3.3 Radioactive Waste Management (RWM) in Indonesia

At the present time, the Development Center for Radioactive Waste Management (DCRWM) is the only institution in Indonesia that has capabilities to treat radioactive waste in the forms of liquid, spent resin, combustible waste, high active waste, and sealed source. DCRWM is equipped with evaporator, compactor, incinerator, chemical treatment, conditioning facilities for spent sources, and also interim storage.

Indonesia utilizes radioactive materials and radiation generators for a wide variety of peaceful purposes - in industry, medicine, research and education. Many uses involve sealed sources with the radioactive materials firmly contained or bound within a suitable capsule or housing; some, also, involve radioactive materials in an unsealed form. The risks posed by these sources and materials vary widely, depending on the radionuclides, the forms, the activities, etc. Unless breached or leaking, sealed sources present a risk from external radiation exposure only. However, breached or leaking sealed sources, as well as unsealed radioactive materials, may lead to contamination of the environment and the intake of radioactive materials into the human body.

The policy of the government of Indonesia for spent radiation sources is whenever possible spent sealed sources should be returned to the supplier. The DCRWM has a general principle that sealed sources should not be removed from their holders, or the holders physically modified (except for Ra-226 needles, smoke detectors and lighting preventors). DCRWM is developing a management information system (MIS) for keeping database of all wastes stored at DCRWM. This system is used to identify accurately and immediately the transportation and storage of the radioactive waste. The other objective of the MIS is to control the record of the waste history (transportation, treatment/conditioning, and storage).

3.3.1 RWM Policy

The use of nuclear energy in Indonesia to support the national development program shall give due consideration to the safety, security, peace, and health of workers and the public and the protection of the environment, as well as the utmost use for public prosperity. This consideration is stipulated in the Act Number 10 Year 1997 on Nuclear Energy, replacing the Act Number 31 Year 1964 on Basic Stipulation of Atomic Energy.

The nuclear activities in Indonesia were started by the operation of TRIGA MARK II 250 kW at the Bandung Nuclear Research Center in 1965. In 1971, the power was upgraded to 1,000 kW for routine production of radioisotopes, and then it was upgraded again to 2,000 kW since June 24, 2000. Another small research reactor, TRIGA MARK II 250 kW at the Yogyakarta Nuclear Research Center was commissioned in 1979.

The radioactive waste produced by Bandung and Yogyakarta Nuclear Research Centers is small in quantity, mostly of low level activity and containing short-life radionuclides. The treatment of aqueous waste at the Bandung and Yogyakarta Nuclear Research Centers is simple, i.e. by collection in a hold-up tank for further decay, down to insignificant activity, then dilute, disperse and discharge in a river. The solid and organic liquid wastes are collected on containers, kept and stored in storage facilities for radioactivity to delay and decay.

The Serpong Nuclear Research Complex of the Development Center for Research Reactor Technology, Development Center for Nuclear Fuel and Recycle Technology, Development Center for Radioisotopes and Radiopharmaceuticals, Development Center for Radioactive Waste Management, and Development Center for Reactor Safety Technology, generates a larger quantity of low and medium level wastes. To deal with these wastes, the Centralized Radioactive Waste Management Station (RWMS) was established in Serpong. The RWMS is organized by the Development Center for Radioactive Waste Management. This center is assigned responsible for the ultimate management of radioactive waste generated from all nuclear activities in Indonesia.

The radioactive wastes from outside of BATAN (Nuclear Application) are generated from: nuclear medicine/hospital (spent sources, liquid waste), industrial application (spent sources for radiography, logging and gauging, lightning protection devices, solid waste from gas mantle lamp production), and research institutes.

Radioactive wastes at BATAN Research Centers are originated from:

- Serpong Site
  - MPR-30 research reactor
  - Radioisotope and radiopharmaceutical production facility
  - Research and power reactor fuel element fabrication facilities
  - Radiometallurgy installation
- Outside of Serpong Site
  - Bandung nuclear research complex
  - Yogyakarta nuclear research complex
  - Pasar Jum'at nuclear research complex

Since the beginning of nuclear activities in Indonesia, BATAN, the National Nuclear Energy Agency of Indonesia, formerly known as the National Atomic Energy Agency, has implemented the Radioactive Waste Management Program with the following objectives:

- To assure that no one shall receive any radiation doses, that comes from radioactive wastes, exceeding the limits of permissible value according to recommendations of the International Commission on Radiological Protection (ICRP), and
- To master the practical and safe technologies for radioactive waste management.

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

- Radioactive waste generation from the use of nuclear energy should be as minimal as possible.
- Any discharge of liquid effluent and gas effluent to the environment should be as low as possible.
- Handling, treatment and disposal of radioactive wastes should be carried out by taking into account the environment protection consideration.

- Conditioning wastes should be emplaced at nuclear site and specially constructed for this purpose.
- Research and development in radioactive waste management should be carried out to support the safety aspect of present and future nuclear energy program.

The objective of radioactive waste management is to deal with radioactive waste in a manner that protects human health and the environment now and in the future without imposing undue burdens on future generation.

