmental impact due to storage/disposal facility operation or due to incidents or accidents occurrence.

Works on storage and (or) disposal facility construction include special studies and economic assessments making considering environmental impact, involving radiation dose exposure for population critical groups.

4.2. Site Criteria

When selecting a land for construction, the following conditions shall be met (briefly):

- availability of ground water unsuitable for drinking and technical water supply because of salinity;

- high sorption and capacity properties of enclosing rocks;

- significant ground water depth (sixty meters and more);

- ground water level at least four meters from bottom of radioactive waste storage/disposal facility;

- geologic horizons which are not aquifers and have no hydraulic connection with underlying aquifers;

- absence of fault tectonics and intensive fissuring, distance to quake-prone fault line over forty kilometers;

- very low sensitivity to faulting, subsidence, depression;

- absence of erosion;

- geomorphologic stability;

- solid and very dense soils and rocks of foundation of facility;

- impermeable rocks of foundation, thickness over ten meters;

- gentle terrain with slope under five percent;

- distance to the closest ground and underground water intake or surface water source at least four kilometers;

- actual land use is not economically effective, potential land use is also not admittedly evaluated;

- cultural and national assets are absent within four kilometers;

- location hold no value for tourists and rarely visited by residents of nearest settlements.

4.3. Exclusion Criteria

Location of radioactive wastes disposal facility is prohibited at:

- residential construction areas;

- at area where there are deposits of useful minerals without approval of exploration authority;

- active karst areas;

- areas of landslides, debris flows and snow slides and other dangerous geologic processes;

- swamps;

- drinking water underground source zones;

- resorts protective sanitary zones;

- urban green belt zones;

- specially protected natural areas;

- areas of I, II, III belt of sanitary protection zone for ground and underground sources of utility and drinking water supply, sewage facilities, water mains;

- water shed areas;

- land under or designated for forests, forest-parks and other green space, which protect and fulfil sanitary-hygienic functions and are public resting places.

4.4. Societal and political acceptability (local acceptance, national approval)

Government of the Republic of Kazakhstan takes a decision on construction and area where storage/disposal is to be constructed, after agreement with local representative bodies of the region where the storage/disposal facility is designed to be constructed.

Ecological and sanitary-epidemiological expertise is obligatory for design documentation for RW storage/disposal facilities.

Radiation-hazardous facilities' construction projects require public hearings.

5. Design and Construction of Disposal Facilities

5.1. Estimated cost and Funding

Organization operating a storage/disposal facility shall have necessary managerial, financial, material and technical resources, as well as qualified personnel to provide safe operation and service of a facility for the whole life-cycle period. This organization provides for funds for design work, project expertise, construction, commissioning and operation of radioactive wastes storage/disposal facility, disposal facility closure, post-utilization, elimination of radiation accidents' consequences, compensation for damage caused to the life and health of people, property of private and legal bodies, and to the environment.

As an example, table 3 presents preliminary information on cost for construction of low-active RW long-term storage/disposal facility 100 000 m^3 with prices as of mid-year 2019.

Table 3 – Implementation period and cost

#	Description of Work	Period				Total
		Cost				
		2021	2022	2023	2024	
1.	Development of Feasibility Study	29 134	4 320	–	–	33 454
2.	Development of Design Documentation	–	–	21 449.87	–	21 449.87
3.	Construction of RW storage/disposal facility	–	–	–	597 654	597 654
Total, thous. tenge		29 134	4 320	21 449.87	597 654	652 557.87

5.2. Requirements

Technical decisions in design of storage/disposal facility shall be state-of-the-art.

Integrity of containers with RW should be preserved during the whole period of storage/disposal. Space between the containers shall be filled with bulk non-radioactive materials or bounding solutions (cement) to prevent their falling down or precipitation.

The foundation of storage/disposal facility must be capable of carrying the whole facility.

Design shall provide for reliable engineering barriers of natural and/or man-made materials. Engineering barriers shall safely isolate waste, prevent erosion process, prevent or limit contact with water and radionuclide migration in all foreseeable situations including unintentional penetration after closure.

Design life of engineering barriers against unintentional penetration shall be at least 500 years.

Minimal thickness of engineering barriers at storage/disposal facility depends upon conditions of dose for population which shall be below determined limits for specified monitoring and control period.

Design shall present limits and conditions for normal operation of facility.

Also, design shall provide for system to detect, collect and remove water from any structure of disposal facility to prevent water erosion of barrier. Water discharge outside facility area without radiation monitoring and decontamination is not allowed.

Design shall provide for alarm and fire-fighting systems, smoke exhaust system and fire barriers taking into account a category of radiation hazard of facility.

Design shall provide for separate storage/disposal of low and medium-active wastes. Separate storage is recommended for waste batches which significantly differ in time of activity reduction to clearance levels.

Design shall provide for sanitary protection zone around storage/disposal facility and environment monitoring system for the period of operation and specified monitoring period.

Monitoring instruments and methods shall not endanger long-term functional characteristics of facility. Size of sanitary protection zone is determined in accordance with applicable sanitary Rules.

Design shall include estimate of staff numbers for radiation safety and monitoring.

Design substantiates and determines limit of total activity at storage/disposal facility. At that SAR shall present quantitative evaluation of potential exposure to population, caused by radionuclide migration, and predict stochastic effects.

Any changes or design deviation which effect storage/disposal facility safety shall be agreed.

5.3. Conceptual design

Construction of RW storage/disposal facility requires pre-design and design documentations be developed.

Pre-design documentation is documents, prepared prior to development of a construction design, including program, reports, feasibility study, technical and economic estimations, results of scientific research and engineering investigation, technological and structure analysis, sketches, mock-ups, site measurements and survey results, and other initial data and material necessary for decision making for design documents elaboration and further design implementation.

Pre-design documents subject to approval include feasibility studies and other investment calculation and justification documents specified by legislation.

Feasibility study for RW storage/disposal facilities includes the following sections:

- initial data;
- introduction;
- marketing section;
- RW storage/disposal facility performance;
- provision of resources;
- design and engineering solutions;
- facility location;
- architectural and construction concept;
- transport;
- engineering systems;
- environmental impact assessment;
- institutional section;
- financial analysis;
- investment economic efficiency;
- social section;
- economic performance;
- general conclusions;

- attachments.

5.4. Basic engineering design

There are two stages of development – design and work.

Design documentation for RW storage/disposal facility at design stage includes the following sections:

- facility passport;
- general explanatory note;
- facility plan and transport arrangement;
- engineering protection of the area;
- technical solutions;
- management of facility, arrangement of conditions and safety engineering for employees;
- architectural and construction concept;
- engineering networks, systems and equipment;
- report (or special section) on safety analysis;
- civil defense engineering measures and natural and technogenic emergency prevention measures;
- public protection plan for radiation accident situation;
- buildings and facilities automatic monitoring system;
- system for integrated safety and security, anti-terrorism security;
- arrangement of construction work scope of which is determined by design task;
- environmental protection;
- estimate documentation;
- investment efficiency (in accordance with conditions of design task) and economic performance;
- summary of basic construction materials, products and equipment;
- preliminary plan for RW storage/disposal facility decommissioning.

Work documentation for RW storage/disposal site is developed at second design stage in compliance with requirements of state standards, technological design administrative regulations.

Work documentation includes:

- drawing design for construction and assembling operations;
- drawing design for building products and structures;
- sketch drawing for overall view of non-typical products;
- estimate documentation;
- bill of quantities of construction and assembling operations, summary list of materials and equipment specifications, products and materials.

5.5. Implementation

To ensure system and equipment functioning at long-term storage/disposal facility in accordance with approved design before regular operations, operating organization shall develop and implement Commissioning Program.

Commissioning of long-term storage/disposal facility is allowed following the completion of construction and assembling operations at underground and ground facilities, which are the part of start-up basics, determined by design.

After construction is completed, State Commission, appointed in accordance with existing legislation, establish facility compliance with taken design solutions and requirements of effective standards and rules. Approved Act of the State Commission is the basis to start-up facility operation.

Operation license, issued as applicable by nuclear power use authority, permits to start accepting wastes.

5.6. Quality assurance (Standard & Certification)

Quality assurance program (QAP), which is a set of administrative and technical measures to assure quality, regulates quality management during life cycle of storage/disposal facility.

QAP elements consider foreseeable impact of operation, structures, systems and components to the safety of disposal facility. Results of safety analysis determine safety-related operations, structures, systems and components.

QAP include as follows:

- general quality assurance program for total life cycle;
- quality assurance program for location selection;
- quality assurance program for design;
- quality assurance program for equipment manufacturing;
- quality assurance program for manufacturing;
- quality assurance program for construction;
- quality assurance program for commissioning;
- quality assurance program for operation;
- quality assurance program for decommissioning.

Preparation of general Quality Assurance Program as well as separate contractor's Quality assurance programs is the responsibility of an operating organization, which maintains control of QAP implementation at separate life cycle stages.

The Programs are developed in compliance with requirements set by nuclear power use authority.

-Part II. Specific Site Safety Assessment of LLW Repository-

1. General Considerations for Safety Assessment

As part of the project for the construction of near surface long-term storage/disposal facility of RW, the works on safety assessment, specifically on assessment of environmental impact of the storage/disposal facility and its radiation safety assessment for personnel and population are ongoing. These works are carried out taking into account: possible external effects of natural and (or) technogenic feature; possible migration of radioactive substances; prevention of damage for population and environment as a result of storage/disposal facility operation or as a result of occurrence of incidents or accidents. In addition, as part of these works, the public is provided with information about the safety of such facility.

1.1. Purpose of Safety Assessment

The objective of long-term storage/disposal is placement and isolation of RW in such a way to exclude an unacceptable risk to human health, long-standing damage to the environment both during the period of long-term storage/disposal operation and after its closure.

The purpose of safety assessment for storage/disposal facility is to demonstrate that the facility can be constructed and operated in accordance with safety criteria defined by the current regulatory legal documents.

1.2. Regulatory Requirement (Limit, Risk)

Since the storage/disposal facility, even after its closure, can pose a potential threat to human health, it is necessary to forecast the expected consequences and develop safety measures to protect future generations. Taking into account the most probable possible ways of the facility's evolution after its closure, the project should specify that the dose forecast for the population does not exceed 0.1 of the dose limit established by radiation safety standards, and the collective annual dose for the critical group of the population does not exceed 1 pers-Sv.

Under the conditions of normal operation of the facility, the limits of doses of technogenic exposure during the year are established on the basis of the following values of individual lifetime radiation risk: 10^{-3} for personnel and $5 \cdot 10^{-5}$ for the population. Negligible risk level is 10^{-6}.

The waste relevant for near surface disposal should have the following properties:

- aggregation state. The wastes acceptable for disposal should be only in solid form. The wastes in liquid form shall be solidified with a low leachability (less than 10^{-3} g/cm^2·day for Cesium ^{137} and Strontium ^{90});

- density. In order to minimize the volume and reduce the possible leaching area, the waste should be compressed;

- radionuclide composition and activity of radionuclides in the package. Radionuclide composition of wastes, specific and total activity of radionuclides in the package (maximal and average values for the complex) must satisfy the restrictions established by design of the storage/disposal facility;

- thermal stability. The waste must be stable to degradation due to residual heat release after disposal and exposure of external thermal sources;

- stability. The waste should be sufficiently stable in order to address the requirements of the Rules together with the natural and engineering barriers of the disposal facility under the conditions of the intended mechanical, chemical, thermal, radiation and biological influences. The form of waste or package may maintain waste stability. Medium level waste should remain stability for at least 300 years;

- toxicity. The content of chemically toxic, poisonous, pathogenic and infectious substances in the waste should be determined with sufficient accuracy and limited as much as reasonably possible;

- chemical stability. The content of strong oxidizing agents, chemically and corrosive-active and unstable substances in the waste is not allowed. The waste must not be decomposed and release gases and vapors;

- chemical compatibility. The content of stable complexable substances, as well as possible chemical transformations in the waste, which may increase their migration capacity in the future, should be taken into account at the stage of preparation for waste disposal.

Medium-level waste (Table 1), containing long-lived radionuclides with semi-half decay period more than 30 years, excepting transuranium ones, with a total specific alpha activity more than 10^4 kBq/kg and/or transuranium radionuclides with a total specific activity more than 10^2 kBq/kg should be disposed in such a way that the upper level will be at least 5 meters from the day surface, or provided with barriers against unintentional penetration with a service life of at least 500 years.

Classifying criteria of waste as radioactive and their separation into low- and medium-level waste by specific activity and radionuclide composition, as well as separation of waste by dose rate of gamma radiation at a distance of 0.1 m from the surface are established in the Environmental Code of the Republic of Kazakhstan. Solid waste is recognized as radioactive when:

- specific activity of radionuclides in the waste is greater than values and its total activity exceeds minimum significant activity (MSA);

- equivalent (exposition) dose (EDR) rate exceeds 0.3 μSv/hour (30 μR/hour) above the natural background for gamma-emitting radionuclides, but for sealed ionizing radiation sources (IRS) exceeds 1 μSv/hour (100 μR/hour) at a distance of 0.1 m from IRS;

- specific activity under undetermined radionuclide composition exceeds: 100 kBq/kg for beta-emitting sources; 10 kBq/kg – for alpha emitting sources; 1.0 kBq/kg – for transuranium radionuclides.

Table 4 – Classification of Liquid and Solid Radioactive Waste upon Specific Activity

Category of wastes	Specific activity, kBq/kg		
	Beta-emitting radionuclides	Alpha-emitting radionuclides (excepting transuranium)	Transuranium radionuclides
Low-Level	less 10^3	less 10^2	less 10^1
Medium-Level	from 10^3 to 10^7	From 10^2 to 10^6	from 10^1 to 10^5

1.3. Time Frame of Assessment (Operation 50 yrs, Institutional Control 300)

The duration of the specified monitoring and control period is justified at the design stage of the disposal site considering composition and nature of the waste, its specific and total activity, as well as the projected activity at the disposal site in the future and the gained experience of the information storage. The specified monitoring and control period should not be less than 100 years. The operation period is not limited by standards.

2. Specific LLW Repository site (planning etc.)

2.1. RW Sources in RK

The RW available in the Republic of Kazakhstan are represented: by the waste of uranium mining, oil and gas production, metallurgic branches of the industry as stockpiles, tailing storages, contaminated soils, tubes, equipment. Also RW represented as liquid and solid wastes from decommissioning the fast reactor BN-350 in Aktau and operating research reactors in Alatau settlement and in Kurchatov; ampoule ionizing radiation sources which are used in various sectors of the industry, medicine and agriculture, and which are time-expired and required to be disposed; as well as contaminated territories and equipment in the result of nuclear tests conducted in Kazakhstan.

At present, the Republic of Kazakhstan has sufficiently complete and centralized information on spent IRS (maintained by Committee of Atomic Energy Supervision and Control CAESC), RW originated from the operating and decommissioning reactors (maintained by the enterprises and presented in the consolidated manner to CAESC), and waste of uranium mining and uranium processing industry (maintained by the enterprises and presented in the consolidated manner to CAESC).

The information of wastes generated from the nuclear weapon tests and radiological warfare agents (RWA) as well as wastes of the mining, coal and oil and gas industries is insufficient and requires surveys and formation of RW cadaster.

