FNCA RS-001

FNCA Consolidated Report on Radiation Safety (Draft)

March 2011

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

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I. Preface

Through the activities of Radiation Safety and Radioactive Waste Management (RS & RWM) Group in the Forum for Nuclear Cooperation in Asia (FNCA), we present the book of “The Consolidated Report on Radiation Safety and Radioactive Waste Management in FNCA Countries”. The purpose of this report is a summary of this region based on the mutual understanding on RS & RWM in FNCA countries. The authors believe the reference of this book will cause further improvements of radiation safety and radioactive waste managing level in FNCA countries.

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II. Framework of Regional Cooperation under FNCA

1. Introduction of FNCA

The Forum for Nuclear Cooperation in Asia (FNCA) has evolved from the International Conference for Nuclear Cooperation in Asia (ICNCA) which was established in 1990 with the aim of promoting the application of nuclear technology through collaboration among Asian countries. During this period the sharing of information, exchanges of scientific personnel and active cooperative research have been pursued in several fields.

2. Participating Countries

Australia, Bangladesh, China, Indonesia, Japan, Kazakhstan, Korea, Malaysia, Mongolia, Philippines, Thailand and Viet Nam

3. Goals

• To achieve socio-economic development by safe utilization of nuclear technology
• To utilize nuclear technology in those fields where it has a distinct advantage
• To respond to the needs of the FNCA countries

4. Operational Strategies

1) Framework of Operation

The basic framework of cooperation consists of the following three:

❑ **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**

(See the figure on the next page):

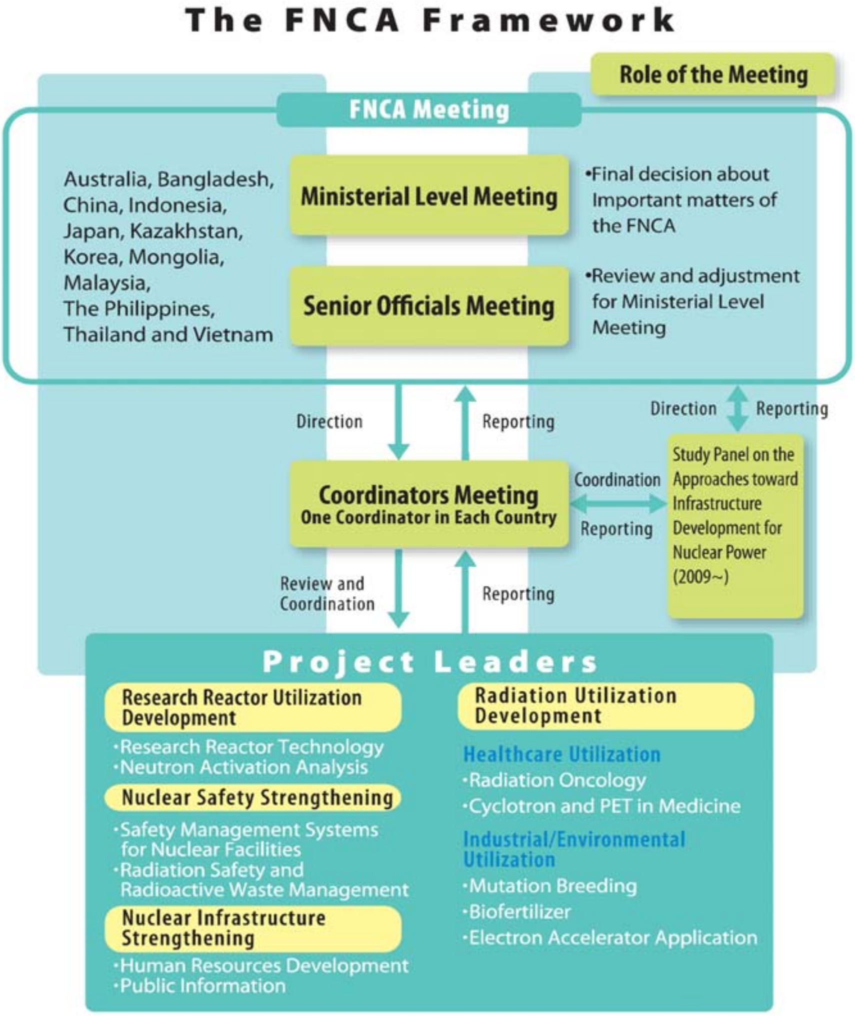


Figure: FNCA Framework

5. 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 RWM Consolidated Report on RWM/RS. These reports are available on the FNCA Website.