3.3.2 RWM Practices

3.3.2.1 Legislative Framework

In anticipation of possible expansion of the nuclear energy application in Indonesia and in order to contribute to the global nuclear safety culture, the Government of Indonesia has, in April 1997, issued the Act of the Republic of Indonesia No. 10/1997 on Nuclear Energy. This law covers various arrangements, including the establishment of Nuclear Energy Control Board (NECB) through 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 ten chapters with 48 articles. The waste management consists of six articles. With regard to the waste management arrangement, the Act stipulates that no single part of Indonesia's territory could be used by foreign or other country as radioactive waste repository.

As stated earlier, the Act No. 10/1997 on Nuclear Energy also stipulated some basic arrangements of waste management. The basic arrangement is accommodated in chapter VI with six articles. It stipulates inter alia:

- The radioactive waste management shall be conducted to mitigate radiation hazards to the workers, the public and the environment (Article 22[1]).
- The Executing Body 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).
- The user generating low and intermediate level of radioactive waste shall be obliged to collect, segregate, or treat and temporarily store the waste before being transferred to the Executing Body (Article 24 [1]).

Furthermore,

- The radioactive waste storage in the premise of the Executing Body shall be subjected to fee and the amount of which will be stipulated in the Degree of the Minister of Finance (Article 26).
- The transportation and storage of radioactive waste shall consider the safety of workers, public and environment (Article 27 [1]).

- The provisions on radioactive waste management including the waste transportation and disposal shall be further implemented in Government Regulations (Article 27 [2]).

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

- Nuclear material consists of nuclear ores, nuclear fuel, and spent fuel. Spent fuel is considered as HLW (Article 2 [1] and its elucidation).
- The user generating HLW shall be obligd 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]).

Article 25 stipulates the following:

- The Executing Body shall provide the final repository for high level radioactive waste.
- The siting of final repository under paragraph (1) shall be stipulated by Government after getting an agreement from the House of Representative of the Republic of Indonesia.

Elucidation of Article 25 prohibits the use of any part of Indonesia territory by any foreign or other country as a radioactive waste repository.

The provisions of the HLW contained in Act No. 10/1997 on Nuclear Energy are legal platform, from which the Government Regulations and the Decrees of Chairman of BAPETEN on the management of HLW would be formulated. There are three important guides that have to be followed, namely:

- HLW should be disposed of some time later in a final repository.
- Final repository should be provided by Executing Body.
- The radioactive waste from other countries shall not be allowed to be stored in Indonesia.

Two basic objectives of safe waste disposal should be taken into consideration, namely:

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

The final repository should be designed in such a way that emplaced fissile material will remain sub-critical. If it is not that case than liability for nuclear damage will be applied.

The proposed Government Regulation on Waste Management is aimed:

- To minimize or to avoid any radiation hazard arises from the waste in which it may endanger the workers, public and environment
- To clearly defined the responsibility of licensee which generate radioactive waste
- To set up the task and responsibility of the Executing Body in respect of radioactive waste management
- To clearly state the role of Regulatory Body

In addition, it will also cover the goal of the waste management, classification of waste, waste transportation and storage, licensing and inspection process. The proposed decree of the Chairman of Nuclear Energy Control Board (BAPETEN) will on the other hand concentrate on technical criteria.

3.3.2.2 Organization and Responsible for Radioactive Waste Management

The Act No. 10 of 1997 states that the development and the use of nuclear energy has to be carried out in such a way to assure the safety and health of workers, as well as the public and also to protect the environment.

To carry out the development and the use of nuclear energy, the Government has established the National Nuclear Energy Agency (BATAN) as the Executing Body, the Nuclear Energy Control Board (BAPETEN) as the Regulatory Body and the Nuclear Energy Advisory Council all being under and directly responsible to the President of the Republic of Indonesia.

The Executing Body has the task to execute the use of nuclear energy by conducting research and development, general surveys, exploration and exploitation of radioactive minerals and nuclear fuel cycle, production of radioisotopes and radioactive substances for research and development, and radioactive waste management. While BATAN as the executing body performs the non-commercial activities, the commercial ones can be done in cooperation with and or by private companies, state-owned enterprises and cooperatives.

The Regulatory Body has the task to control any activity using nuclear energy. The purpose of control is to prevent the workers, the public, and the environment from any harmful effect of radiation.

The task is administered by the following means:

- Establishing regulation on the nuclear safety covering the radiological and radiation safety
- Issuing the licenses to control that the user of nuclear energy is qualified and in accord with the nuclear safety regulation, criteria, standards, and guidance, as well as practices
- Doing inspection to ensure that all regulations are observed in practices

The Nuclear Energy Advisory Council has the functions to give advices and opinions on the use of nuclear energy to the Government. The Nuclear Energy Advisory Council is an independent and a non-structural institution, and its members consist of experts and public figures.

The structure of the radioactive waste management in Indonesia is illustrated in Figure 3.3-1. The structure shows that the promotional side, i.e. the National Nuclear Energy Agency and the Ministry for Science and Technology, sets up the plans and coordinates research and development activities.