2.2. RW Storage/Disposal Facilities Available in RK

Low and medium level waste from BN-350 reactor are placed in a structure representing two parallel-located earth trenches in volume of 4590 m^3 and 3910 m^3. After filling, the trenches are backfilled with ground in layer thickness not less than 0.5 meter and covered by concrete (asphalt). About 6418 tons of low level and about 642 tons of medium level waste of total activity about $4.4\cdot10^4$ GBq are placed in the storage.

Liquid (from 6 to 24 m^3 per a year, activity of up to 3 GBq) and solid (from 50 to 500 kg per a year, activity of up to 14 GBq) waste from RR WWR-K are cemented and transported to a near surface storage facility, located at RR site. The total activity of waste, that have been disposing since 1988 in the current facility, designed for liquid and solid wastes, currently composes 328011 GBq.

Average speed of radioactive wastes accumulation at IGR, IVG.1M and RA reactor complexes is as follows: solid RW – 300…400 kg/year; liquid RW – 2.0…3.0 m^3/year. Accumulated radioactive wastes are transported in prescribed manner to long-term storage facility at research reactor complex (RRC) "Baikal-1" located in Kurchatov. The quantity of solid radioactive wastes at RRC "Baikal-1", referred to the enterprise's own accumulations, composes 184 501.87 kg with total activity – 4923·GBq. Total quantity of RW, placed for long-term storage at RRC "Baikal-1" including RW, received from outside (enterprises, organizations, ownerless), composes 2 722 490.48 kg with total activity– 6876 GBq.

RRC "Baikal-1" is one of the main enterprises of republican significance engaged in temporary storage of IRS (ionizing radiation source). Besides, IRS storage facilities operate in Kazakhstan as part of the following organizations: LLP "MAEK-Kazatomprom" (Aktau), JSC "Ulba-Metallurgical Plant" (Ust-Kamenogorsk), as well as a storage for low and medium level IRS in RSE "INP RK" (Almaty) and LLP "Kazfosfat" in Taraz city. The last one is supposed to be decommissioned and sources should be transported to RRC "Baikal-1". All mentioned facilities are licensed for a long-term storage of RW.

The following facilities are designed for wastes management originated from uranium mining and uranium processing industries available in the Republic of Kazakhstan:

- tailing storage of Stepnogorsk Mining and Chemical Plant LLP (SMCP), located 25 km away from Stepnogorsk and 160 km away from Kazakhstan's capital. Hydrometallurgical plant (HMP) processes beside design products – uranium-bearing ore – natural uranium concentrates as well, received from enterprises of the "Kazatomprom" National Nuclear Company". Industrial sewage waters are drained to the tailing storage, consisting of three tanks (cells) in area of 757 ha (cell # 1 – 162 ha, cell # 2 – 270 ha, evaporation cell – 303 ha and intermediate pumping and sludge pipes – 22 ha) with total quantity of 49.1 mln tons of highly dispersed radioactive slurry. Environmental system can guarantee the object safety when stable working conditions are provided. Due to modernization realized the plant operability exceeded the design capacity and composed 4000 tons of uranium ore per a year. To cover uranium tailings with low-toxic solid wastes of copper-molybdenum industry a molybdenum concentration plant is constructed for ore processing at available capacities of LLP SMCP. Today the tailing storage contains 41979 thous. cub. m. (49116 thous. tons) of low level waste with total activity of 7100 TBq;

- liquid low level wastes are placed in 5 evaporation cells of Shantobe deposit, LLP SMCP, located 450 km away from Stepnogorsk and 420 km away from Nur-Sultan of total area 6.5 ha. Currently 181.4 thous. tons (178 thous. cub. m) of LRW with total activity of 1752 GBq are at the deposit;

- "Koshkar-Ata" tailing storage of the former Pre-Caspian Mining and Metallurgical Combine located near Aktau. "Koshkar-Ata" tailing storage contains 120000000 cub. m of RW. Remediation program on the tailing storage has been implementing since 2006;

- UMP tailing storage (cell). Waste are placed in tailing dam facility within "UMP" JSC. Receiving tanks in tailing dam facility of open type meant for liquid waste are made in form of ponds (cells) that accumulate drainage and slimes, with partial evaporation. Since 2014, total quantity of RW composed 6411667.7 cub.m with total activity of 194 GBq;

- there are two RW storage facilities within PV-1 and PV-2 industrial sites of 10000 cub. m storage capacity and 16 cub. m correspondingly, JE "Inkay" NAC-Kazatomprom (Kazakhstan) and Cameco Corporation (Canada), located 10 kilometers northward from Taykonur settlement in Suzaksk region, South-Kazakhstan oblast;

- RW storage facilities at "Kanzhugan" deposit, with 7200 cub.m. storage capacity, owned by LLP "Taukent Mining and Chemical Enterprise", Taukent settlement, Suzaksk region, South-Kazakhstan oblast;

- RW storage facilities of 10000 cub.m storage capacity, owned by JSC "RU-6", located 90 km away from Shieli settlement, Kyzylordinskaya oblast

- RW storage facilities of 80000 cub. m. storage capacity, owned by JSC "Stepnoye Radio Control", Kyzemshek settlement, Sozakskiy region, South-Kazakhstan oblast, which was put into operation in 2007.

There is a facility for pipes and metal equipment decontamination meant for RW management of oil industry in Mangystau region. Areas are arranged at Kalamkas and Zhetybay deposits in Mangystau region for pipes and equipment decontamination. Radioactive waste storage facilities are launched in Zhetybay and Zhana-Ozen deposits of designed volume as 100 thous. t (Zhana-Ozen) and 70 thous. t (Zhetybay).

2.3. Proposed long-term storage/disposal facilities

Application is currently under consideration in the RK for construction of near surface storage facility of radioactive waste (hereinafter NSRWSF), resulted from remediation activity at Semipalatinsk Test Site (STS) radioactive contaminated areas. The RW is a surface layer of natural soil contaminated by technogenic radionuclides as a result of radiological warfare testing.

Location for NSRWSF is proposed at "Experimental Field" site of the former STS.

2.1.1. Infrastructure

Proposed location has necessary transport and engineering infrastructure: there is a motor road of 48 km from the location to nearest town (Kurchatov). Kurchatov town has motor road to Semey town (130 km) and Pavlodar town (250 km). There is a hard surfaced road network inside the town. Trunk railway line Semey-Pavlodar goes through the suburb of Kurchatov town.

Electric power for radioactive waste storage facility shall be delivered from existing power supply line.

2.1.2. Parameters of storage/repository

Basic performance characteristics of NSRWSF are provided in table 5.

Table 5 – Basic Performance Characteristics of NSRWSF

Description	Value
Designed site	18.57 ha
Building area	3.84 ha
Area of “dirty zone”	18.37 ha
Area of “clean zone”	0.2 ha
Reserved area for future construction	2.14 ha
Design capacity of NSRWSF	100 000 m^3
Quantity of cells	8
Design capacity of one cell	12500 m^3
RW activity	Low-active
Operation term	50 years
Regulating ponds	3360 m^2
Mound around site	13895.4 m^3
Ring canal around site	7417 m^2
On-site roads	1.63 km
Fencing	1726 m
Number of regular staff, involved in operation	16 pers

Preliminary diagram of NSRWSF is given in Figure 1.

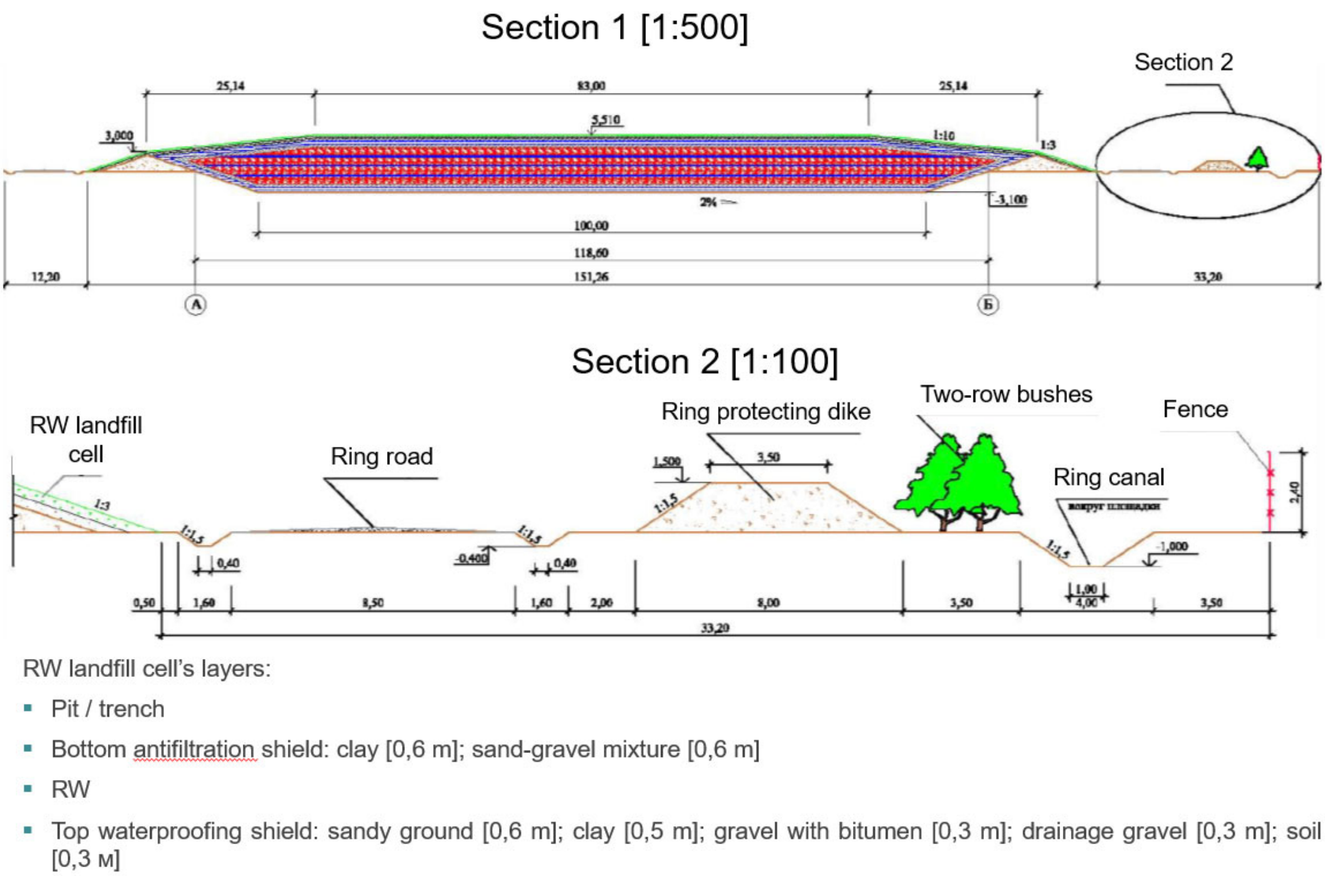


Figure 1 – Preliminary Diagram of NSRWSF

2.1.3. Direct and Final Results

Direct results:

– Volume of radioactive wastes to be disposed for long-term storage is about 100 000 m^3;

– Cleaned area is over 67.23 km^2;

– Construction of radioactive waste storage facility, volume 100000 m^3;

– Activity of radionuclides to be disposed is (Bq):

$^{241}Am - 6.5\times10^{8}$;

$^{137}Cs - 9.3\times10^{6}$;

$^{239+240}Pu - 1.0\times10^{10}$;

$^{90}Sr - 3.4\times10^{12}$.

Final results:

– Solution of issue concerning RW utilization from contaminated area of the former STS;

– Improvement of radiation situation at STS area;

– Reduction of radiation contamination risks at areas adjacent to testing site area, reduction of impact to environment and human health.

3. Guidelines for Safety Assessment

Safety assessment requirements for RW storage/disposal are mainly determined by two regulatory documents of RK: “Safety Manual for Near Surface Radioactive Waste Disposal” and Technical guideline “Nuclear and Radiation Safety”.

According to the documents, a comprehensive safety analysis shall be executed for designed facility considering whole operation term and post-closure term, prior to construct storage/disposal facility.

Safety assessment is a procedure for evaluating functional parameters of storage/disposal facility and, in particular, its potential radiological consequences for health of people and environment.

With an analysis, special attention is paid to assessment of various ways and mechanisms, which may lead to exposure of people during operation of facility and after its closure.

Assessment includes quantitative assessment of radiation consequences for the most adverse scenario of negative events during operation and after its closure, and assessment of impact in case of unintentional penetration after termination of control period.

Safety assessment includes the following stages:

– setting a goal of assessment, safety requirements and operational (functional) characteristics of storage/disposal facility;

– collecting information and description of storage/disposal facility including proper form of wastes, characteristics of site and engineering structures;

– determination of factors, events and processes, which may influence long-term safety of storage/disposal facility;

– development and testing conceptual and mathematic model of behavior of facility and its components;

– determination of initial events and description of scenarios of their developments;

– determination of ways of possible radionuclides migration from storage/disposal facility to environment;

– assessment of results of conceptual and mathematical modelling;

– estimation of assessment error;

– comparison of assessment results and specified design criteria;

– conclusions on feasibility of requirements established by effective regulatory documents concerning safe use of nuclear power, both in operation and after its closure, including risk assessment in terms of storage/disposal facility negative impact to health of critical group of population.

Results of safety assessment are submitted to nuclear power use authority as a report on safety analysis being a part of supporting documents to license request for construction of storage/disposal facility.

4. Confidence Building

Activity performed at the former Semipalatinsk Test Site caused radiophobia among population of Kazakhstan. That is not easy to regain the trust of people who suffered from nuclear weapon testing. For many years, people were unaware of the truth concerning consequences of testing carried out at STS and public opinion in Kazakhstan was affected by accidents that happened at Chernobyl NPP and Fukushima NPP.

Activity of every nuclear power enterprise and facility in the republic, as well as implementation of any new project related to radiation or nuclear technologies is, therefore treated by public as hazard in terms of environmental safety.

Thus, efforts aimed at reduction of radiophobia among population is one of high-priority missions in the Republic of Kazakhstan that means confidence-building to radiation and nuclear technologies. This is achieved by sharing information to the maximal extend concerning environmental safety of all nuclear power facilities, and state control in environmental protection maintained by Ministry of Energy of RK.

Promoting public awareness is a part of research program approved by Government of RK. Means for the effort are different – meetings with population, scientific conferences, workshops, round table discussions, tours to the sites of nuclear power enterprises, such as National Nuclear Center, Kazatomprom, etc.

Public hearing with participation of non-governmental organizations and public is an effective means. The hearings are held prior to implementation of any radiation or nuclear hazardous project, or after completion of the project activity. Public hearing is held both in big cities of the Republic and back country.

Considerable attention is paid to Mass Media. This provides television or radio broadcasting (news, analytical, interactive), information releases, speeches, reports with comments from representatives of governmental agencies and national companies. Leading specialists of national companies are also invited to give explanations if necessary.

Brochures and booklets are being published about peaceful use of atomic power, and results of latest radioecological researches at STS and adjacent areas.

