3.3 Radioactive Waste management (RWM) in Indonesia

At the present time, The Radioactive Waste Technology Center (RWTC) 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. RWTC is equipped with evaporator, compactor, incinerator, chemical treatment, conditioning facilities for spent sources and also interim storage and quite recently been assigned to be responsible to manage the interim storage for spent fuel from the adjacent MTR type research reactor.

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 radionuclide, 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 general policy of the government of Indonesia is to return the spent sealed sources to the origin as much as possible. The RWTC 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 detector and lightning arresters. The RWTC is developing the management information system (MIS) for keeping database of all waste stored in the premises of RWTC. This system is used to identify accurately and immediately the radioactive waste being on the transportation as well as in the storage. The other objective of MIS is to control the record of the waste history (transportation, treatment/conditioning, and storage).

3.3.1 Radioactive Waste Management 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 Bandung Nuclear Research Center in 1965. In 1971, the power was upgraded to 1000 kW for routine production of radioisotopes, and then it was upgraded further to

2000 kW on June 24, 2000. In 1979, TRIGA MARK II 250 kW at Yogyakarta Nuclear Research Center was commissioned.

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, then dilute, disperse and discharge in 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 Centralized Radioactive Waste Management Station (RWMS) was established in Serpong and started its operation in 1989. The RWMS is under the management of the Radioactive Waste Technology Center. This 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 premises (i.e. resulting from nuclear applications) are mostly resulting from activities in: 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 institute.

Radioactive wastes resulting from BATAN Research Centers are originated from:

- Serpong Site
  - MPR-30 research reactor operation
  - Radioisotope and radiopharmaceutical production activities
  - Research and power reactor fuel element fabrication activities
  - Radio metallurgy activities.

- Outside of Serpong Site
  - Bandung nuclear research complex
  - Yogyakarta nuclear research complex
  - Pasar Jum'at nuclear research complex

Since the beginning of the nuclear activities in Indonesia, the National Nuclear Energy Agency of Indonesia (BATAN) 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 minimum 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 the future generation.

3.3.2 Radioactive Waste Management 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, since 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) 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*:

- 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 (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)

- 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)).

Furthermore,

- 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)

- 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 Regulation {Article 27 (2)}

With respect to 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 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)}

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 the Government after getting an agreement from the House of Representatives of the Republic of Indonesia

Elucidation of Article 25 prohibits the use of any part of Indonesian territory for any foreign or other country radioactive waste repository.

The provisions for the HLW contained in Act No. 10/1997 on Nuclear Energy are a legal platform, from which the Government Regulations and the decrees of the 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 the 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 the 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 define the responsibility of licensee which generates 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 the Regulatory Body

In addition, it will cover also 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 Government 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 management of 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 advice 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 promotion side, i.e. the National Nuclear Energy Agency and the

Ministry of Research and Technology respectively sets up the plans and coordinates research and development activities.

On the regulatory side, the Nuclear Energy Control Board, the Ministry of Health and the Ministry of Environment respectively 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 organization to comply with basic radiation protection requirements as described in ICRP and IAEA Basic Safety Standard. The Radioactive Waste Technology Center, BATAN is the undertaking organization, as well as the responsible party for carrying out the radioactive waste management which is the statutory task of the Executing Body. The scheme of control mechanism of nuclear activities in Indonesia is shown in Figure 3.3-2.