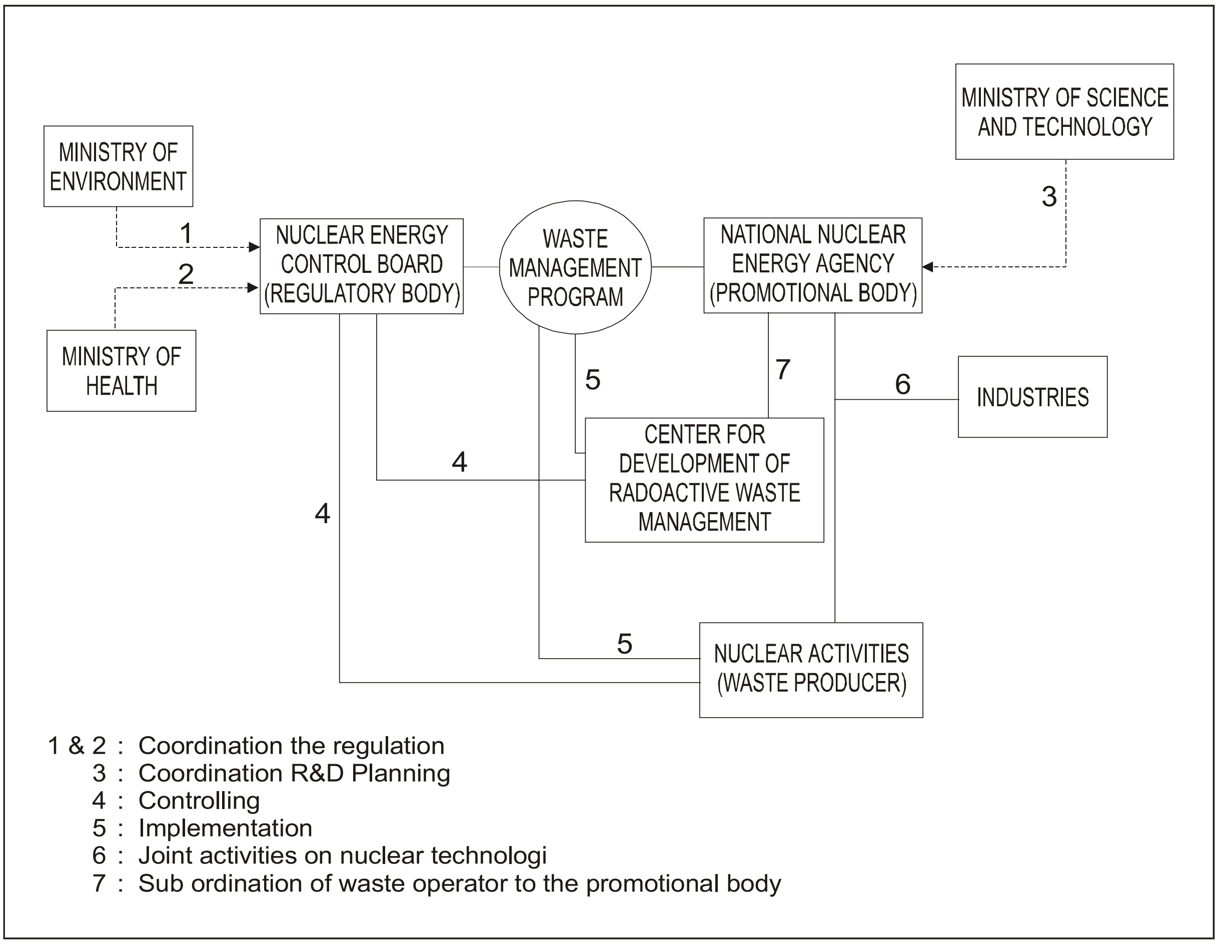

Figure 3.3-1 Radwaste Management Structure in Indonesia

On the regulatory side, the Nuclear Energy Control Board, the Ministry of Health and the Ministry of Environment coordinate the regulation, guidance and criteria, as well as examine the safety assessment. The Nuclear Energy Control Board carries out the safety examination on the waste management program and also sets up guidance to be implemented by the waste management organization to comply with basic radiation protection requirements as described by ICRP and IAEA Basic Safety Standard. The Development Center for Radioactive Waste Management, BATAN is the undertaking organization, as well as responsible organization for carrying out the radioactive waste management which is statutory task of the Executing Body. The scheme of control mechanism of nuclear activities in Indonesia is shown in Figure 3.3-2.