Special attention is paid to training of journalists who are about to deal with the nuclear industry development issues. For the purpose, there are trainings for journalists in the Republic. In order to deliver reliable information and form unified information policy, government Central communication service organizes press conferences and briefings, where radioecology and nuclear power leading specialists give explanations.

There are materials published in special periodicals as “Human.Energy.Atom”, “Nuclear society of Kazakhstan”, etc. which are distributed among population free of charge. Creative products (printed, videography, photo report, collage) regarding nuclear power are being developed and promoted.

It is noted in application documents for NSRWSF construction (see p. エラー！参照元

が見つかりません。), that right established information support of the NSRWSF design and further remediation of separate STS areas allows first, to reduce radiophobia among population, caused by availability of open, uncontrolled areas of radionuclide contamination, second, improve reputation of state authority inside the country and reputation of the country at world stage. This in its turn will have good effect on investment attractiveness of the region. With design's safety assessment, attention is focused on confidence-building to evaluation methods and results, in particular: applicability of computer software (calculation codes) is based on comparative calculations and analysis of their sensitivity to changes in initial parameters, analytical methods and applied simulators; quality assurance programs shall be developed at all stages of lifecycle for consecutive implementation; independent expertise for safety assessment data can be conducted upon request of public or regulatory body.

MALAYSIA

MALAYSIA

-Part I. General Outline of LLW Repository-

1. General Policy

1.1. Radioactive waste management plan

Malaysia has recognized the need to construct a national low level repository to dispose radioactive waste generated from research institutions, medical and selected waste from the industries. The siting process to identify potential areas has begun in 2011, via a site screening campaign nationwide. In 2013, works on national repository project have slowed down, giving more focus on the Borehole Disposal Project for the disposal of Disused Sealed Radioactive Sources. This is consistent with the overall waste management plan where the repository is planned to be constructed in 2040. The repository is expected to have a service life of tens of years, which specific period is yet to be further defined. The timeline for the project is depicted in Figure 1.

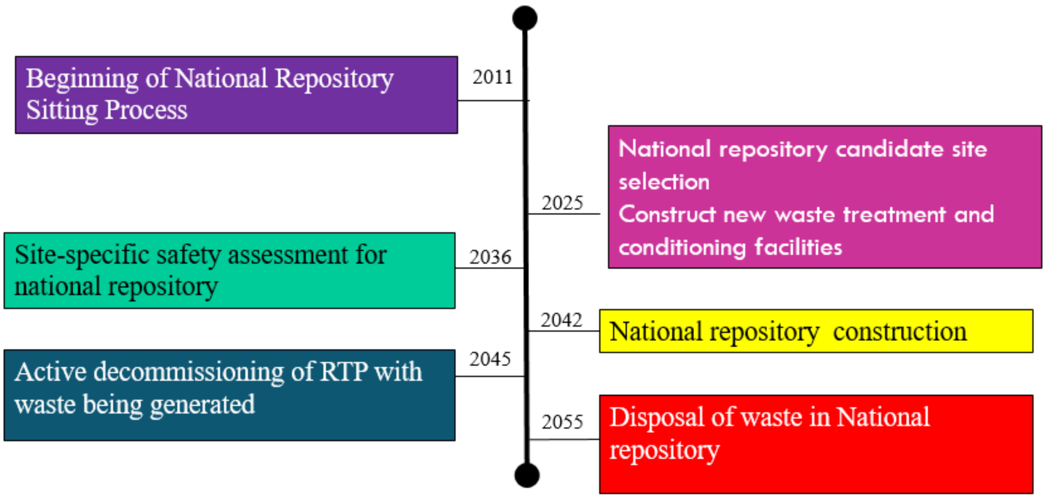


Figure 1: Overview of the Near Surface Repository project milestone

1.2. Legal Frame work : Act & Regulation

According to Act 304 on the disposal of radioactive waste;

"Any radioactive waste cannot be disposed of, accumulated or transported without prior authorization in writing and subject to such conditions imposed. The appropriate authority may direct the licensee or any person who is responsible for premises, nuclear installation, conveyance or site where any situation or condition endangering life, health, property or the environmental to adopt such measure as would eliminate or protect against such situation or condition. "

Current governing regulation with regards to radioactive waste management is bounded in the Atomic Energy Licensing (Radioactive Waste Management) 2011.

1.3. Safety Objective

The safety objective for this project is to site, design, construct, operate and close a Low Level Waste Repository so that protection after its closure is optimized. The overall safety objectives are to demonstrate that:

- The repository provides long-term isolation and containment for the low level waste;
- The pre-closure and post-closure safety criteria are met;
- The repository system is robust,
- The repository can be constructed, operated and closed safely; and
- The performance of the repository meeting all relevant standards for safety

1.4. Disposal Strategy

The repository is dedicated to dispose low level waste that meet the waste acceptance criteria, in a near surface facility. The exact depth of the facility will be determined via detail site characterization study of the site.

2. Principles and Safety Assessment

2.1. Fundamental safety principles

The ten safety principles established in the IAEA Fundamental Safety Principles are applied in all radioactive waste management activities including the disposal of radioactive waste. The repository is designed in a manner that it constitutes inherent parts of the safety strategy like the isolation, passive safety, containment, and robustness of the system, as explained in the subsequent sub-sections below.

2.2. Isolation of Radioactive Waste

Isolation of the waste away from human and the biosphere is provided by disposing of the waste at depths of greater than 30 m. The site to be selected will have low probability of intrusion and excavation since the site will be selected from an area that has no natural resources (oil, gas and minerals, precious stones).

2.3. Application of passive safety

Passive safety ensures that the long term performance of the repository system does not rely on the active measures in ensuring the protection to human and the environment. Passive safety is provided by engineered barrier and complemented by natural barrier of the host rock.

2.4. Containment, Robustness of the System, and Application of the Defence in Depth Principle

Containment, robustness and defence-in-depth would be provided by a combination of engineered and natural barriers to radionuclide release and migration, together with the appropriate management and administrative controls over operations. This combination of barriers provides multiple safety functions.

2.5. Management of Uncertainties

Uncertainties are inherent to the safety case development process. Technical uncertainties encountered during the course of this project will be resolved through experimental analysis, demonstration session and hands-on training. As for the post-closure safety assessment, three general different types of uncertainties are:

- Uncertainties in the future evolution of the system (scenario uncertainty). This is treated by performing assessments for various scenarios that account for alternative evolutions of the system.
- Model uncertainties including conceptual, mathematical, and computer model uncertainties. This can be managed by using established models and computer tools such as RESRAD, ECOLEGO, and AMBER.
- Data and parameter uncertainties will be minimized by performing sensitivity analyses for key parameters and performing studies with simplified models.

2.6. Application of Graded Approach

The IAEA recommends application of graded approach in the selection of disposal option hence the ability of a chosen disposal system to contain the waste and isolate it from humans and the accessible biosphere is commensurate with the hazard potential of the waste. According to para 3.24, Principle 5 – Optimization of Protection of the Fundamental Safety Principles (IAEA, 2006)

"3.24. The resources devoted to safety by the licensee, and the scope and stringency of regulations and their application, have to be commensurate with the magnitude of the radiation risks and their amenability to control."

The graded approach in this project takes rationale from the inventory aspects, safety, security, costs and economics, including development of technical capacity and competencies.

3. Safety Criteria (Dose limit/ Dose constraint for Occupational worker and Public)

From the radiological protection aspect, control of the exposure or the radiological impact is bound in the Atomic Energy Licensing (Basic Safety Radiation Protection) Regulation 2010, that specifies the public dose limit of 1 mSv/yr. This implies that the sum of dose to the public from all pathways from a reasonably foreseeable event and processes do not pose a radiological dose impact of more than 1 mSv/yr. To ensure the limit is conformed, the post-closure safety assessment applies the dose limit as one of the safety criteria. For radiation workers dealing with the packaging, transferring, emplacement, operation and closing of the future repository, the safety criterion is set to be 20 mSv/yr, as stipulated in the same regulation.

4. Operational System Preparation

4.1. Responsibility to Develop and Operate of Waste Repository

Malaysian Nuclear Agency, who is entrusted to run the National Radioactive Waste Management Centre, will be the lead agency to develop this facility. In addition to strengthening the technical capacity and capabilities required to perform the studies required for this project, potential collaboration with technical agencies such as Mineral and Geological Department, Remote Sensing Malaysia, and Universities are foreseen and expected to be carried out in stages according to the project progress. Construction will be carried out as per government's procurement process by open tender. The Radioactive Waste Management Centre is expected to operate the facility.

5. Site Selection

5.1. Site screening

A national area survey site screening was performed back in 2011. The report underwent two IAEA peer review missions, with recommendations to further improve the works and chart the way forward for the siting process.

5.2. Site selection Criteria

A suitable site for repository embodies long-term stability and attributes that will enable the wastes to be isolated so that there is no unacceptable risk to people or the environment either while it is operating or after the site has been closed. Criteria for site selection include natural physical characteristics as well as socioeconomic, ecological and land-use factors.

- The repository site should be built in area with less vegetation.
- The repository site should be constructed on clay-rich soils
- The repository site should be located on an area with low precipitation
- The repository site should be built on an area of low landslide potential as well as low density of lineament
- The repository site should be located on a terrain with a slope between 5 to 15 degrees to prevent erosion
- The repository site should be constructed on an area which less influence of groundwater in order to restrict the transport of radionuclides
- The repository site should be constructed on elevated area between 50 to 300 meters from mean sea level which considered as area free of flooding

5.3. Exclusion Criteria

- The repository site shall not be built on protected land area, which has economics and security values. The site, therefore, should not be built on gazette forested land, national parks, historical area, archaeological importance and surface water bodies.
- The repository site shall not be built on island due to public concern regarding the sea transport of waste might be expected.
- Site area is within 5km away from urban area.

6. Design, Construction and Operation of the LLW Repository

6.1. Estimated cost and Funding

The estimated costs and funding mechanism have not been deliberated so far. However, it is anticipated that the fund to develop and construct the repository facility will be borne by the Government of Malaysia.

6.2. Conceptual design

A conceptual design for a near surface repository was developed back in 2005 based on the collated data then. The proposed design is based on a concrete vault type as shown in Figure 2. The initial design concept comprises 4 vaults. Dimension of each vault is 12m x 5mx 4m, with estimated volume of 240 m^3. Each vault can cater up to 800 drums of 200 liter capacity. The near surface facility will also be equipped with building(s) for supporting activities such as security house, transit (interim) storage, administrative and services.

No review of the conceptual design is performed yet to date.

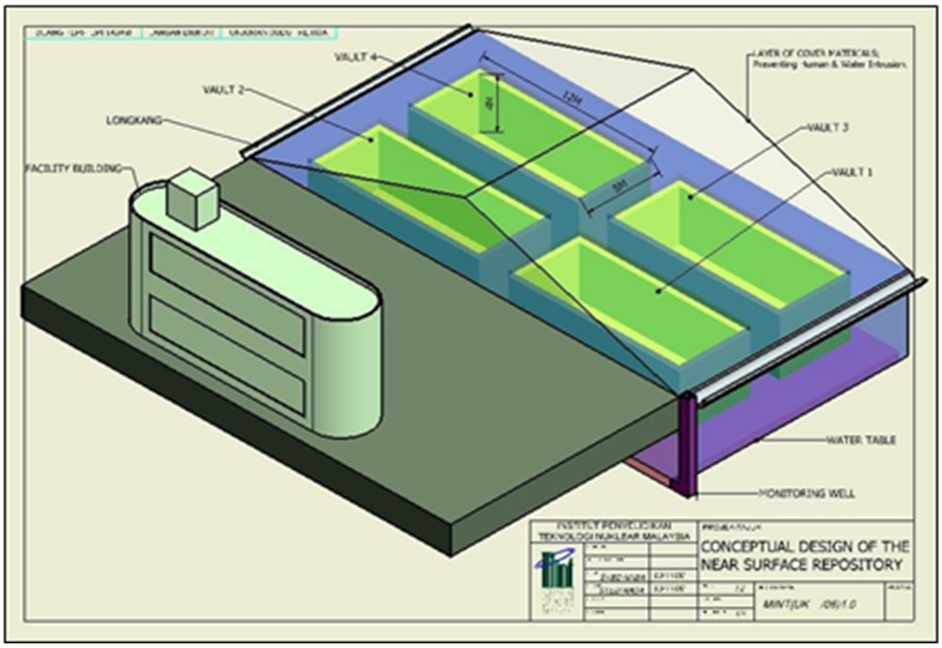


Figure 2 : Initial Conceptual Design of the Near Surface Repository

6.3. Basic engineering design

No engineering design is developed at this stage yet. However, it is believed that the project can benefit and emulate from one existing near surface repository in Malaysia built for the disposal of thorium waste and thorium contaminated waste. This repository was built for the Asian Rare Earth company and was fully constructed and operated by the GSM Consulting. This facility is now at the post-closure phase.

6.4. Inventory

The current projected waste inventory volume for disposal at the near surface repository is 2200m^3. Breakdown of this projection is depicted in Table 1.

Table 1: Breakdown of estimated waste inventory for disposal in repository

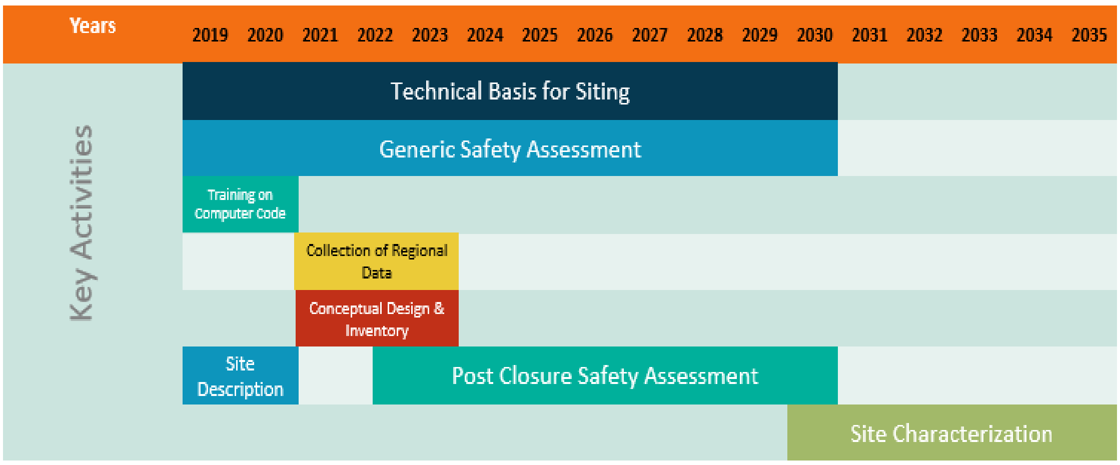
Type of Solid Waste	Example of waste stream	Projection of accumulated volume in 30 years
Operational Waste	Compacted waste Un-compacted waste	1250m^3
Spent Resin		4m^3
Contaminated items in the Interim Stor	Bulky metal items Structures HDPE Drums Pipes Heat Exchanger	80 m^3
Research sample	Sludge, tin slag	3m^3
Reactor Decommissioning	Internal core components Operational waste (Not included is concrete cement from biological shield)	40 m^3
Radioactive Sources	Pre-conditioned sources in cement DSRS Depleted Uranium	12 m^3
Solidified waste	Liquid and organic waste solidified in cement or absorbed in saw dust	140m^3
Thorium Plant Decommisioning	Structures Sludge and residue	250m^3

	Solidified liquid organic waste	
LLETP Decommissioning	Structures, Tanks and Equipment	300m^3
Decommissioning other laboratories in Nuclear Malaysia	Structures, Tanks and Equipment	52m^3
Existing waste from previous Decommissioning	Concrete and soil	40m^3
Total Volume		**2,171 m^3**

6.5. Project Implementation

A master plan for the near surface repository project is drawn up for year 2019 till 2030. The current emphasis is focusing on the siting and developing a generic safety assessment for the repository. It is planned than a candidate site will be determined by the end of 2030, hence detailed site characterization follows and expected to be carried out in year 2030-2035.