[URL: http://www.fnca.mext.go.jp/english/e_project.html]

III. Status of Radiation Safety in FNCA Member Countries

1. Australia

1. Australia

Part 1. Radiation Safety in Radiation Industry Facilities

1.1 General

1.1.1 Legislative Framework and Policy for Radiation Safety

There are nine jurisdictions for radiation protection in Australia - the federal government, six States, and two Territories. Radiation Safety legislation is implemented within each jurisdiction in Australia and is in compliance with the IAEA BSS and IAEA GS-R-1. A committee comprised of Commonwealth and State representatives ensures national coordination between jurisdictions.

1.1.2 Structure and System (Regulatory organizations)

Australia has a federal system of government, and the regulation of radiation safety and radioactive waste management and disposal comes under both Commonwealth (federal) and State/Territory regulation. The States and Territories are responsible for regulating the use, manufacture, transport and disposal of radioactive materials under their control or the control of private companies or individuals in accordance with State and Territory Acts and Regulations. These Acts and Regulations are administered by State or Territory radiation safety authorities such as the environmental protection authorities and health departments in each state.

Table 1: Legislative jurisdictions, Regulators and Regulations

Jurisdiction	Regulator	Acts/Regulations
New South Wales	Department of Environment, Climate Change and Water	**Radiation Control Act 1990, Radiation Control Regulation 2003**
Australian Capital Territory	ACT Health	**Same as Federal government**
Victoria	Department of Health	**Radiation Act 2005, Radiation Regulations 2007**
Tasmania	Dept of Health and Human Services	**Radiation Protection Act 2005 and Radiation Protection Regulations 2006**
South Australia	Environment Protection Authority	**Radiation Protection and Control Act 1982, Radiation Protection Control (Ionising Radiation) Regulations 2000, Radiation Protection and Control (Transport of Radioactive Substances) Regulations 2003**
Western Australia	Radiological Council	**Radiation Safety Act 1975-1999, Radiation Safety (General) Regulations 1983-2003, Radiation Safety (Qualifications) Regulations 1980-2000, Radiation Safety (Transport of Radioactive Substances) Regulations 2002**
Queensland	Queensland Health	**Radiation Safety Act 1999, Radiation Safety Regulation 1999.**
Northern Territory	Department of Health and Families	**Radiation Protection Act 2009, Radiation Protection Regulations 2009.**
Federal government	**Australian Radiation Protection and Nuclear Safety Agency**	**Australian Radiation Protection and Nuclear Safety Act No. 133, 1998, Australian Radiation Protection and Nuclear Safety Regulations 1999.**

Similarly, the Commonwealth Government is responsible for managing radioactive material in organisations under its control, including Departments, Agencies, Bodies Corporate and contractors. All activities undertaken by these organisations with respect to radiation (including nuclear activities, dealings, handling radioactive materials or transport) are regulated by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), which is funded by government as part of the Health and Ageing Portfolio. This includes regulating the management of nuclear activities and storage of radioactive waste at Commonwealth agencies such as the Australian Nuclear Science and Technology Organisation (ANSTO), the Commonwealth Science Industry and Research Organisation (CSIRO) and the Department of Defence.

ARPANSA is also tasked with promoting uniformity of radiation protection and nuclear safety policy and practices across all jurisdictions (Commonwealth, the States and the Territories). In addition to the Acts and Regulations listed in the table above, a series of codes and standards on radiation protection have been issued by ARPANSA as the Radiation Protection Series and provide guidelines for handling, processing and disposal of radioactive materials and waste. These codes and standards are issued following Commonwealth/State consultation and public comment.