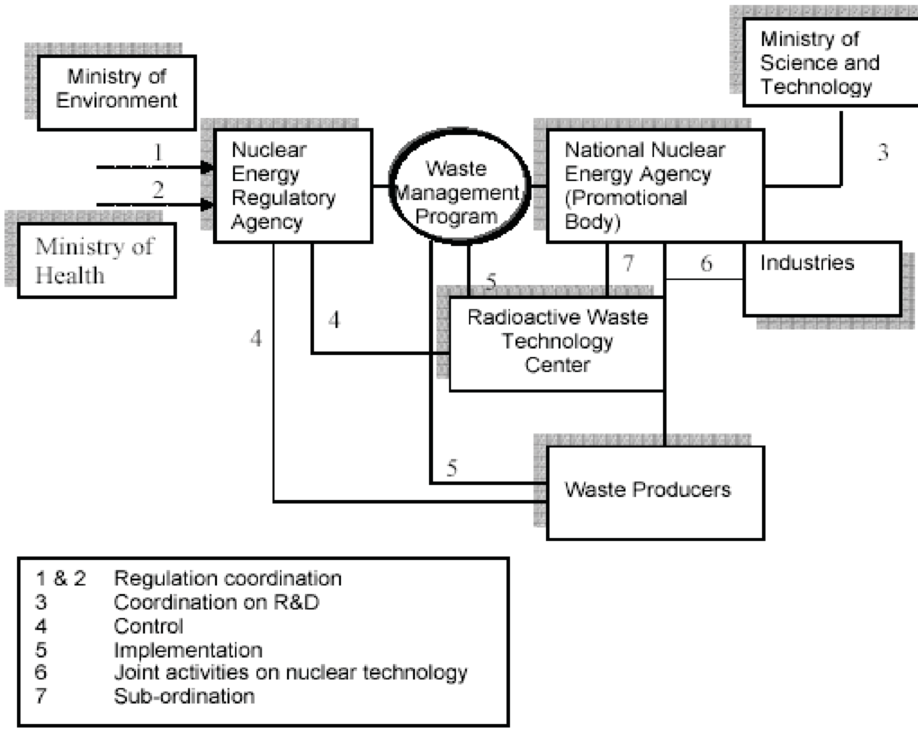

Figure 3.3-1 Radwaste Management Structure in Indonesia

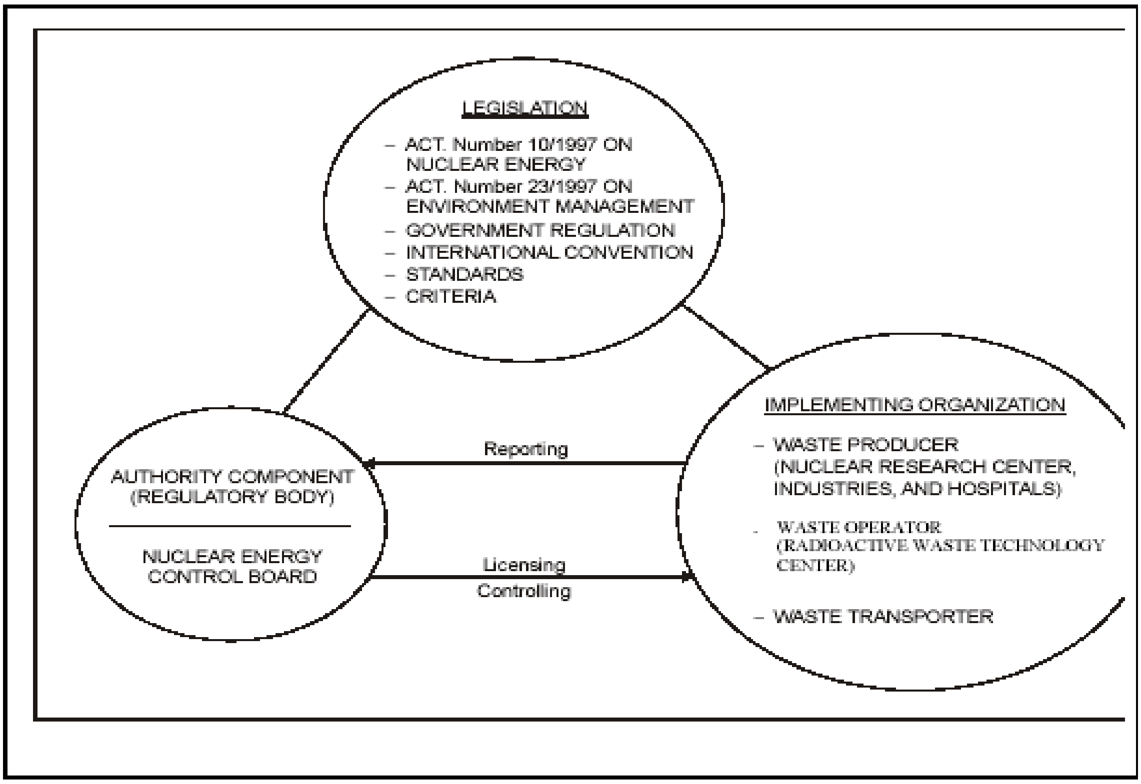

Figure 3.3-2 Scheme of Control Mechanism
Control of Nuclear Activities in Indonesia

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 from the Executing Body.

The regulation is prepared to regulate and control the nuclear activities by the regulatory body in compliance with basic radiation protection requirements as described in ICRP and IAEA Basic Safety Standard and other applicable requirements, early the planning stage of a project in the forms of environment impact analysis preparation, licensing application, regulating and controlling of activities. Certain necessary rules and regulation for the management of radioactive waste have been issued as indicated in Table 3.3-1.