Figure 3: Master Plan for the Near Surface Repository for the period of 2019-2030



For year 2019-2021, training for new project team member is given an emphasis. Training will be provided mainly through the IAEA Technical Co-orperation Platform. The current running IAEA TC project is TC MAL 7006 for the duration of 2018-2020. New TC project will be applied in future for continuous assistance in the subject matter.

6.6. Quality assurance

Quality of a data will determine the quality of a safety assessment. As such, data management is crucial for the repository project, amplified by the fact that a repository development phase spans a long time frame of more than 10 years. This is to ensure that data particularly on siting data such as maps, reports, analytical reports, are preserved, retrievable and traceable. A training on data management is planned in Q1 2020 under the framework of IAEA TC project.

-Part II. Specific Site Safety Assessment of LLW Repository-

Referring to the Borehole Disposal Facility for disposal of Disused Sealed Radioactive Sources

1. General Considerations for Safety Assessment

The Malaysian Nuclear Agency is proposing to construct a Borehole Disposal Facility (BDF) for the disposal of disused sealed radioactive sources (DSRS) at its main complex located in Kajang, Selangor. The assessment context specifies the purpose of the assessment which is to evaluate the post-closure performance and safety of the BDF, and was written for technical audience of the regulatory body Atomic Energy Licensing Board (AELB), International Atomic Energy Agency (IAEA) and Nuclear Malaysia community.

- Purpose of safety assessment

  The main purpose of the assessment is to demonstrate the safety of the BDF as a safe disposal facility for DSRS with a sufficient level of confidence.
- Regulatory requirement (limit, risk)

  The end points of the assessment are the measure of impact reported as radiation dose. The radiation safety argument is based on a dose constraint (0.3 mSv/yr) or, if appropriate, a risk constraint (1 x 10-5 per year). Other safety indicator such as the concentration of radionuclides, fluxes and the time for which the maximum dose is attained are also presented to support the radiation dose argument.
- Time Frame of assessment

  In the assessment, 30 years was conservatively taken as the period of institutional control. No cut-off time was specified for the calculations in order to demonstrate that the time of peak calculated dose has occurred.

Description of the Repository System

BDF System	The BDF system consists of near field components (the BDF itself), geosphere components and the biosphere components. The disposal borehole is 260 mm in diameter and is drilled to a depth of 175.5 m. It comprises the following distinct zones: a) 115 m effective disposal zone; b) 60 m closure zone d) 0.5 m borehole plug
Waste Packages	A waste package consists of sources, a capsule, a containment barrier (cement) and a disposal container. Capsules and containers are made from stainless steel

	316L. There are allocations for 60 waste packages for disposal.

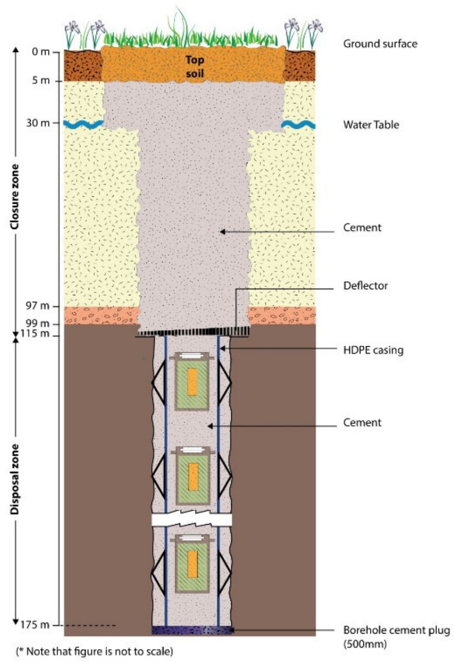


Fig 1. Schematic diagram of the near field components in the BDF

- Waste acceptance criteria

  DSRSs that is planned to be disposed are 15 species of radionuclides in Cat 3-5 conditioned into 60 capsules, total activity 1.18 TBq (30.19 Ci). Excluded are liquid waste, neutron source, plutonium and its isotopes, uranium, thorium, depleted uranium and larger size DSRS that doesn't fit in the capsule.

- Site

  The final site was chosen based on siting criteria, practicality and political considerations. Having the BDF constructed in Nuclear Malaysia, the facility will benefit from the current arrangements of the security, radiological monitoring and control system.

2. Guidelines for Safety Assessment

Detailed site characterization program was performed for the Borehole Project from 2013-2017. The program covers study of regional geology, regional lithology, topography, hydrology, hydrogeology, hydro-geochemistry, seismicity. Also evaluated are the slope stability analysis of the site.

- Base line data

  Meteorological data (rain, temperature etc), and Population and land use from the Municipality Development Plan. Data on climate change pattern extracted from the

Intergovernmental Panel on Climate Change (IPCC) report 2002.

- Detailed site specific parameters

Geosphere	The reference site for the borehole disposal facility is located in crystalline weathered rock area which is saturated with the water table at 27 m below the ground surface. It is underlain by metamorphic rocks of the Kenny Hill Formation which is made up of predominantly psammitic schist of sandstone origin and phyllite. There are minor joint sets trending in N-S and E-W directions. The rocks tend to break or split along the foliation/schistosity planes. Hydrogeological low yield of groundwater groundwater flow velocities ranging 2.23 to 4.34 x 10^{-4} m/s. Geochemistry Acidic (pH 4.55 to 5.08) Eh value (22.24 mV to 118.89mV) Sulphate, chloride and calcium concentrations are 3.40 mg/l, 7.91 mg/l, and 3.76 mg/l respectively
Geology setting	The reference site has undulating topography with the land above the BDF being 70 m above mean sea level. No natural resources No sources of geothermal heat or gas Seismically low probability
Biosphere	A river (Sungai Semenyih) 1300m from the site runs in the southwest direction. The Semenyih Water Treatment plant is located 5 km from the site. Estimated population around Nuclear Malaysia up to 6km radius is 95,110 people. Land use around 5km radius constitutes a mixture of mainly agricultural land, institutions and housing area.

- Scenario

Based on the considerations of the external factors and FEP (feature, event and process) analysis, the following scenarios were identified and justified for the system.

Design Scenario	The disposal system will evolve and the engineering barrier will fail eventually due to natural degradation. Radionuclides will be released and transported by groundwater along the groundwater flow direction and discharge into a river.
Alternative Scenario -Defect Scenario	Four Defect Scenario variants were identified. • D1: welding defect in one waste container • D2: welding defect in one waste capsule • D3: degradation time for cement and near field components is reduced by a factor of 10 compared to the reference criteria • D4: welding defect in one waste package (capsule +container)
Alternative Scenario -Well Scenario	The groundwater is assumed to be abstracted from the geosphere via an abstraction borehole that is drilled 100m at the start of the post-institutional control period.

- Formulation and Implementation of models

The calculation was performed using **AMBER 6.0.** Input data consists of collection of site-specific data from site characterization and laboratory analysis, published Malaysian data and generic data generated from a range of sources.

Example of a representative scenario:

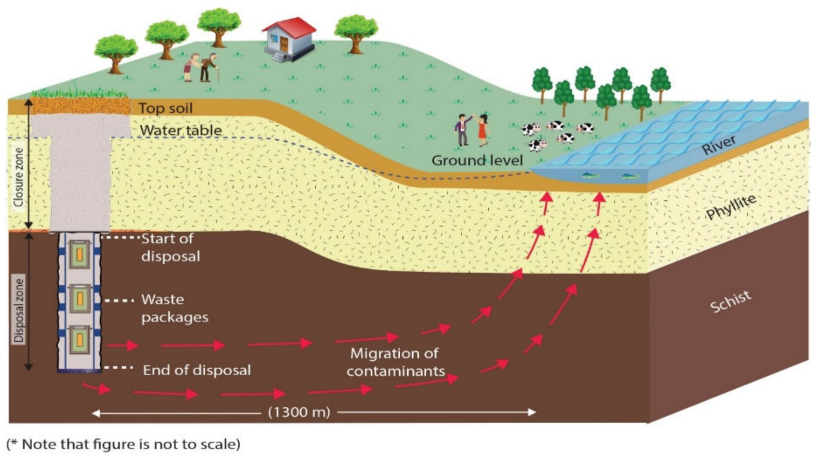


Fig.2: Design Scenario - Liquid Release in Saturated Zone with River as the Geosphere-Biosphere Interface

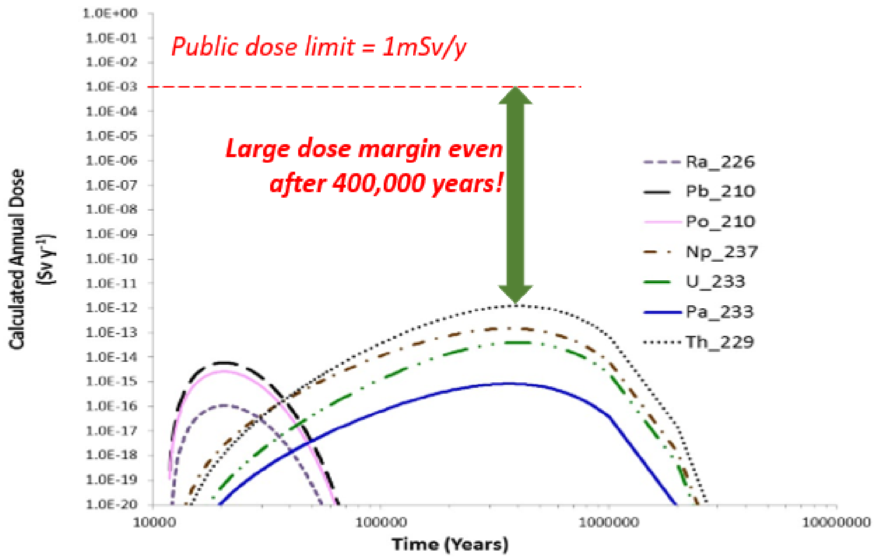


Fig.3: Calculated Annual Dose for the Design Scenario

3. Confidence Building

- Management of uncertainties (Scenario, input data and model)

  The uncertainties recognized have been bounded by the calculations carried in the assessment. Uncertainties in the post-closure safety assessment arise from three sources namely:

  a. Uncertainty in the evolution of the disposal system and the changes of human behaviour over the timescales of interest (scenario uncertainty)
  b. Uncertainty in the conceptual, mathematical and computer models used to simulate the behaviour and evolution of the disposal system (model uncertainty)
  c. Uncertainty in the data and parameters used as inputs in the modelling (parameter uncertainty)

- Peer Reviews

  1x Expert Mission on Site Characterization and Design of the BDF
  1x Expert Mission on the Post-Closure Safety Assessment
  3x IAEA Peer review sessions on the Safety Case Report

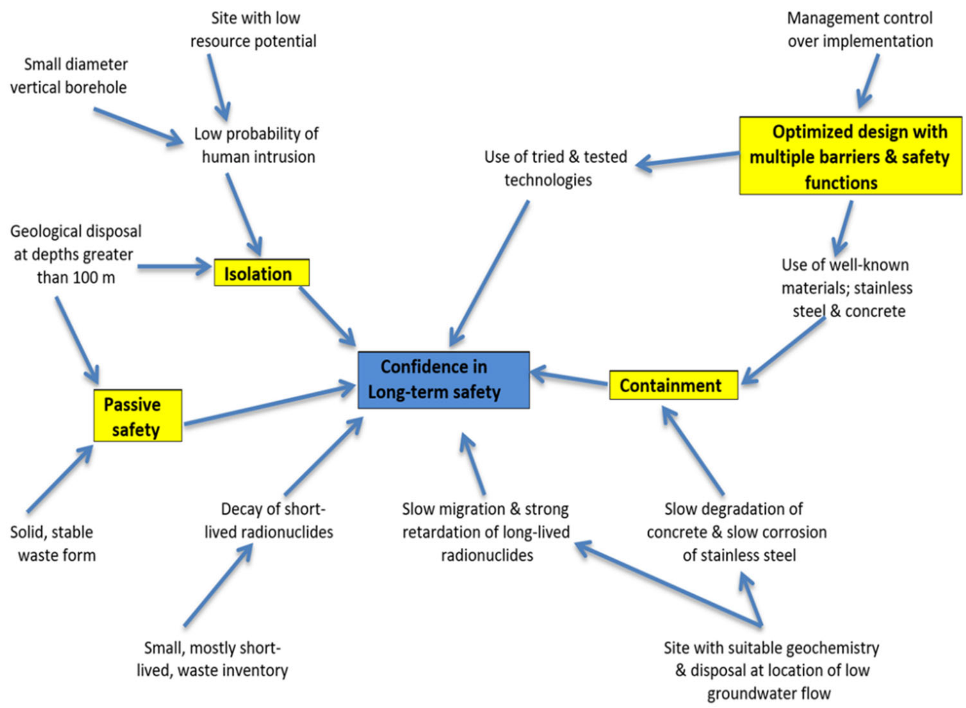


Fig 4. Factors towards ensuring safety of the people and environment, now and for future generation

MONGOLIA

MONGOLIA

-Part I. General Outline of LLW Repository-

1. General

Mongolia is a land-locked country in the Central Asia with large area of approximately 1.5 million square kilometers territory and a population of 3.23 million people. Mongolia is developing country without nuclear power. Economic development in Mongolia has been limited by the harsh climate, scattered population and sizeable expanses of unproductive land. The infrastructure is not well developed, vehicular transport is slow. But our country is rich in mineral resources. The uranium industry in Mongolia was very important in the economy. Nuclear power plants currently cost more to build than power plants using coal or gas. Mongolia is a non-nuclear country, since there are no nuclear power plants and research reactors.

2. Present achievements

The hierarchy of Mongolia's regulatory authorities for nuclear and radiation safety within the overall administrative framework is shown in Figure 1. The administrative framework has been subject to various changes and reorganisations over the past few years.