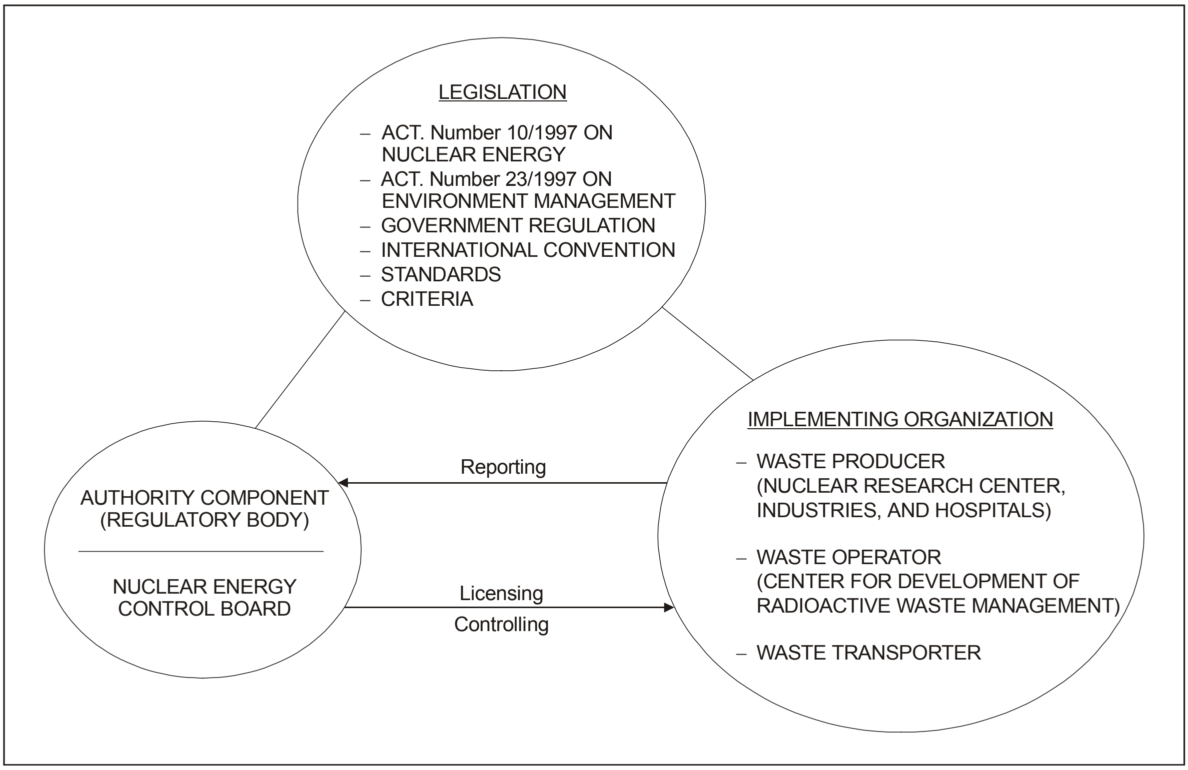

Figure 3.3-2 Scheme of Control Mechanism Control of Nuclear Activities in Indonesia

3.3.2.3 Regulatory on Radioactive Waste Management

According to the Act No. 10/1997 on Nuclear Energy, the Regulatory Body is fully separated fully from the Executing Body.

The regulation is prepared to regulate and control the nuclear activities by regulatory compliance early on the planning of project in the manner of environment impact analysis preparation, licensing demand, regulating and controlling of activities. Certain necessary rules and regulation for management of radioactive waste have been issued as indicated in Table 3.3-1.

Table 3.3-1 List of Existing Indonesian Government Regulation Concerning Radioactive Waste Management

No.	Name of Regulation
1	Government Regulation of the Republic of Indonesia No. 11/1975 on Working Safety Against Radiation
2	Government Regulation of the Republic of Indonesia No. 12/1975 on Licensing of Utilization of Radioactive Materials and or Another Radiation Sources
3	Government Regulation of the Republic of Indonesia No. 13/1975 on Transport of Radioactive Materials
4	Government Regulation of the Republic of Indonesia No. 51/1993 on the Preparation of Environment Impact Analysis
5	Decree of Ministry of Environment No. Kep.-42/MENLH/1994 on General Guidelines on Environmental Audit
6	Decree of Ministry of Environment No. Kep.-39/MENLH/1996 on Activities Criteria Obligate to Prepare the Environment Impact Analysis
7	Act of the Republic of Indonesia No. 10/1997 on Nuclear Energy
8	Act of the Republic of Indonesia No. 23/1997 on Environment Management
9	Decree of President of the Republic of Indonesia No. 76/1998 on Nuclear Energy Control Board
10	Decree of Chairman of the Nuclear Energy Control Board No. 01/Ka. BAPETEN/V-99 on Working Safety Provision Against Radiation
11	Decree of Chairman of the Nuclear Energy Control Board No. 02/Ka. BAPETEN/V-99 on Radioactivity Dose Value on the Environment
12	Decree of Chairman of the Nuclear Energy Control Board No. 03/Ka. BAPETEN/V-99 on Safety Aspect of Radioactive Waste
13	Decree of Chairman of the Nuclear Energy Control Board No. 04/Ka. BAPETEN/V-99 on Radioactive Materials Transport Safety
14	Decree of Chairman of the Nuclear Energy Control Board No. 06/Ka. BAPETEN/V-99 on Construction and Operation of Nuclear Reactor
15	Decree of Chairman of the Nuclear Energy Control Board No. 07/Ka. BAPETEN/V-99 on Quality Assurance of Nuclear Installation

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 interrelations of them are shown in Figure 3.3-3.

The user generating high level radioactive waste shall be obliged to have an interim storage capability to temporarily store the wastes generated during the period of not less than the life time of the nuclear reactor. The executing body shall provide the final repository for high level radioactive wastes.