Table 3.3.1 List of Existing Indonesian Government Regulations Concerning Radioactive Waste Management

No.	Name of Regulation
1.	Government Regulation No. 11/1975 on Working Safety Against Radiation
2.	Government Regulation No. 12/1975 on Licensing of Utilization of Radioactive Materials and or Another Radiation Sources
3.	Government Regulation No. 13/1975 on Transport of Radioactive Materials
4.	Government Regulation No. 51/1993 on the Preparation of Environment Impact Analysis
5.	Decree of the Minister of Environment No. Kep.-42/MENLH/1994 on General Guidelines on Environmental Audit
6.	Decree of the Minister of Environment No. Kep.-39/MENLH/1996 on Criteria of Activities Requiring an 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 the President of the Republic of Indonesia No. 76/1998 on Nuclear Energy Control Board
10.	Decree of the Chairman of the Nuclear Energy Control Board No. 01/Ka. BAPETEN/V-99 on Provisions for Occupational Safety Against Radiation
11.	Decree of the Chairman of the Nuclear Energy Control Board No. 02/Ka. BAPETEN/V-99 on Radioactivity Dose Value for the Environment
12.	Decree of the Chairman of the Nuclear Energy Control Board No. 03/Ka. BAPETEN/V-99 on Safety Aspect of Radioactive Waste
13.	Decree of the Chairman of the Nuclear Energy Control Board No. 04/Ka. BAPETEN/V-99 on Radioactive Materials Transport Safety
14.	Decree of the Chairman of the Nuclear Energy Control Board No. 06/Ka. BAPETEN/V-99 on Construction and Operation of Nuclear Reactor
15.	Decree of the 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 inter-relations of them are shown in Fig. 3.3-3.

The user generating high level radioactive waste (i.e. the spent fuels) 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 such high level radioactive wastes.