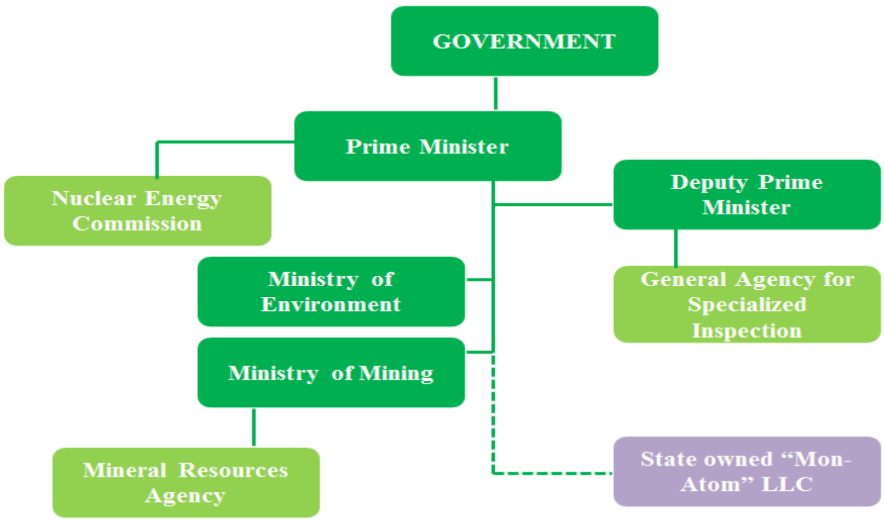


Figure 1: Hierarchy of Mongolia's regulatory authorities for nuclear and radiation safety

On 2 March 2015, the Government of Mongolia accepted a resolution on establishing the Nuclear Energy Commission (NEC). NEC is responsible for developing and implementing the national policy on the exploitation of radioactive minerals and use of nuclear energy, the

1responsible for coordination activities to ensure nuclear safety and radiation protection, for developing and adopting safety and security regulations, and for licensing of nuclear facilities.

The activities of the Nuclear and Radiation Regulatory Authority (NRRA) of the General Agency For Specialised Inspection (GASI) and the Nuclear and Radiation Inspection Division of the Metropolitan Inspection Agency are largely focused on the control of: the uses of radiation sources in industry, medicine and research centres, installation of portal monitors to combat illicit trafficking of nuclear and radioactive materials, the exploitation, processing, import, export and transport of radioactive minerals.

The split of responsibilities of the former NEA to NEC and other organisations is shown in Figure 2.

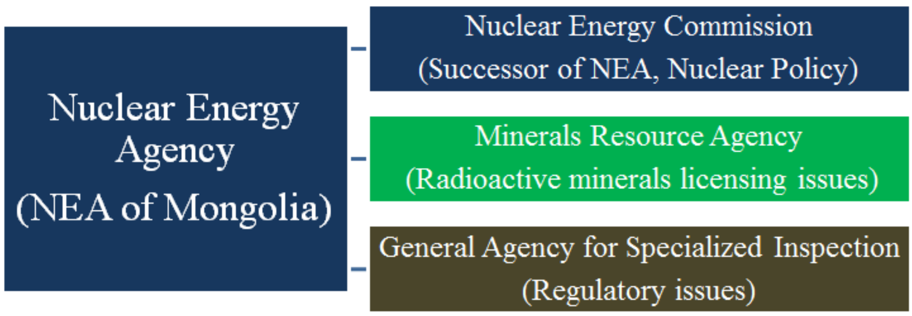


Figure 2: Split of responsibilities of NEA's successor organisations (since 2015) in the field of radioactive minerals (may also become relevant for extraction of NORM minerals)

3. Nuclear Energy Commission

The Amendment of the Nuclear Energy Law issued on February 13 of 2015, and The Nuclear Energy Commission is responsible for the coordination of peaceful uses of radioactive minerals and nuclear energy, research and development of nuclear technology and nuclear and radiation safety. Chairman of the Nuclear Energy Commission of Mongolia is The Prime Minister of Mongolia. Members of The Commission, that provide nuclear technology matters, technology transfer, and relevant issues; which have to be discussed in higher grade, are state secretaries of Ministry's and Seniors from governmental bodies and separated with each other. The structure of the NEC is shown in

Figure 4.

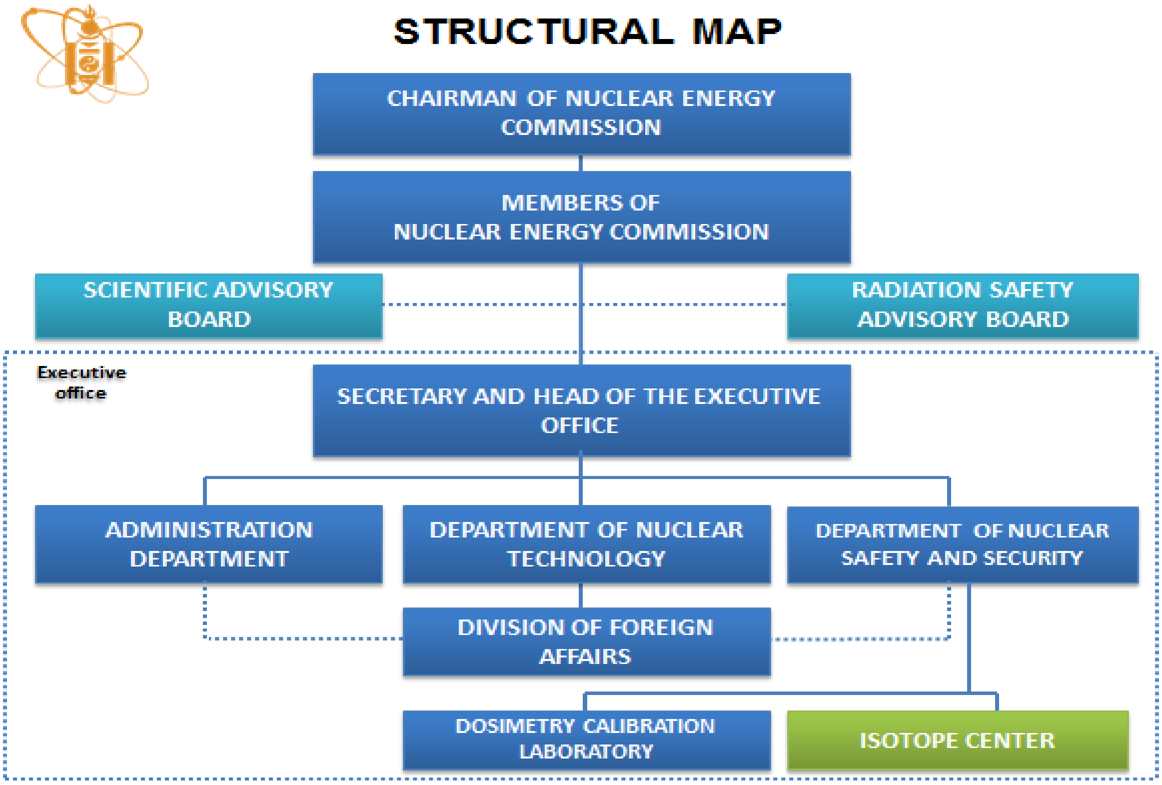


Figure 4. Structure of the Nuclear Energy Commission

4. Framework

4.1. State policy and Nuclear Energy Law

- National Security Concept of Mongolia,
- Mongolia's Sustainable Development Cencepts-2030
- Law on Nuclear Weapon Free status,
- State Policy on the Exploitation of Radioactive Minerals and Peaceful Uses of Nuclear Energy,
- Nuclear Energy Law of Mongolia, /2009/
- Program for Implementation of the State Policy,
- Government's Action Plan for 2016-2020

4.2. New approved regulation, 2015-2018, based on IAEA safety standard, guidence and etc,.

- Radiation Safety Standard,
- Basic radiation protection and safety standard,
- Security of Radiation Sources,
- Radioactive Waste Management from Mining and Milling of ore,
- Radiation Safety Procedures for Uranium Exploration,
- Rule for Radiation Control Unit within the Radiation User Organizations,

- Safety regulation on Portable Nuclear gauge,
- Safety regulation on Fixed Nuclear gauge,
- Safety regulation on Safe use of Sealed Radioactive Source in Borehole Logging,
- Safety regulation on Radioactive Mineral's Milling and Mining
- Safety regulation on Transport Regulation for Radioactive Sources.

5. Radioactive waste management facility

The Isotope Center which is Radioactive waste management facility of Nuclear Energy Commission is responsible for the safe storage of radiation sources and radioactive wastes and safe transport of radioactive materials in Mongolia. Isotope center is an object of the state protection by Governmental Resolution **No 135** dated 26 May 2004. According to Governmental Resolution **No 135** (Internal troops operational regulation) and **organizational procedure** for controlling the transport and people at the state essential properties Internal troops of National police agency provides and implements safe and security activities of Isotope center. Functions and activities of Isotope Centre on radiation safety have been described in the **Law on Nuclear Energy** following:

- To take the appropriate steps to ensure that radiation protection, physical protection and technical support of the radioactive waste management facility,
- To store, process and dispose nuclear materials, disused radioactive sources and radioactive wastes,
- To organize safe and secure storage, processing, disposal of radioactive waste, nuclear waste and radioactive wastes from mining and milling of ores,
- To maintain nuclear and radioactive waste management,
- To prepare relevant procedure, regulation, standard and to ensure their implementation.

The Law on Nuclear Energy, Article 11.3. "The state administrative authority shall have a special facility of national level to centrally store, transport and dispose of nuclear material, nuclear waste and non-exploitable radioactive waste. This facility shall be the state restricted object.

The Isotope Centre has a long term waste storage facility which providing radiation protection technical service in Mongolia. Orphan or abandoned radiation sources should be secured and stored at Isotope center without any charge and also functions and activities on radiation safety have been described in the Law of Mongolia on Nuclear Energy, 2015.

NEC and DOE Joint Program to Strengthen Physical Protection of the Isotope Center since 2009, security of the Isotop center good cooperation with:

ISOTOPE CENTER NEC

INTERNAL TROOPS

POLICE

CIA

NATIONAL EMERGENCY MANAGEMENT AGENCY

THE PHILIPPINES

THE PHILIPPINES

-Part I. General Outline of LLW Repository-

1. General Policy

The general policy for control of toxic and hazardous wastes is governed by the Republic Act 6969 entitled “Toxic Substances and Hazardous and Nuclear Wastes Control Act of 1990”. However, it is limited in scope and only includes the prohibition of entry, even in transit, of hazardous and nuclear wastes. On the other hand, the general policy for regulating peaceful uses of nuclear technology is governed by Republic Act 2067 and the Executive Order 128. The current scope of these policies relevant to radioactive waste and spent fuel management are however limited. The policies are being updated under the proposed bills: “Hazardous and Radioactive Wastes Management Act” and the “An Act Providing for a Comprehensive Nuclear Regulatory Framework”.

2. Principles and Safety Assessment

The principles of safety assessment adopted are according to the following: a) IAEA General Safety Requirements (GSR) Part 3 – Radiation Protection and safety of Radiation Sources: Int'l. Basic Safety Standards General and the PNRI Code of PNRI Regulations Part 3: "Standards for Radiation Protection and Safety of Radiation Sources" and the b) Principles of safety assessment for borehole disposal according to the IAEA TecDoc No. 1824 “Generic Post-closure Safety Assessment for Disposal of Disused Sealed Radioactive Sources in Narrow Diameter Boreholes.

3. Regulatory and Operational System Preparation

The Philippine Nuclear Research Institute (PNRI) – Nuclear Regulatory Division performs the regulatory functions in licensing and regulating the possession and use of nuclear and radioactive materials and facilities in support of international commitments on radiation protection, nuclear safety, safeguards and security. There are five Sections that comprise the Division: Regulations and Standards Development Section; Licensing Review and Evaluation Section; Inspection and Enforcement Section; Nuclear Safeguards and Security Section; and Radiological Impact Assessment Section.

Regulations relevant to RWM have been developed through the Code of PNRI Regulations (CPR) among of which are: a) CPR Part 3: Standards for Protection Against Radiation, b) CPR Part 4: Regulations for the Safe Transport of Radioactive Materials in the Philippines, c) CPR Part 23: Licensing Requirements for Land Disposal of Radioactive Waste.

While there is an existing waste acceptance criteria (WAC) for the processing of wastes (pre-treatment, treatment and conditioning) established by the operator of the Radioactive Waste Management Facility and approved by the regulatory body, there has not yet WAC for interim storage and for disposal. Naturally occurring radioactive materials are not considered radioactive waste since it has not yet been regulated.

The country has no nuclear weapons and operating NPP and RR, thus most of the wastes are from industrial and medical uses. The facility currently manages Category 1-5 disused sealed sources (DSRS), solid wastes, and liquid wastes. There are no spent fuel but there are in storage about 130 TRIGA Fuel Elements for research reactor.

4. Site Selection

The Philippine Nuclear Research Institute (PNRI) and its collaborators have been investigating a proposed site as the final solution for the disposal of low-to-intermediate (LILW) level radioactive waste and disused radioactive sources and waste arisings generated by hospitals, industries, and research institutions including the PNRI nuclear facilities.

The strategy adopted was to co-locate 2 disposal facilities that will address the types of radioactive waste generated from the use of radioactive materials taking advantage of the benefits provided by shared infrastructure and R&D work. This strategy is expected to compensate for the small volumes of waste generated in the Philippines as compared to countries with big nuclear energy programs. A potential site was selection and for which various site characterization studies were conducted.

It was concluded that the site can be developed as a near-surface disposal facility in the geotechnical and geologic standpoint even though the initial hydrogeological findings reveals that the site is underlain by highly fractured “andesitic volcaniclastics” mantled by residual clayey with slight to moderate permeability, and groundwater in the area is relatively dilute and acidic due to the formation of sulfuric acid by the oxidation of the pyrite in the andesite.

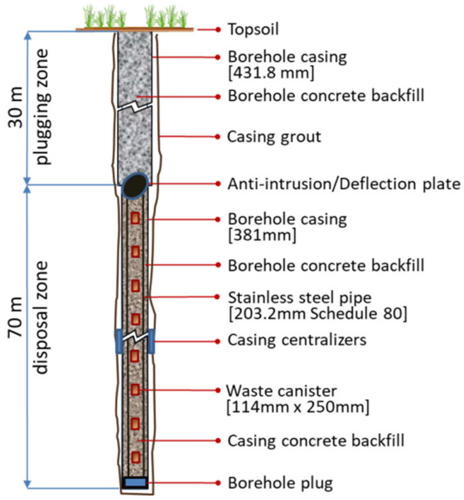
5. Design and Construction of Disposal Facilities

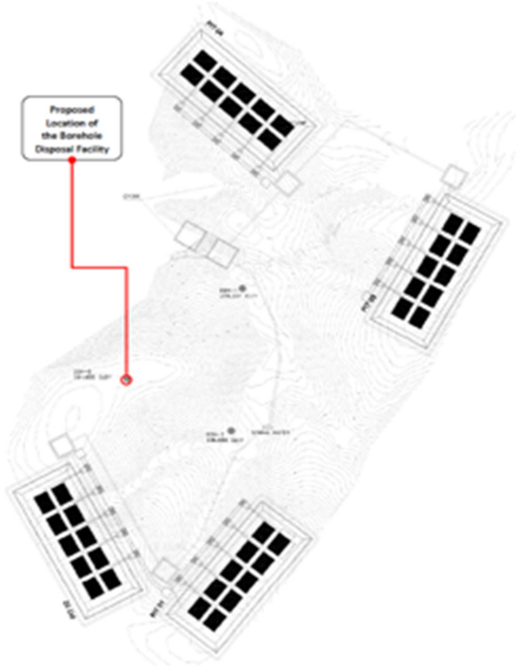
The concept design of the LILW disposal facility has the following design features and characteristics that is intended to manage both short and long-lived radionuclides:

Design characteristics

- o Near-surface disposal facility
  - To accommodate 50 m^3 of conditioned waste
  - To host 4 disposal pits
  - Roofs are self supporting with enough reinforcement
  - Roof designed to avoid bath-tubbing

- Borehole Disposal Facility
    - Co-located with near surface disposal facility
    - 100-meters deep, 70 meters – disposal zone, 30 meters – plugging zone, diameter = 381-mm
    - Capacity : 57 canisters





Co-disposal concept in the proposed site

As a way forward, further site characterization including a more detailed topographic map, soil erosion study, further iteration of performance and safety assessment studies, drafting of a safety case report, and public acceptance campaign are among the activities that the PNRI technical team are planning to do in the future.