As part of ARPANSA's Radiation Protection Series, A National Directory for Radiation Protection was established to provide an agreed framework for radiation safety, including both ionizing and non-ionizing radiation, together with clear regulatory statements to be adopted by the Commonwealth, States and Territories. The regulatory elements of the Directory are adopted and enforced by each jurisdiction using existing Commonwealth/State/Territory regulatory frameworks. The first edition of the directory was published in 2004 and an amended version released in 2010 for adoption by the States and Territories.

1.2 Outline of Radiation Facilities and Radiation Sources

1.2.1 Number of Specialists and Workers in Related Organizations

The number of people working with radiation related industry in Australia is difficult to correctly define however a number is available and is referenced in the Australian Radiation Protection And Nuclear Safety Agency (ARPANSA) Technical Report 139, "Personal Radiation Monitoring Service and Assessment of Doses Received by Radiation Workers (2004)". ARPANSA provides a Personal Radiation Monitoring Service that enables radiation workers to monitor the radiation dose received in their occupations. Currently the Service monitors approximately 35,000 workers and maintains dose histories for over 115,000 people.

Refer to date from Tables 3,4 &5 of TR 139.

1.2.2 Number of Radiation Facilities including Related Facilities

There are a number of small commercial and state run operators of radiation facilities associated chiefly with medical treatment. These include eight cyclotron facilities in operation in Australia: three in Melbourne, two in Sydney, one in Perth and two in Brisbane. There are around 100 linear particle accelerators Australia wide which are located in cancer treatment facilities. There are also 2 commercial facilities for the irradiation of food which are located in NSW and Victoria.

The largest radiation facilities are run by the Australian government. These include:

- OPAL, a 20 MW open pool light water research reactor and associated neutron scattering facilities at ANSTO. ANSTO produces radioisotopes for medical and commercial use from reactor operations and also operates the Gamma Technology Research Irradiator.

- The Australian Synchrotron, a 3 GeV radiation facility built in Melbourne, Victoria

1.2.3 Activity and Number of Radiation Sources and Generators

Sources are registered with the relevant regulators in each state and territory however there are no inventories for these in each jurisdiction. ANSTO maintains inventories of its radioactive sources which are licensed by ARPANSA.

Large inventories of disused radioactive sources exist in many countries that have no other nuclear activities and therefore represent the only radioactive waste that needs to be managed safely. The absence of nuclear activities may also contribute to the risk associated with the management of disused radioactive sources since these countries often lack the necessary infrastructure and technical personnel required for the safe management of radioactive waste. Whilst Australia does not lack the necessary infrastructure to manage its disused sources the absence of a centralised storage or disposal facility for such radioactive sources provides for a level of concern and uncertainty.

In Australia the main source and generation of spent and disused sources is in medical applications by hospitals and medical facilities typically for teletherapy and brachytherapy applications. Most of the old radium sources used in brachytherapy have been replaced by 60Co, 137Cs and 192Ir. Cobalt-60 is the most common radionuclide used in teletherapy, although some 137Cs sources are also in use. Gamma radiation is used to treat approximately half of all cancer patients with solid tumours. Cobalt and caesium teletherapy sources are among the higher activity sources in general use.

Radioactive sources are also used in education and research and contain a wide variety of radionuclides including Co60, Cs136 and Am-241. Industrial applications typically use I-131 for

Non-destructive imaging of pipe welds. Cobalt-60 and 137Cs sources are also used for industrial radiography. Large neutron and gamma sources are used in mining, as well as in oil and gas well logging. The most common industrial radioactive sources are used in level and thickness gauges and in process control. If these gauges are not removed when a facility is closed, they can end up in metal recycling facilities.