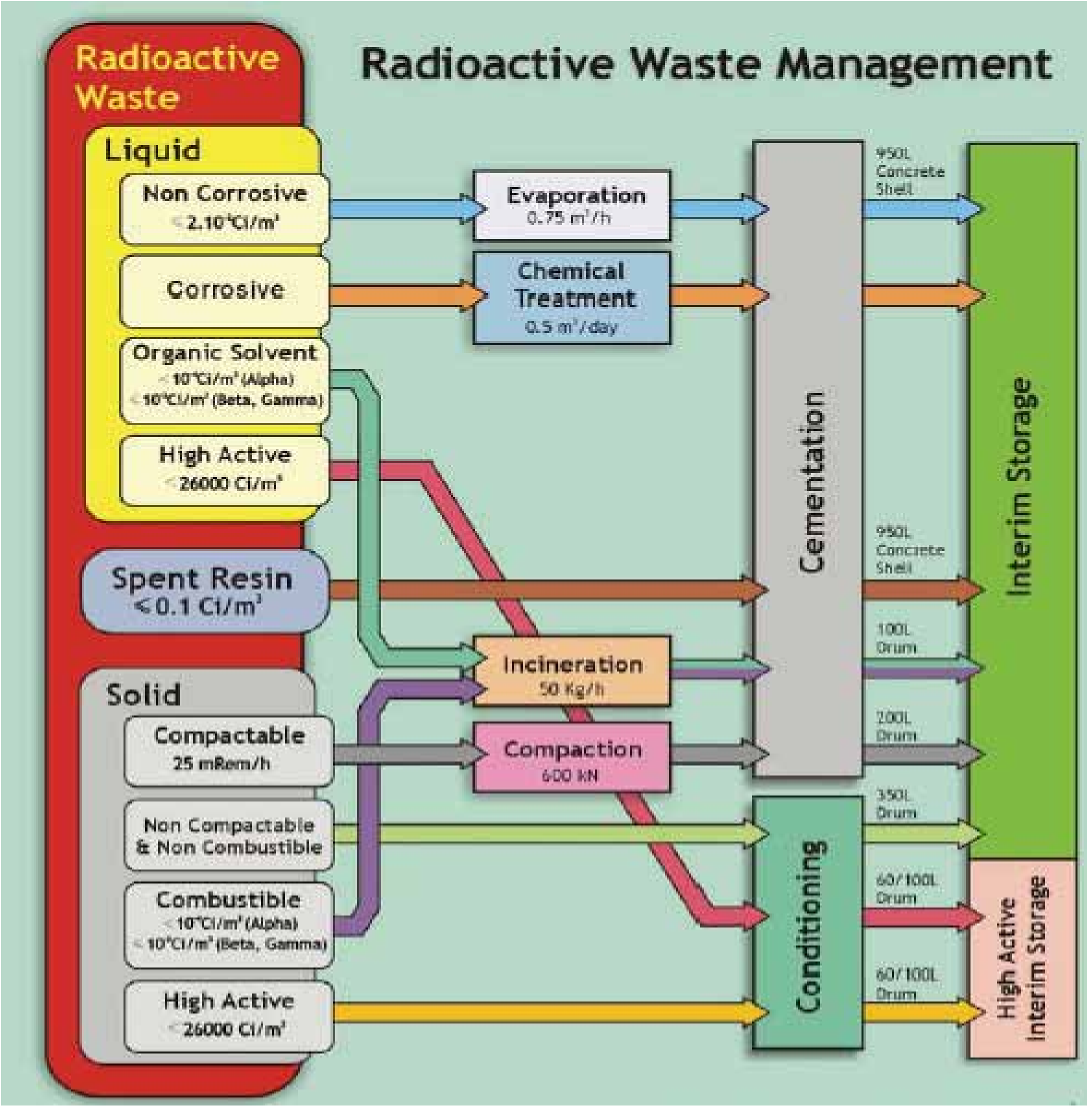

Figure 3.3-3 Principles of Management of Low and Intermediate Level Wastes

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 designate a state-owned 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 to 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 obligated to temporarily store those wastes (spent fuels) 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.

Further, the 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 is accommodated in chapter VII are 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 Use to Define and Categorize Radioactive Waste

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

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

From the radioisotope facility the liquid radioactive waste consists of low level originated from shower and wash water, decontamination activities, etc. having a maximum activity of 10^{-2} Ci/m^3, and high level waste coming from the processing of irradiation target in the hot cell. The solid waste are classified into two categories, one having dose rate less than 1000 mR/h at the surface.

The radioactive liquid wastes that come from fuel element fabrication are 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, shoes-cover, gloves, etc. on the maximum dose rate 25 mR/h, are collected in plastic bags and put into 100 l drums and brought to the RWMS.

The radioactive waste from nuclear medicine operation consists of spent sources i.e. Cs-137, Ra-226, and C0-60 and liquid waste i.e. I-131 liquid excretions.

From industrial application the radioactive waste consists of spent sources for radiography, logging and gauging, lightning protection devices, as well as 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.

The evaporation system processes liquid wastes has a maximum activity of 2 x 10^{-2} Ci/m^3 into radioactive concentrates (maximum activity 1 Ci/m^3) and normal water distillates. The evaporator unit is a thermo siphon circulating thermal evaporator with 0.75 m^3/h operating capacity and is designed to reduce the waste volume in a maximum ratio of 50 : 1 depending on the initial salinity.

The cementation system solidifies evaporator concentrates and spent resins (with a maximum activity of 0.1 Ci/m^3) using 950 l concrete shells. The 350 l shells and 200 l shells are used for immobilization of non-compatible solid waste such as spent-sources. The compaction system is used to treat low compactable 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's carcasses into radioactive ashes and off-gases. The radioactive ashes are then solidified by cementation in 100 l steel drum. The interim storage used for engineered storage of the solidified wastes covering 100 l and 200 l steel drum, 200 l, 350 l and 950 l concrete shells.

The Interim Storage for High Level Waste (ISHLW) has been erected and commissioned by 1997. The facility has 20 dry wells (each having capacity of 6 drums of 60 l), and three dry ponds (one pond size being 2 m x 6 m x 6 m). The HLW from radioisotopes production and nuclear fuel examination are filled in standard drums of 60 l, then stored in the dry well of the ISHLW. After decay of the radioactivity, the HLW will become low and intermediate waste and then be treated in the existing waste treatment facility.

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

According to the bilateral agreement between the United States and Indonesia, the spent fuel having uranium originated from USA could be re-exported back to America. On March 1, 1999, a batch of spent fuel elements from RSG-GAS has been sent to US. Further on, in 2004 another batch of fuel elements were returned to USA.

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 operates under the management of the Radioactive Waste Technology Center. The facilities are located at the premise of the Center at Kawasan PUSPIPTEK, Serpong.

The RWMS comprises some facilities (processing 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 Level Waste (ISHLW).

- The evaporation system processes liquid wastes having a maximum activity of 2×10^{-2} Ci/m^3 into radioactive concentrates (maximum activity 1 Ci/m^3) and normal water distillates. The evaporator unit is a thermo siphon circulating thermal evaporator with 0.75 m^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 0.1 Ci/m^3) using 950 l concrete shells. The 350 l shells and 200 l shells are used for immobilization of non-compatible solid waste such as spent-sources.

- The compaction system is used to treat compactable 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's carcasses into radioactive ashes and off-gases. The radioactive ashes are then solidified by cementation in 100 l steel drum.