There is currently no policy decision regarding the actual construction of the proposed facility.

-Part II. Specific Site Safety Assessment of LLW Repository-

1. General Considerations for Safety Assessment

The general considerations for the safety assessment are:

a) To demonstrate compliance with the Code of PNRI Regulations particularly Part 3: Standards for Protection Against Radiation, CPR Part 23: Licensing Requirements for Land Disposal of Radioactive Waste and other relevant regulations and

b) To Justify that the design features of the RWMF (physical and procedural) can be operated safely and effectively

2. Specific LLW Repository site (planning etc.)

- Predisposal:

The PNRI – Nuclear Services Division through the Radiation Protection Services Section operates the national predisposal radioactive waste management facility (RWMF) for the management and interim storage of radioactive wastes. The RWMF consists of three Trenches where sources are stored, conditioning areas, compactor, chemical precipitation, decay storage rooms among others.

The country has no operating NPP and RR, thus most of the wastes are from industrial and medical uses. The facility currently manages Category 1-5 disused sealed sources (DSRS), solid wastes, and liquid wastes. There are no spent fuel but there are in storage about 130 TRIGA Fuel Elements for research reactor. In terms of costs, the waste generator bears all decommissioning and waste management costs.

The current strategies for the pre-disposal of wastes are the following:

- DSRS - return to supplier, transfer to the RWMF or store in a licensed facility for decay. For wastes processed at the RWMF, DSRS are dismantled, retrieved and encapsulated in stainless steel capsules
- Solid wastes are compacted and cemented in 200L drums
- Liquid wastes - liquid aqueous wastes are incorporated in cement mixture in 200L drums. the management strategy for organic liquid wastes has not been identified
- Current Waste inventory: Solid – 52m^3 1.6e^{9}Bq; Liquid (Aqeous) – 1.6m^{3}3e^{10}Bq, Liquid (Organic), DSRS – 2421 units 3.4e^{14} Bq

- Disposal:

After the potential site for a permanent repository was selected using the IAEA site selection criteria, site characterization studies were performed at the site to determine the geologic, hydrogeologic, and hydrologic properties, to establish and recommend monitoring networks for atmospheric meteorological, hydrogeological, flora and fauna observations to establish baseline environmental conditions, and other geotechnical and geophysical data that may be obtained from the study.

Performance assessment based on the conceptual model was performed using various modelling softwares, namely Hydrus-1D for simulating the analysis of water and solute transport, GMS Modflow for the groundwater modelling and AMBER for the biosphere, and other supporting tools.

A 2-D electrical resistivity survey was also commissioned to detect geological structures and lithological profiles for the presence of faults and fractures from the resulting profiles for proper location and design of proposed disposal facility.

Although the initial results show that the site has the potential to be suitable location, A more expensive engineering intervention and mitigating measures are necessary which may include appropriate engineered ground treatment (grouting), provision for surface drainage and treatment to ensure non-contamination of surrounding downstream surface water, slope stabilization measures involving extensive earthworks.

Public consultation was conducted with local decision makers, but it needs to be updated and a full stakeholders study need to be conducted

3. Guidelines for Safety Assessment

- Predisposal: Included in the current safety program. Includes identification of hazards, calculation of doses, operating limits and conditions, etc. full safety case to be developed once suitable training to the staff have been conducted.
- Disposal: Drafted 1st Iteration Safety case developed and includes scenario analysis, among others

4. Confidence Building

- Verification of models will be performed after the safety case is completed

THAILAND

THAILAND

-Part I. General Outline of LLW Repository-

1. General Policy

0 Radioactive waste and spent nuclear fuel in Thailand will be safely managed to protect human health and environment now and in the future in a sustainable and cost-effective manner.

0 The current and future financial responsibility for the management of radioactive waste will be borne by the generator of the radioactive waste.

0 The Government will ensure that funding set aside for this purpose will be preserved for the time when it is needed.

0 All radioactive waste management activities will be conducted in an open and transparent manner and the relevant parties will make information on the safety of radioactive waste management activities available to members of the public.

0 Decisions regarding radioactive waste management will take into account the interests and concerns of all interested and affected people.

0 Thailand will commit to the international safety standards on radioactive waste and SNF management in order to achieve and demonstrate a high level of safety.

0 The license holders, who generate, process, or possess radioactive waste, will be responsible for the safe management of radioactive waste, until the waste is accepted by the waste management organization (TINT).

0 The radioactive waste will be transferred to TINT within a timeframe specified in a license

0 The waste management organization (TINT) will be responsible for the safe management of radioactive waste, including sealed radioactive sources that are not usable or intended for further use.

0 Radioactive sources for which owners cannot be identified (often referred to as "*orphan sources*") will be recovered by OAP and managed by TINT.

0 Ultimately, all the radioactive waste in Thailand that cannot be recycled, discharged or cleared from regulatory control will be disposed of in a licensed radioactive waste disposal facility.

- In a defined time scale, the Government of Thailand will investigate options for a radioactive waste disposal facility and assign the responsibility of managing such facility to one of the government agencies.

2. Principles and Safety Assessment

- Safety assessment is a procedure for evaluating the performance of a disposal system and, as a major objective, its potential radiological impact on human health and the environment.
- The safety assessment of near surface repositories should involve consideration of the impacts both during operation and in the post-closure phase.
- Potential radiological impacts following closure of the repository may arise from gradual processes, such as degradation of barriers, and from discrete events that may affect the isolation of the waste.
- The potential for inadvertent human intrusion can be assumed to be negligible while active institutional controls are considered fully effective, but may increase afterwards.
- The technical acceptability of a repository will greatly depend on the waste inventory, the engineered features of the repository and the suitability of the site.

3. Regulatory and Operational System Preparation

- Nuclear Energy for Peace Act 2559 (2016) and Related regulations on Licensing of Disposal of Radioactive Waste (Being drafted).
- Other safety requirements from the Thai Regulatory Body (Being drafted).
- Waste acceptance requirements
- The operator will use the national inventory to establish the waste acceptance criteria and design of the facility**.**

4. Site Selection

4.1. Characteristics of acceptable site

4.1.1. Geological characteristics (seismic, fault activity and erosion, hydrogeology)

Study on Active Fault Zones in Thailand [1]

Recently Department of Mineral Resources put an enormous effort to produce the active fault map of Thailand (Fig. 1) with the co-operative research studies of Chulalongkorn University (Thailand) and Akita University (Japan).

- Detailed geodetic survey has been performed in detail to locate the appropriate site for exploratory trenching.

- Detailed stratigraphic logging has been done prior to sampling for Quaternary dating have been made.

- Based upon these consecutive sequences of work, we can delineate the Fault Zone (FZ), which is herein defined as linear or elongate zone of seismicity commonly classified by neotectonic movement and coincident with major tectonic structures. As displayed in Fig. 1.

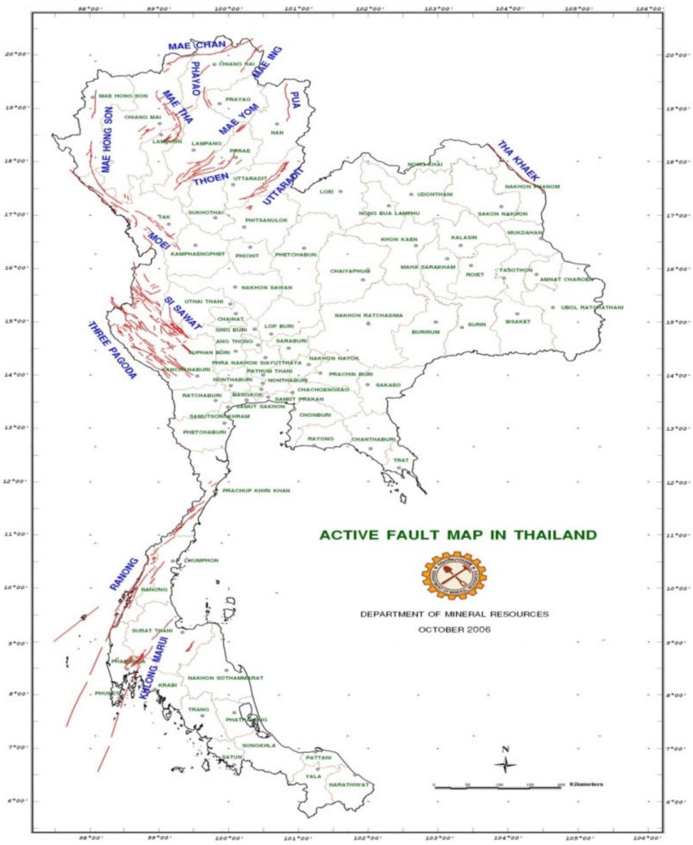


Fig.1 The active fault map of Thailand

Thailand consists of 15 Active Fault Zones

- Researchers are now focusing their work on active faults in southern Thailand following the recent minor earthquake in Phuket, which is not strong enough to cause the island to sink as rumored in some quarters.

- Experts said that the Mae Chan fault - a major fault in the northern province of Chiang Rai that is now building up stress - is no longer the only geological feature of interest in the country.

- Down south, the coastal Ranong fault is capable of triggering an earthquake of magnitude 5 to 6, although so far it has only caused small undersea tremors that did not have enough power to create a tsunami.

The Ranong fault is thus an area of concern as it continues to build up Geological evidence indicates that faults in southern Thailand like the Ranong and Khlong Malui faults have previously caused land earthquakes of magnitude 6-7 roughly 2,000 years ago.

Another major quake at these faults may happen at any time and is an impossible event to predict."

Study on Earthquakes in Thailand [2]

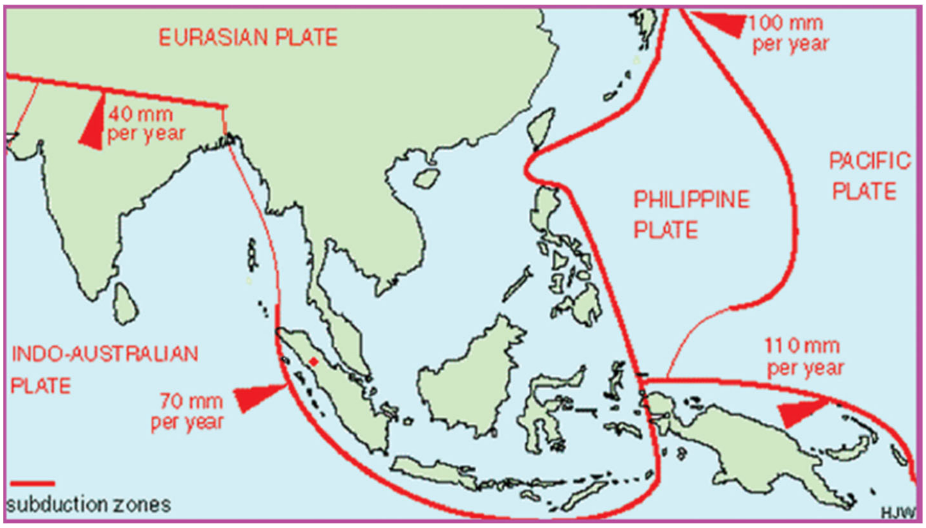


Fig 2. The Indo-Australian plate is colliding into the Eurasian plate at a speed of 70 millimeters per year

Thailand sits on the Eurasian tectonic plate, which is flanked by the Indo-Australian and Pacific plates. While the country is located in a region that is relatively safe from earthquakes, but historical records show that the area has previously been affected by a number of tremors.

- Thailand has a number of active faults with the potential to trigger tremors, many of which are concentrated in the northern and western regions.
- These faults do not have the capability to cause strong quakes like those in the Ring of Fire or in areas directly on top of tectonic plate boundaries.
- Over the past 40 years, Thailand has experienced mid-sized earthquakes (magnitudes 5.0-5.9) 8 times or once every 5 years.
- 5 of these tremors struck in the north, while the other 3 were centered in the west.

- Virtually all earthquakes recorded in Thailand are under magnitude 6.0, although significant seismic activity in far-away locations like Indonesia or Myanmar can be felt in areas with soft soil like Bangkok.

4.1.1. Geological characteristics(seismic)

Which areas in Thailand are prone to earthquakes? [2]

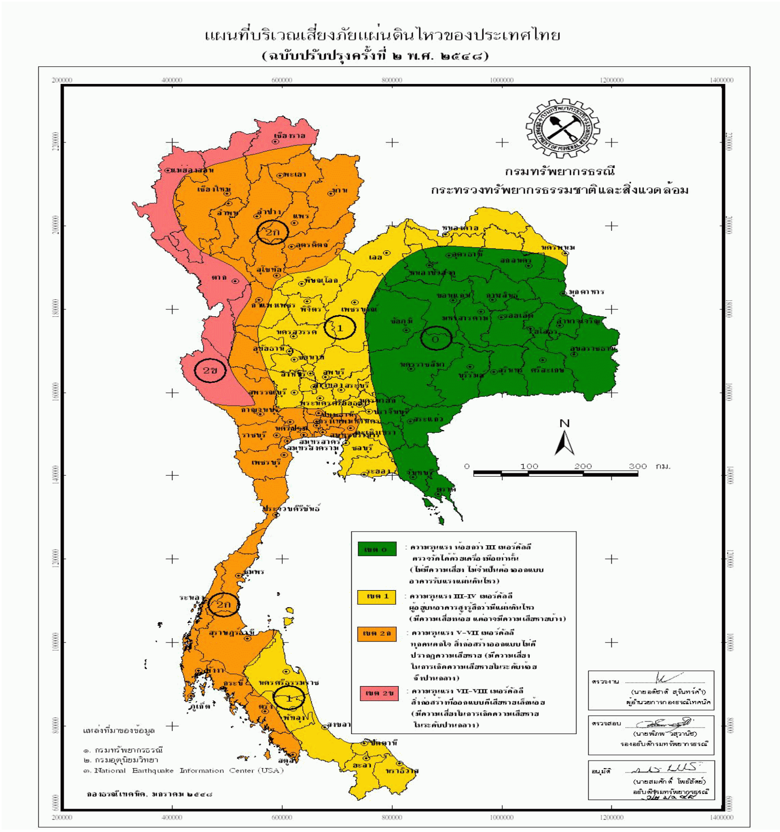


Fig 3. The following parts of Thailand have higher risks of experiencing tremors

The following parts of Thailand have higher risks of experiencing tremors:

1. Areas that may be affected by earthquakes: Krabi, Chumphon, Phang Nga, Phuket, Ranong, Songkhla and Surat Thani.

2. Areas with soft soil, which may be affected by distant earthquakes:Bangkok, Nonthaburi, Pathum Thani, Samut Prakan and Samut Sakhon.