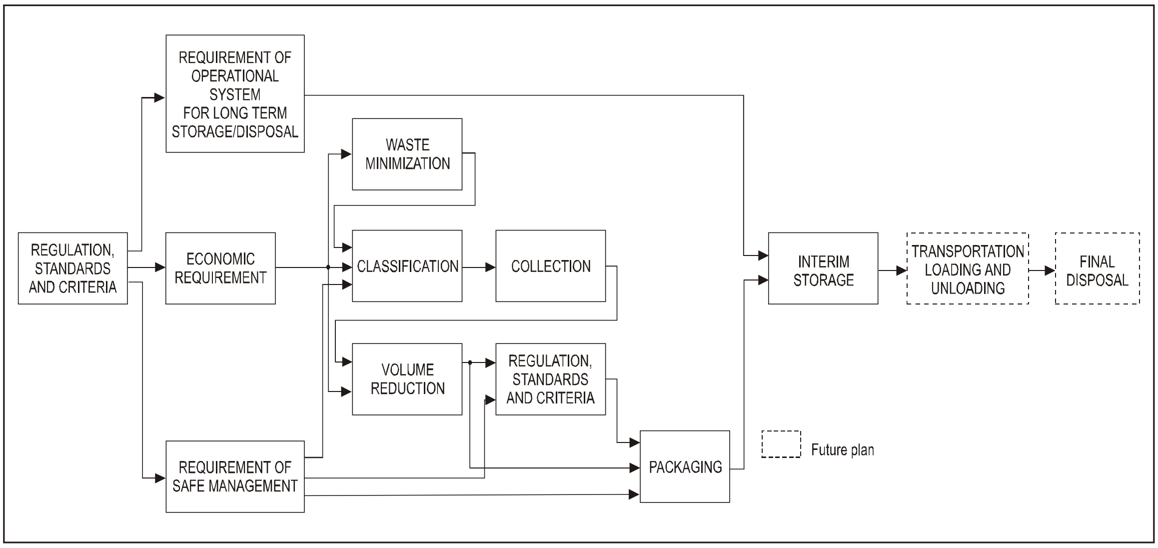

Figure 3.3-3 Principles of Management of Low and Intermediate Level Radioactive Wastes

3.3.2.4 Responsibility of License Holder

Radioactive waste management shall be administered by the Executing Body based on the safety concern and technical capability possessed by the Executing Body and also for the ease in implementation of control. The management is administered in a non-commercial manner. For commercial activities of radioactive waste management, the Executing Body may be designate a State Company, Cooperatives, and/or any private company in accordance with the existing regulations.

The obligation of the user generating low and medium level radioactive wastes is to manage the radioactive wastes within the location of the nuclear installation so that they will not pose hazards to workers, the public and the environment and enabling further easy management by the Executing Body. The purpose of temporary disposal is to reduce the radiation level of short live radioactive materials before transferring them to the Executing Body. The user generating high level radioactive wastes shall be obliged to temporarily store those wastes during the period not less than the life time of the nuclear reactor.

The determination of a final repository site for high level radioactive wastes shall be discussed with the People's House of Representatives of the Republic of Indonesia to obtain approval, since it converts the function of a beneficial site to a site that can never be used for anything else. Radioactive wastes from other countries shall not be allowed to be disposed of in the territory of the Republic of Indonesia.

Furthermore, Act No. 10/1997 on Nuclear Energy also stipulates some basic arrangement of nuclear damage liability related to responsibility of license holder. The basic arrangement accommodated in chapter VII is as follows:

- The Operator of a nuclear installation shall be liable for damage suffered by the third party resulting from any nuclear incident inside the nuclear installation (Article 28).

- In the case of nuclear damage occurring during the transportation of nuclear fuel or spent fuel, the Consignor shall be liable for nuclear damage suffered by the third party (Article 29 [1]).
- The Consignor under paragraph (1) may transfer the liability to the Consignee or the Carrier, by written agreement (Article 29 [2]).
- Where nuclear damage engages the liability, under Article 28, of more than one Operator, the Operators involved shall, in so far as the damage attributable to each Operator is not reasonably separable, be jointly and severally liable (Article 30 [1]).
- The liability of each Operator under paragraph (1) shall not exceed each liability limit in respect to any one of them (Article 30 [2]).
- If a nuclear incident has occurred in one location having more than one nuclear installation under one Operator, the Operator shall be liable for damage in any individual installation (Article 31).
- The Operator shall not be liable for damage caused by a nuclear incident directly due to an act of international or non-international armed conflict, or a grave natural disaster exceeding the safety limit established by the Regulatory Body (Article 32).
- If the Operator, having paid the compensation under Article 28, is able to prove that the nuclear damage resulted from the intent of the third party suffering the damage the Operator may be relieved wholly or partly from his obligation to pay compensation (Article 33 [1)].
- The Operator under paragraph (1) shall have a right of recourse against the third party who has acted with intent causing nuclear damage (Article 33 [2]).