- The interim storage used for engineered storage of the solidified wastes covering 100 l and 200 l steel drum, 200 l, 350 l and 950 l concrete shells.

- The Interim Storage for High Level Waste (ISHLW) has been erected and commissioned by 1997.

    1. The ISHRW has 20 dry wells (one capacity is 6 drums 60 l), and three dry ponds (one pond size is 2 m x 6 m x 6 m).
    2. The HLW from radioisotopes production and nuclear post irradiation fuel examination are filled in standard 60 l drums, and then stored in dry well of the ISHRW.

3. 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.

3.3.4.2.1 Interim Storage for spent Fuel (ISFSF)

The Interim Storage for spent Fuel (ISSF) has been built and put into cold commissioning in 1998. The capacity of the ISSF is to be sufficient to store the spent fuel arising over 25 years of research reactor operation. The ISSF facility is under the management of the Radioactive Waste Technology Center.

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 sitting and preliminary environment impact assessment on candidate NPP site. Research activities concerning the HLW have been conducted using simulated solution of waste i.e. process to separate fission product (FP) and actinides (TRU) fol1lowed 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 RWTC has been accomplished since 1990 to 2000 as shown in Table 3.3-2. All of the liquids, semi liquid, solid and HEPA filter waste 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 ISHLW and the waste coming from industry (oil company, cigarette industry, mining company, etc.) were conditioned and stored in the interim storage.

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

No.	Source of Radioactive Waste	Type of Waste	Major Radionuclides	Activity Level (Radiation Dose)	Quantity of Waste	Management Process
1.	BATAN Nuclear Research Center	Liquid Waste	Co-60, Cs-137, Zn-65, Cd-109, Mn-54, Zr-95	$10^{-6} \le A \le 10^{-2}$ Ci/m^3	224 m^3/year	Evaporation, Cementation and Interim Storage
		Semi Liquid (Spent Resin)	Co-60, Cs-137, I-131	1 Ci/m^3	2.001 l/year	Cementation and Interim Storage
		Solid Waste	Cs-137, I-131, I-125	Max. 25 mRem/hour	1.184 drums	Compaction, Cementation and Interim Storage
			Co-60	Max. 200 mRem/hour	32 shell	Delay, Decay, Cementation and Interim Storage
		HEPA Filter	Co-60, I-125	5 mRem/hour	142 pieces	Compaction, Cementation and Interim Storage
2.	Nuclear Application Nuclear Medicine (Hospital)	Spent Sources Close Sources	Cs-137 Ra-226 (Plaque) Co-60	(400 - 1.300) Ci 25 mCi 1.000 Ci	25 pieces 8 pieces 5 pieces	Interim Storage
3.	Industrial Application (Oil Company, Cigarette Industries, Paper Industries, Mining Company, Schlumberger Company, etc.)	Close Sources	- Co-60, Cs-137, Sr-90, Am-Be, Kr-85 - Ra-226 (Needles)	22.125 Ci 170 mg	37 pieces 17 pieces	Conditioning, and Interim Storage
	- Lighting Protection Devices	Solid Waste	Ra-226	0,72 mCi/piece	320 pieces	Conditioning, and Interim Storage
			Am-241		489 pieces	
	- Gas Mantle Lamp Production	Solid Waste (ash)	Th-233, Th-228, Ac-228	2,2 µCi/kg	226 Drum 100 L	Conditioning and Interim Storage

3.3.6 Present Status of Research Reactor Decommissioning Program

At present Indonesia has 3 research reactors: a 30 MW MTR type multipurpose reactor at Serpong Site, a 2 MW TRIGA type research reactor at Bandung Site and a small 100 kW TRIGA type reactor at Yogyakarta site. The Research Reactor data are shown in Table 3.3-3

Table 3.3-3 Research Reactor Data in Indonesia

Place/Site	Maker	Type	Power	Critical	Status
Bandung	GA	Triga	1000 kW	1971	Upgrading for operational condition of 2 MW (start operation on July 24, 2000
Yogyakarta	GA	Triga	100 kW	1979	In preparing for up-rating
Serpong	Interatom	MTR	30 MW	1987	Operation

The oldest reactor is the TRIGA Reactor at Bandung Site that reached criticality at 250 kW on 1964, and then was operated at a maximum power of 1,000 kW in 1971. The reactor totally has been operated for 35 years. There is no decision yet for the decommissioning this reactor, however sooner or later it will be an object for the near future decommissioning program. Anticipation for the above situation is necessary. Until now, the regulation for the decommissioning of research reactor has been available and 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, talking into account the high land pricing, the availability of radioactive waste repository, and cost analysis.

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