3. Areas close to faults that may be affected by earthquakes: Kanchanaburi, Chiang Rai, Chiang Mai, Tak, Nan, Phayao, Phrae, Lampang, Lamphun and Mae Hong Son

4.1.2. Climatic conditions (rainfall, extreme events)

Rainfall Map in Thailand [3]

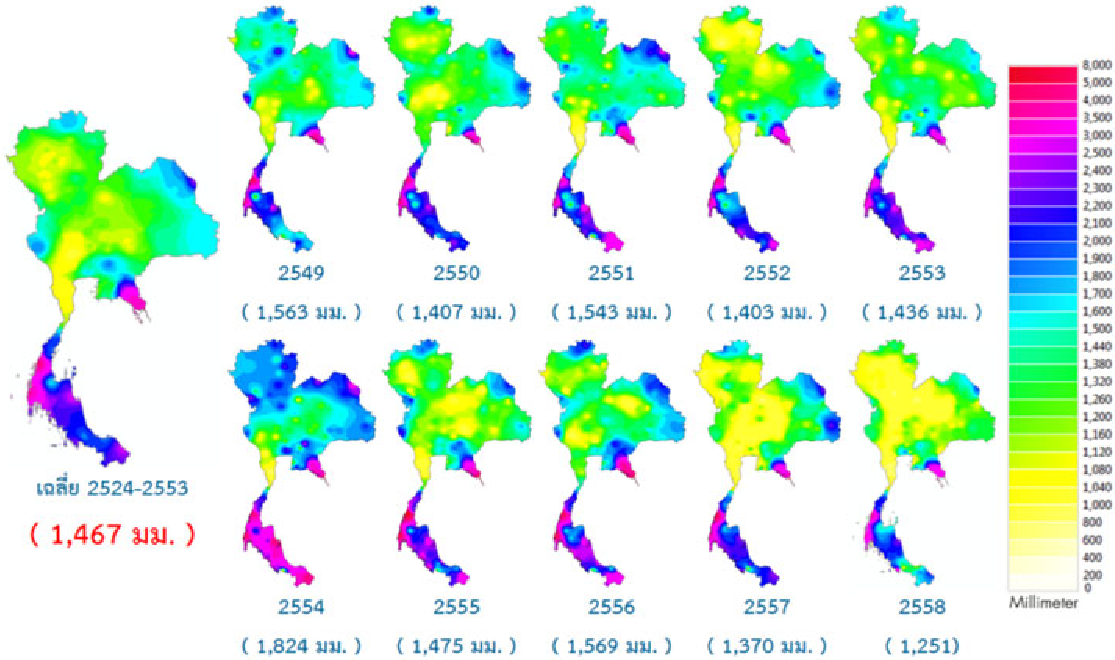


Fig 4. Rainfall Map in Thailand

Rainfall Upper Thailand usually experiences dry weather in winter because of the northeast monsoon which is a main factor that controls the climate of this region. Later period, summer, is characterized by gradually increasing rainfall with thunderstorms. The onset of the southwest monsoon leads to intensive rainfall from mid-May until early October. Rainfall peak is in August or September which some areas are probably flooded. However, dry spells are commonly occur for 1 to 2 weeks or more during June to early July due to the northward movement of the ITCZ to southern China.

Rainy season in the Southern Part is different from upper Thailand. Abundant rain occurs during both the southwest and northeast monsoon periods. During the southwest monsoon the Southern Thailand West Coast receives much rainfall and reaches its peak in September. On the contrary, much rainfall in the Southern Thailand East Coast which its peak is in November remains until January of the following year which is the beginning of the northeast monsoon. According to a general annual rainfall pattern, most areas of the country receive 1,200 - 1,600 mm a year. Some areas on the windward side, particularly Trat province in the Eastern Part and Ranong province in the Southern Thailand West Coast have more than 4,500 mm a year. Annual rainfall less than 1,200 mm occurs in the leeward side areas which are clearly seen in the central valleys and the uppermost portion of the Southern Part.

4.1.3. Physical site characteristics (flooding, draining, land gradients)

Floods in Thailand Are Regular Natural Disasters [4]

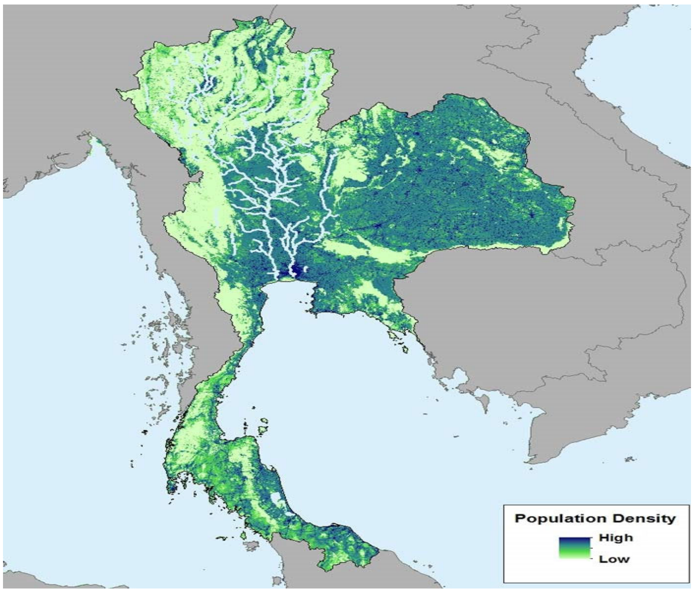


Fig .5 Floods in Thailand Are Regular Natural Disasters

Population density of Thailand with major rivers. (Source: AIR)

Twelve of Thailand's 14 southern provinces recently experienced major flooding resulting from several days of heavy precipitation from an active northeast monsoon that began covering the region and the Gulf of Thailand.

Severe flooding also impacted central Thailand and areas of the Malay Peninsula and northern Indonesia about October and early November.

Landslides in Thailand [5]

Fig.6 Landslides in Thailand

- The landslide hazard is one of the major natural disasters in Thailand that has caused tremendous loss of lives and properties.
- Public awareness was significantly arisen when the severe flooding and landslide occurred in Kathun district, Nakhon Sithammarat Province, southern Thailand in 1988 where theworst hit was approximately 230 casualties in Ban Kathun Nua.
- Subsequent devastated landslides occurred in Ban Nam Kor and Ban Nam Chun areas in Petchabun Province.
- In Year 2006, there have been two major landslide events in Uttaradit and in Nan Provinces, northern Thailand in May and August respectively.
- A nationwide landslide hazard study and mapping project has been studied to determine landslide potential and affected areas, mitigation plan all over the country.

A large landslide in Thailand [6]

Over the last few days torrential rainfall has affected parts of Thailand, causing very substantial levels of damage. The NASA TRMM satellite has captured some good data on the location and extent of this rainfall event.

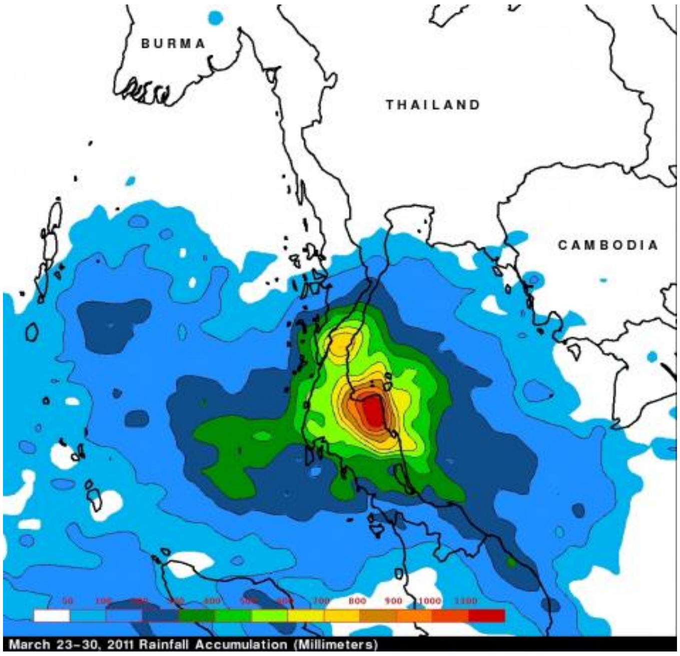


Fig.7 A large landslide in Thailand

- Landslides appear to have been triggered quite extensively.
- The largest seems to have occurred at Ban Ton Harn in Khao Phanom district of Krabi province, where a large and highly energetic debris flow has destroyed the village.
- The final toll from the landslide is a little unclear, with estimates varying substantially, but five people have been confirmed as having been killed.

Fig.8 landslide in Thailand

The size of the boulders here is clearly notable; given that the village was directly struck by the event, the death toll seems surprisingly low. A more detailed description of losses across Thailand from this heavy rainfall event is provided in this article, which indicates that more than 800,000 people have been affected, and 13 killed.

4.2. Social characteristics (prospects of future growth / use,)

Thailand Population Growth [7]

Until very recently, the population numbers were growing at a far greater rate, but it's claimed that the government-funded family planning program has raised awareness and led to a dramatic fall in birth figures. In 1960, the population growth was at its height with figures of around 3.1% but this has fallen to around 0.34% today.

- As countries become more developed, it's natural to see a decline in fertility rates and an increase in its aging population over time. Thailand has gone through this transition faster than most countries, with the average number of children born to the typical woman dropping from 6 to 2 in less than twenty years between 1970 and 1990.

- Fertility rates in Thailand are now 30% below replacement level, although this doesn't mean that Thailand isn't growing. Something known as population momentum, which results from a fairly high concentration of people of childbearing age, should result in slow natural increases for the next decade.

- Thailand is currently facing two population problems: a quickly aging population and urbanization. Urbanization is mostly concentrated around Bangkok and its surrounding areas, and many educated Thais are moving abroad while less educated migrants from neighboring countries like Myanmar and Cambodia move into the country.

Thailand has worked to reduce its fertility rates for nearly 3 years, but it now faces an issue with a fertility rate that is too low.

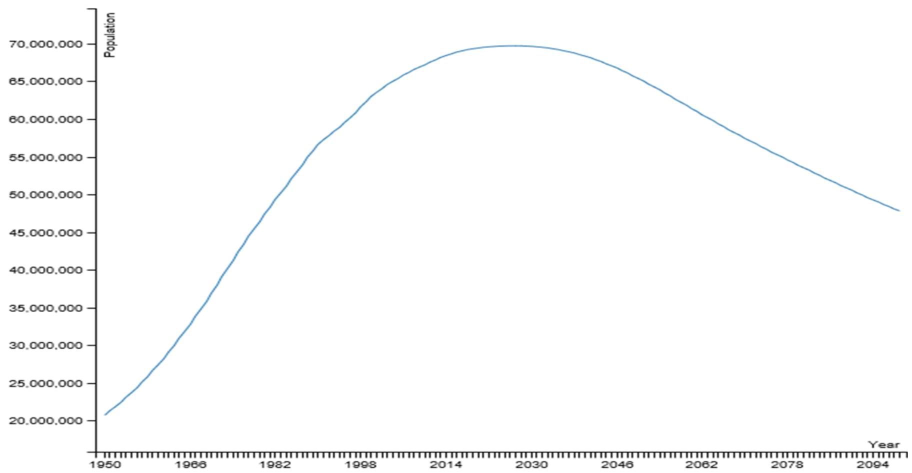


Fig.9 Fertility rates

Thailand Population Density

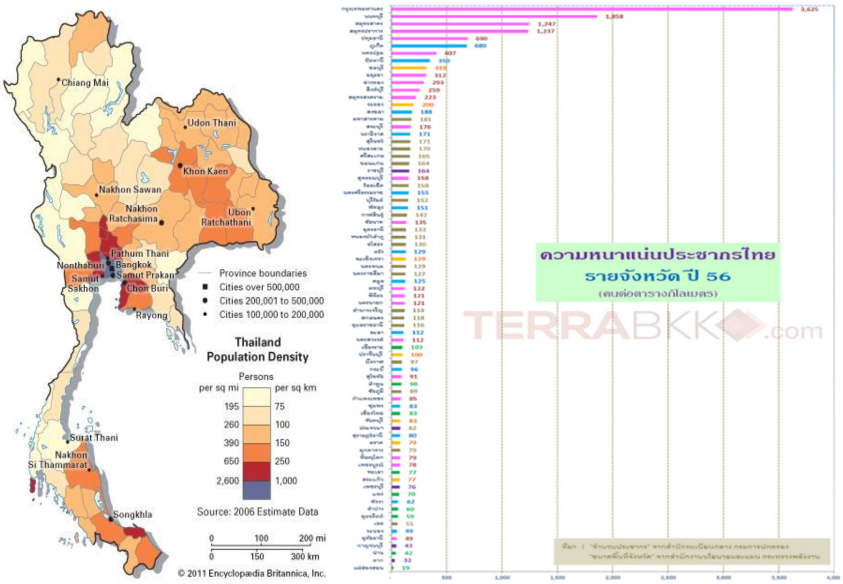


Fig.10 Thailand Population Density is Bangkok 3,625 person/ km^2 and Mea Hong Son 19 person/ km^2

5. Challenge

- Thailand is a flood-prone country; because flooding is a regular occurrence and the population and number of exposed properties continue to grow, losses from this peril will continue to rise.

- Flooding in this area in 2011 was some of the most severe in modern history; its impact not only devastated a major city, but propagated through manufacturing supply chains around the world.

- Siting a radioactive waste disposal facility refers to the process of selecting a suitable location that must take into account technical and other considerations.

- Technical factors cover a long list: geology, hydrogeology, geochemistry, tectonics and seismicity, surface processes, meteorology, human induced events, transportation of waste, land use, population distribution, and environmental protection.

- Another key factor today is public acceptance, particularly in industrialized countries where a locality's "not-in-my-backyard" attitude can hinder the siting of all types of industrial waste facilities, not just radioactive waste sites.

- This has caused planners to focus greater attention on societal factors during early phases of the siting process.

- o Political factors and public concerns are the most challenge!

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-Part II. Specific Site Safety Assessment of LLW Repository-

1. General Considerations for Safety Assessment.

Due to the management of the radioactive waste in Thailand; however, there is not the disposal at the present time. Currently, there are a lot of increasing quantities of the radioactive waste. Consequently, the disposal method is more crucial. As a result, Thailand Institute of Nuclear Technology (Public Organization), TINT supports for this method; consequently, we need to have any plans and choose "Near Surface Disposal Method" that we hopefully think we must finish this process not over 10 years, but we have the siting problem which we must plan and survey the siting not over 3 years.