3.3.3 Criteria Used to Define and Categorize Radioactive Waste

In Indonesia, radioactive wastes are generated mainly from activities from research reactor operation, radioisotope production, nuclear fuel fabrication, nuclear medicines, industrial applications, and other nuclear researches. The radioactive waste is classified into low level radioactive waste, intermediate level radioactive waste, and high level radioactive waste.

In a reactor facility, the liquid wastes are classified into two categories, i.e., low active wastes having the activity of 10^{-6} to 10^{-2} Ci/m^3 and intermediate active wastes for activity 10^{-2} to 10^{2} Ci/m^3. The system or components from which low level liquid wastes are originated are: pool drainage, shower and wash water, and ventilation system. The intermediate level radioactive liquid wastes are from: resin flashing, power ramp test facility, and decontamination of isotope box. The spent resin coming from the water purification system having maximum activity of 0.1Ci/m^3 is handled as semi liquid. Solid wastes which consist of used reactor components, filters, paper, contaminated linen, etc. are classified into compactible solid wastes having maximum dose rate of 25mR/h and burnable solid wastes having maximum activity of 10^{-4}Ci/m^3 for alpha emitter and 10^{-3}Ci/m^3 for beta-gamma emitter.

From the radioisotope production facility, the liquid radioactive waste consists of low level originated from shower and wash water, decontamination activities, etc. having aximum activity of $10^{-2}Ci/m^3$, and high level coming from the processing of irradiation target in the hot cell. The solid waste is classified into two categories, the one having dose rate greater than 1,000mR/h at the surface and the other having dose rate less than 1,000mR/h at the surface.

The radioactive liquid waste that comes from fuel element fabrication is mostly contaminated with chemical waste in which the uranium content is very low.

The solid waste from Serpong site, such as contaminated linen, paper, filters, shoe-covers, gloves, etc., having maximum dose rate of 25mR/h are collected in plastic bags and put into 100-liter drums and brought to the RWMS.

The radioactive waste from nuclear medicine comprises spent sources, i.e., Cs-137, Ra-226, and Co-60; and liquid waste, i.e., I-131 liquid excretion.

From industrial application, the radioactive waste comprises spent sources for radiography, logging and gauging, lightning protection devices, solid waste from gas mantle lamp production.

Table 3.3-2 shows various low and intermediate level radioactive wastes being generated in Indonesia and its management, while Figure 3.3-4 shows radwaste treatment processes existing at the Development Center for Radioactive Waste Management (DCRWM). The evaporation system that processes liquid wastes has a maximum activity of $2x10^{-2}Ci/m^3$ into radioactive concentrates (maximum activity $1Ci/m^3$) and normal water distillates. The evaporator unit is a thermo siphon circulating thermal evaporator with $0,75m^3/h$ operating capacity and is designed to reduce the waste volume in a maximum ratio of 50:1, depending on initial salinity.

Table 3.3-2 List of Diverse Low and Intermediate Level Radioactive Waste Generating in Indonesia and Its Management

Source of Radioactive Waste	Type of Waste	Major Radionuclides	Activity Level (Radiation Dose)	Quantity of Waste	Management Process
BATAN Nuclear Research Center	Liquid Waste	Co-60, Cs-137, Zn-65, Cd-109, Mn-54, Zr-95	$10^{-6} \leqq A \leqq 10^{-2}$ Ci/m^3	224m^3/year	Evaporation, Cementation and Interim Storage
	Semi Liquid (Spent Resin)	Co-60, Cs-137, I-131	1Ci/m^3	2.001L/year	Cementation and Interim Storage
	Solid Waste	Cs-137, I-131, I-125	Max. 25mRem/hour	1.184 drums	Compaction, Cementation and Interim Storage
		Co-60, U-235, U-238	Max. 200mRem/hour	32 shell	Delay, Decay, Cementation and Interim Storage
	HEPA Filter	Co-60, I-125, U-235, U-238	5mRem/hour	142 pieces	Compaction, Cementation and Interim Storage
Nuclear Application in Nuclear Medicine (Hospital)	Spent Sources	Cs-137	(400-1.300) Ci	25 pieces	Interim Storage
	Close Sources	Ra-226 (Plaque)	25mCi	8 pieces	
		Co-60	1.000Ci	5 pieces	
Industry Application					
Oil Company, Cigarette Industries, Paper Industries, Mining Company, Schlumberger Company, etc.	Close Sources	Co-60, Cs-137, Sr-90, Am-Be, Kr-85	22.125Ci	37 pieces	Conditioning and Interim Storage
		Ra-226 (Needles)	170mg	17 pieces	
Lighting Protection Devices	Solid Waste	Ra-226	0,72mCi/piece	320 pieces	Conditioning and Interim Storage
		Am-241		489 pieces	
Gas Mantle Lamp Production	Solid Waste (ash)	Th-233, Th-228, Ac-228	2,2µCi/kg	226 Drum 100L	Conditioning and Interim Storage