Talking about the general considerations for safety assessment, the safety objective will focus on site, design, construct, operate and close a near surface disposal facilities; consequently, protection after its closure is optimized social and economic factors being taken into account. The general consideration for the safety assessment is to equip radiological safety. In addition, safety assessment is an iterative procedure to evaluate the performance of the disposal system and its potential influence on human health and the environment. Besides, the purpose of safety assessment is to equip a rational scientific assurance that disposal system will equip an adequate level of safety and meet the requirements to protect human health and the environment. As previously mentioned must be followed IAEA Safety Standards. Moreover, we need to concern about the protection of the public and the environmental and non-radiological concerns. Talking about the protection of the public, we prevent and control release from Near Surface facilities and access to the site. Furthermore, a rational assurance must be equipped that doses and risks to the members of the public that must be controlled by IAEA Safety Standards. Talking about the environmental and non-radiological concerns, the scope of safety requirements for Near Surface Disposal of radioactive waste is the prevention of the environment against radiological hazards assorted with the radioactive material in the Near Surface Disposal facilities that is followed IAEA Safety Standards.

2. Specific LLW Repository site (planning etc.).

Site characterization is a crucial part of the Near Surface Disposal Facilities that should start as soon as the site has been identified that we can divide into four stages should be concerned as the followings:

1. The conceptual and planning stage;
2. The area survey stage;
3. The site investigation stage;
4. The stage of detailed site characterization leading to site confirmation for the Near Surface Disposal Facilities.

Talking about the site for a Near Surface Disposal facility shall be characterize at a level of detail sufficient to support a general understanding of both the characteristics at a level of the site and how the site will evolve over time.This shall include its present condition,its probable natural evolution and possible natural events,and also human plans and actions in the vicinity that may affect the safety of the facility over the period of interest. It shall also include a specific understanding of the impact on safety of features, events and processes associated with the site and the facility. Moreover, we need to concern about the geology, hydrogeology, geochemistry, meteorology, transport of waste, land use, population distribution and protection of the environment.

3. Guidelines for Safety Assessment.

The safety assessment of the Near Surface Disposal Facilities should include, among other things, the following works: characterization of the main radiation sources (type, shape, location, properties and geometry of protective materials, etc.); substantiation of the use of various methods and programs for calculating prevention and dispersion; consideration of postulated initiating events and factors that individually or collectively can affect safety, as well as analysis and evaluation of sequences of events resulting from postulated initiating events; modeling of the processes of dispersion (diffusion) of pollutants (emissions, discharges) in the environment (air, surface and groundwater, soil), calculation of radiation protection and exposure under normal operation and accidents; and so on. In addition, the safety assessment is the process of systematically analysing the hazards associated with a disposal facility, and the capacity of the site and the design of the facility to provide for the completion of safety functions and to meet technical requirements. Safety assessment must include quantification of the whole level of performance, analysis of the assorted uncertainties, and comparison with the relevant design requirements and safety standards. Safety guides equip comprehensive guidance on and international best practices for meeting the requirements of disposal facility the Safety assessment of a disposal facilities need to address the following important components.

4. Confidence Building.

In the course of the safety assessment really attention is paid to building the confidence to the methods and results of the assessment that is a crucial issue; namely: by making comparative calculations and sensitivity analysis, a feasibility assessment of computer programs (codes), analytical methods and models is provided; at all stages of the repository's life cycle, quality assurance programs are developed and implemented; at the request of the public or the regulatory body, an independent examination of the materials of the safety assessment can be carried out. Moreover, the confidence must be performed in the safety assessment and its results that is a need to have the confidence in any aspects of the long term safety of the Near Surface Disposal Facilities to perform the confidence to the satisfaction of all stakeholders. Talking about the quality assurance that need to apply to the all activities related to safety, structure, systems and components of the Near Surface Disposal Facilities that includes all related activities that we must plan site studies, design, construction, operations, various stages for the safety, closure, maintenance of long-term records and institutional control. Talking about the construction of building, construction and installation of equipment and utilities, and construction of associated support systems. Best practices for construction techniques should be identified and incorporated into construction procedure. All construction activities should be performed in a manner that ensures occupational health and safety during the construction of the facility to protect both workers and the public.

VIETNAM

VIETNAM

-Part I. General Outline of LLW Repository-

1. **General Policy**

- Implementing a consistent policy of our Party and State is to use nuclear energy for peaceful purposes, ensure safety and security, Vietnam has so far participated in most of the most important international treaties in the nuclear field.
- In the field of nuclear safety: the Early Notification Convention on nuclear accidents (1987); Convention on Assistance in the event of a nuclear accident or radiation emergency (1987); The Nuclear Safety Convention (2010) and the General Convention on the Safety of Used Fuel and the Safety of Radioactive Waste Management (2013).
- In the field of anti-nuclear proliferation: Nuclear Non-Proliferation Treaty (1982); Agreement between the Government of the Socialist Republic of Vietnam and the International Atomic Energy Agency on the application of inspection under the Non-Proliferation of Nuclear Weapons Agreement (Inspection Agreement) (1989); Southeast Asia Regional Treaty for non-nuclear weapons (1997); Prohibition Treaty on Comprehensive Nuclear Weapons Test (2006); signed (2007) and ratified (2012) an additional Protocol to the Inspection Agreement.
- In the field of nuclear security, we have joined the Convention on the Protection of Nuclear Materials and the Revised Part (2012); and undertaking to implement the Code of Conduct for safety and security of radioactive sources and additional guidance on the import and export of radioactive sources (2006).
- Vietnam joined the General Convention on the Safety of Used Fuel and the Safety of Radioactive Waste Management (hereinafter referred to as the General Convention) from October 2013 and became a member of the Convention from October. 01/2014.
- The General Convention on Used Fuel Safety and Radioactive Waste Safety is a multilateral mechanism with the main goal of establishing and encouraging countries to commit to the same framework, general and unified legislation on the safe management of used radioactive waste and nuclear fuel.

Major Policy:

- Protection of Human Health and Environment
- Environmental Impact Assessment
- Radioactive waste and spent nuclear fuel in Vietnam will be safely managed to protect human health and environment now and in the future in a sustainable and cost-effective manner.

2. Principles and Safety Assessment

Viet Nam uses the IAEA structures and guidance for its regulation and expectations of radioactive licencees. One of the main requirements is to justify the use of radioactivity and demonstrate that the safety of the action to individuals, the community and environment. Safety assessment is a procedure for evaluating the performance of a **Repository** and, as a major objective, its potential radiological impact on human health and the environment.

Radiation and Environmental Protection Principles: For the disposal of radioactive waste the essential protection goal are: • Long term protection of man and the environment against hazardous effect of the release of harmful substances from RW packages • Unnecessary radiation exposure or contamination of man and environment must be avoided • Adequate safety compliance with the regulatory requirements • Determine guide research and development priorities • Contribute to confidence of policy makers and scientific community The protection goals have to be further to be suitable for consideration in the development of the site selection procedure. In this regard, the safety principles are refereed, to as formulated by IAEA.

In Viet Nam the dose limit for radiation personnel and the public does prescribed in Circular No. 19/2012 / TT-BKHCN

3. Regulatory and Operational System Preparation

- Atomic Energy Law No. 18/2008 / QH12, dated June 3, 2008, effective from January 1, 2009, of the XII National Assembly, 3rd session;
- Decree No. 07/2010 / ND-CP dated January 25, 2010 of the Government detailing and guiding the implementation of a number of articles of the Law on Atomic Energy;
- Decision No. 115/2007 / QD-TTg dated July 23, 2007 of the Prime Minister on the Regulation to ensure security of radioactive sources.
- Decision No. 2376 / QD-TTg dated December 28, 2010 of the Prime Minister approving the planning for the location of radioactive waste storage and burial till 2030, with a vision to 2050;
- Circular No. 23/2010 / TT-BKHCN of December 29, 2010, guiding the security of radioactive sources issued by the Ministry of Science and Technology.
- Decision No. 450 / QD-TTg dated 25/3/2011 of the Prime Minister approving the Project "Implementation of security assurance measures in the field of atomic energy";
- Circular No. 19/2012 / TT-BKHCN of November 8, 2012, of the Ministry of Science and Technology, providing for the control and assurance of radiation safety in occupational and public radiation;
- Circular No. 23/2012 / TT-BKHCN dated November 23, 2012 of the Ministry of Science

and Technology guiding the safe transport of radioactive materials.

- Joint Circular No. 13/2014 / TTLT-BKHCN-BYT dated June 9, 2014 of the Ministry of Science and Technology and the Ministry of Health providing regulations on ensuring radiation safety in health.
- Circular No. 22/2014 / TT-BKHCN dated August 25, 2014 of the Ministry of Science and Technology: Regulations on management of radioactive waste and used radioactive sources;
- Directive No. 17 / CT-TTg dated July 10, 2015 of the Prime Minister on strengthening the assurance of radiation safety and security of radioactive sources;
- TCVN 6866-2001 Radiation safety - Dosage limits for radiation workers and the public.
- Atomic Energy Law (No.18/2018/QH12);
- Circular No.08/2010/TT-BKHCN, date 22/7/2010, Guidance on the declaration, granting of licenses for conducting radiation work and granting radiation staff certificates;
- QCVN 40:2011/BTNMT-National Technical regulation on industrial wastewater;
- Other national safety requirements.

Regulatory body

- MOST: Under the Article 29 of Ordinance and the Article 34 of Decree 50/CP the MOST was designated as the Regulatory Authority for Radiation safety and control. MOST is a Regulatory Body being responsible to Government for the exercise of unified State management over radiation safety and control throughout the country, responsible for organizing and directing all radiation safety and control activities within the scope its function and duties. https://www.most.gov.vn/vn/Pages/Trangchu.aspx
- VINATOM: Under direction of the MOST, the VINATOM is responsible for conducting all R&D activities in the field of the application of nuclear energy in Vietnam and assisting the VARANS on technical aspects. https://vinatom.gov.vn/
- VARANS: Under direction of the MOST, the VARANS is responsible for building of legislative documents, code of practice, procedures and regulations for radiation and nuclear safety & control; organizing and implementing the notification, registration, license, renewal, amendment and withdrawal of licenses for radiation and nuclear establishments,...; conducting regulatory inspections on radiation and nuclear safety according to law. https://www.varans.vn/
- VAEA:Vietnam Atomic Energy Agency under MOST, which advise and assist the Minister to fullill the State management functions for research, use and develope nuclear energy nationwide carry out professtional activities in the Agency's management function. http://vaea.gov.vn/
- DOST: The 63 Provincial Departments of Science & Technology (DOSTs) are responsible for radiation protection and nuclear safety within the province under supervision by VARANS.

4. Site Selection

Site selection is the most complex issue for Radioactive Waste storage or landfill sites. This is a common problem for many countries around the world. When selecting locations, it is necessary to pay attention to two main areas: social, economic and technical.

Socially: the most difficult issue is community acceptance. The creation of a new location for a nuclear facility or radiation facility has been an unacceptable problem, sometimes requiring long-term campaigning by communication, social mobilization and sometimes using Therefore, the experience of countries often build national storage of used radioactive sources in the area allocated by the National Atomic Energy Research Institute of the country. . Typical examples in countries around us such as Thailand, Philippines, Malaysia, Indonesia, Bangladesh...

In terms of economic and technical criteria: Economic issues are closely related to the location and its technical characteristics. Sometimes, due to the difficulty of site selection, people are willing to accept the cost increase to overcome the site's technical limitations. Technically, if merely choosing a location for building storage, there are not many strict technical requirements (because often the warehouses are not too large, usually low-rise warehouses (one storey)), the load is not high ...), If looking for the long term, if looking for a location for the landfill, consider the following criteria: meteorological, hydrological, groundwater, geological, ...

- In 2003-2004, an State-level Project was carried out, the official studies on meteorological, geological and hydrogeological conditions of Vietnam show that on the territory of Vietnam, the only Coastal Region of South-Central Area might be considered as relevant and the most suitable region for construction of the future national near surface disposal facility of low and intermediate levels Radwaste.
- There are 3 most suitable candidate sites: Tu Thien village, Son Hai village, Ninh Phuoc district and Thai An village, Ninh Hai district, Ninh Thuan Province. They are near the site for building of the first nuclear power plant.

5. Design and Construction of Disposal Facilities

☐ Design, construction, operation, closure, post-closure phase

☐ Quality assurance

The operator of a disposal facility is responsible for all necessary activities for design, construction, operation and closure, in compliance with the regulatory requirements and within national legal infrastructure. The operator is responsible for developing and for demonstrating its safety, consistent with the requirements of the regulatory body. The facility and its engineered barriers need to be designed to provide safety during the operational period. The construction activities have to be carried out in such a way to ensure safety during the operational period.

The design is performed to satisfy the following requirements:

- Sufficient capacity to store the amount of forecast resources according to demand
- Ensuring economy, not too wasteful.
- The design ensures the dose limit for radiation personnel and the public does not exceed the dose limit as prescribed in Circular No. 19/2012 / TT-BKHCN, specifically:o Limit the dose for radiation workers: 20 mSv / year.

o Limit the dose to the public: 1 mSv / year.

o Radioactive sources before being stored in the warehouse are placed in containers to ensure the dose rate on the outside of containers (within 100 cm) is smaller:

+ 50 µSv / h, for gamma source security group A

+ 10 µSv / h, for gamma sources of security groups B and C

+ 10 µSv / h, for gamma D security source, Alpha / Beta source

+ 10 µSv / h, for neutron source.

o The source warehouse is divided into separate compartments according to: security level of radioactive sources, major radiation type of radioactive sources, long half-life (> = 30 years) or short.

o The dose rate on each compartment after closing the lid is less than 10 µSv/h.

o The dose rate outside the source warehouse is less than 0.5 µSv / h.

RECENT ACTIVITIES

2019 Workshop

- **Date**: 1st – 3rd October 2019
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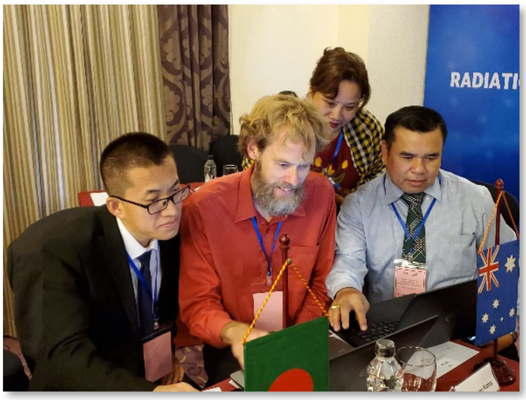

2018 Workshop

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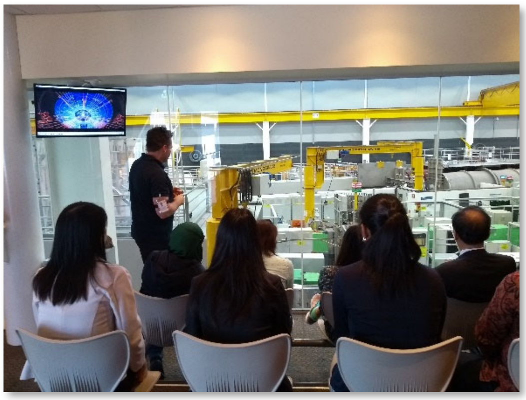

2017 Workshop

- **Date**: 1st – 3rd August 2017
- **Host**: Thailand Institute of Nuclear Technology (TINT)

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