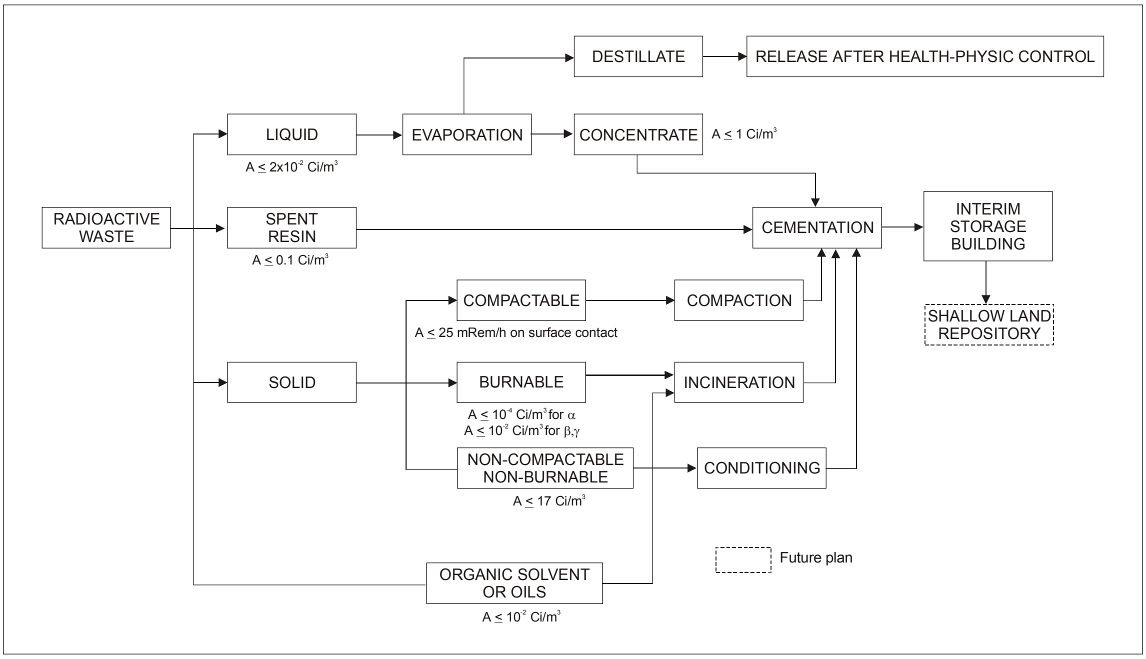

Figure 3.3-4 Radwaste Treatment Processes Existing in Radioactive Waste Management Development Center

The cementation system solidifies evaporator concentrates and spent resins (maximum activity of 0,1Ci/m^3) using 950 *l* concrete shells. The 350 *l* shells and 200 *l* shells are used for immobilization of non-compactible solid wastes such as spent-sources. The compaction system is used to treat low compactible level solid wastes; it compresses solid wastes being contained in 100 *l* mild steel drums. In compacting step, 100 *l* drums are compacted in a 200 *l* steel drum by means of a 600 kN hydraulic press. This drum is then solidified with cement slurry, closed and sealed. The incineration system processes burnable solid wastes having activities of 10^{-4}Ci/m^3 for alpha emitter and of 10^{-2}Ci/m^3 for beta, gamma emitter, waste oils and liquid organic solvents, and animal carcasses into radioactive ashes and off-gases. The radioactive ashes are then solidified by cementation in 100l steel drums. The interim storage used for engineered storage of the solidified wastes covering 100l and 200l steel drum, 200l, 350l and 950l concrete shells.

The Interim Storage for High Radiation Waste Facility (ISHRWF) has been erected and commissioned by 1997. The ISHRWF has 20 dry wells (one capacity is six drums 60l), and three dry ponds (one pond size is 2m X 6m X 6m). The HLW from radioisotopes production and nuclear fuel examination are filled in standard drum 60l, then to be stored in dry well of the ISHRWF. After decay and delay of the radioactivities, the HLW will become low and intermediate waste and then to be treated with the existing waste treatment facility.

The Interim Storage for spent Fuel (ISFSF) has been built and put into cold commissioning in 1998. The capacity of the ISFSF is to be sufficient to store the spent fuel arising over 25 years reactor operation and unloading of the whole fuel in the core since eight fuels to be discharged per cycle for seven cycles per year on the reactor operation (8 x 7 x 25 + 48 = 1,448 elements).

According to the bilateral agreement between the United States and Indonesian governments, the spent fuel having uranium originated from the US must be re-exported back to America. On March 1, 1999, 47 spent fuel elements from RSG-GAS have been sent to the US.

3.3.4 Radioactive Waste Management Facilities

3.3.4.1 Centralized Radioactive Waste Management Station (RWMS)

The Centralized Radioactive Waste Management Station (RWMS) for managing low and intermediate level radioactive wastes has been built and commenced its first operation in 1989.

The RWMS is managed by the Development Center for Radioactive Waste Management (CDRWM). The facilities are located at Kawasan Puspiptek - Serpong.

The RWMS comprises some facilities (units), i.e., Evaporation System (ES), Compaction System (CS), Incinerator System (IS), Cementation System (CeS), Interim Storage for Embedded Waste (ISEW), Interim Storage for High Radiation Waste (ISHRW).

- The evaporation system processes liquid wastes having a maximum activity of $2x10^{-2}Ci/m^3$ into radioactive concentrates (maximum activity $1Ci/m^3$) and normal water distillates. The evaporator unit is a thermo siphon circulating thermal evaporator with $0.75m^3/h$ operating capacity and designed to reduce the waste volume in a maximum ratio of 50:1, depending on initial salinity.
- The cementation system solidifies evaporator concentrates and spent resins (maximum activity $0.1Ci/m^3$) using 950 *l* concrete shells. The 350 *l* shells and 200 *l* shells are used for immobilization of non-compactible solid waste such as spent-sources.
- The compaction system is used to treat compactible low level solid wastes. It compresses solid wastes being contained in 100 *l* mild steel drums. In compacting step, 100 *l* drums are compacted in a 200 *l* steel drum by means of a 600 kN hydraulic press. This drum is then solidified with cement slurry, closed and sealed.
- The incineration system processes burnable solid wastes having activities of $10^{-4}Ci/m^3$ for alpha emitter and of $10^{-2}Ci/m^3$ for beta, gamma emitter, waste oils and liquid organic solvents, and animal carcasses into radioactive ashes and off-gases. The radioactive ashes are then solidified by cementation in 100l steel drum.
- The interim storage used for engineered storage of the solidified wastes covering 100l and 200 *l* steel drum, 200 *l*, 350 *l* and 950 *l* concrete shells.
- The Interim Storage for High Radiation Waste (ISHRW) has been erected and commissioned in 1997. The ISHRW has 20 dry wells (capacity is six 60 *l* drums), and three dry ponds (one pond size is 2m x 6m x 6m). The HLW from radioisotopes production and nuclear post irradiation fuel examination are filled in standard 60 *l* drums, then stored in dry well of the ISHRW. After decay and delay of the

radioactivity, the HLW will transform into low and intermediate waste and then to be treated with the existing waste treatment facility.

3.3.4.2 Interim Storage for Spent Fuel (ISFSF)

The Interim Storage for Spent Fuel (ISFSF) has been built and put into cold commissioning in 1998.

The capacity of the ISFSF is sufficient to store the spent fuel arising over 25 years of research reactor operation. The ISFSF facility is under the management of the Development Center for Research Reactor Technology.

Research and development (R&D) in various fields of radioactive waste management is carried out to meet the present and future needs. The Serpong Nuclear Facilities for radioactive waste management have been operating since 1989. Several research activities to support routine operation of waste management have been already performed, some of its results being, for example, the utilization of silicone oil anti-foaming on the evaporation process, de-scaling process of the evaporator circuits, utilization of evaporation data to determine fouling factor, utilization of some additives for cementation process, study of chemical treatment, design-construction and commissioning of chemical treatment plant. R&D activities to meet the future needs have also been performed, i.e., study on waste disposal siting and preliminary environmental impact assessment on candidate NPP site. Research activities concerning the HLW has been conducted using simulated solution of waste, i.e., process to separate fission product (FP) and actinides (TRU), followed by immobilization of FP by vitrification and immobilization of TRU waste by polymerization.

3.3.5 Inventory of Radioactive Waste

Some achievements in the management of low and intermediate level radioactive waste by DCRWM has been made since 1990 to 2000 as shown in Table 3.3-2.

All of the liquid, semi-liquid, solid and HEPA filter wastes coming from BATAN activities were processed and stored in the interim storage. The spent sources and sealed sources coming from the nuclear medicine activities were stored in the ISHRW and the wastes coming from industry (oil company, cigarette industry, mining company, etc.) were subject to conditioning and stored in the interim storage.

3.3.6 Present Status of Research Reactor Decommissioning Program

At present, Indonesia has three research reactors: a 30 MW MTR type multipurpose reactor at Serpong Site, a 1 MW TRIGA type research reactor at Bandung Site and a small 100 kW TRIGA type reactor at Yogyakarta Research Center. The Research Reactor data are shown in Table 3.3-3.

Table 3.3-3. Research Reactors in Indonesia

Place/Site	Maker	Type	Power	Critical	Status
Bandung	GA	TRIGA	1,000 kW	1971	Upgraded to operational condition of 2MW (start of operation on June 24, 2000)
Yogyakarta	GA	TRIGA	100 kW	1979	In preparation for up-rating
Serpong	Interatom	MTR	30 MW	1987	Operational

The old one is the TRIGA Reactor at Bandung Site that reached its criticality at 250kW in 1964, and then was operated at the maximum power of 1,000 kW in 1971. The reactor totally has been operated for 35 years. There is no decision yet for decommissioning this reactor, however sooner or later it will be an object for the near future decommissioning program. An anticipation for the above situation is necessary. Until now, the regulation for the decommissioning of research reactor is available and the regulatory has been separated from the executing body. For Indonesian case, an early decommissioning strategy for research reactor and restricted use of the site for other nuclear installation is more favorable taking into account high land pricing, availability of radwaste repository, and cost analysis.

The spent graphite reflector from TRIGA reactor is recommended to be stored in the interim storage and disposed of after conditioning, without volume reduction treatment. The development of human resources and technological capability, as well as information flow from advanced countries, are important factors for the future of research reactor decommissioning program in Indonesia.