ARPANSA's Radiation Health & Safety Council is looking into Australia's need to establish a process that ensures the integrity and security of a source database, security checks, and threat of diversion of radioactive material. ANSTO is coordinating and funding the S-E Asia Regional Security of Radioactive Sources Project to address awareness of poorly controlled or vulnerable radioactive sources in S-E Asia and the Pacific, a lack of border controls, detection capability and regulation. The aim of the ANSTO project was to prevent acquisition of sources by unauthorised persons, and prevent serious accidents from uncontrolled sources. The four objectives were to strengthen regulatory and legislative controls, apply standards and train regulators, develop capabilities in equipment and provide training in its operation, and to identify and address situations involving vulnerable or orphan radioactive sources. Outcomes of the project so far included regulations developed and being implemented in Indonesia, Philippines and Vietnam, with progress in Malaysia and Thailand. Radiation detection equipment provided (with US NNSA) to Indonesia, Philippines, Vietnam, Thailand and Cambodia, including training. Capacity building has included running over 20 workshops for 430 participants from 11 countries. Source management activities have included identifying and managing orphan sources in Cambodia and PNG, assessing storage of disused sources in Indonesia, Philippines, Vietnam and Thailand, and giving advice on disused sources in Fiji, Vietnam and Cambodia.

1.3 Education and Training

1.3.1 Radiation Industry Usage

The ARPANSA National Directory for Radiation Protection requires that all occupations and professions who use radiation sources meet the relevant professional competency requirements. In most cases, competency is evidenced by formal qualification in their field and radiation safety training is incorporated in the overall curriculum. Health related occupations include medical practitioners, dental practitioners, veterinary surgeons, diagnostic radiographers, radiation therapists, nuclear medicine technologists, health and medical physicists and chiropractors. Industry related occupations include industrial radiographers, borehole loggers, radiation source testers and persons servicing, installing, commissioning, maintaining, repairing or manufacturing radiation sources. The evidence of qualification required for each of these occupations is listed in Schedule 6 – Competency Requirements for Authorisation to Use Radiation Sources for Specified Practices (ARPANSA National Directory for Radiation Protection).

1.3.2 Radiological Protection

Education and training in radiation safety and radiological protection is provided by numerous companies, health departments and institutions within Australia with formal training courses undergoing approval by ARPANSA. There are around fifty providers of around 100 radiation safety training courses covering subjects including general radiation awareness, radiation protection, use of radionuclides, use of gauges, transport, and use of radiation in medical procedures.

1.4 Standardization on Radiation and Radioactivity

Training courses are developed according to the jurisdictional regulations and as such there may be some different recommendations and exemption criteria (some are based on total activity and others are on activity concentration). However, the approaches to radiation protection should be generally consistent and the dose limits in line with those stated in the National Directory for Radiation Protection (see Table 2).

Part 2. Status of Radiation Safety Management

2.1 Radiation Safety Management in various Radiation Industries

2.1.1 Radiation Safety Management System

The management of radiation safety within various radiation industries is governed by the jurisdictional regulator according to their regulations, standards and codes. Federally, the management of radiation safety is governed by the specific standards, codes and guides in the Radiation Protection Series (RPS) published by ARPANSA.

These encompass all radiation management considerations for research, industrial and medical related facilities as follows:

- Limiting exposure to ionizing radiation and national standard for limiting occupational exposure to ionizing radiation (RPS 1)
- Code of practice and safety guide for the safe transport of radioactive material (RPS 2 & 2.1)

- Recommendations for the discharge of patients undergoing treatment with radioactive substances (RPS 4)
- Code of practice and safety guide for portable gauges containing radioactive sources (RPS 5)
- National Directory for Radiation Protection, December 2009 (RPS 6)
- Recommendations for intervention in emergency situations involving radiation exposure (RPS 7)
- Code of practice for exposure of humans to ionizing radiation for research (RPS 8)
- Code of practice and safety guide for radiation protection and radioactive waste management in mining and mineral processing (RPS 9)
- Code of practice and safety guide for radiation protection in dentistry (RPS 10)
- Code of practice for the security of radioactive sources (RPS 11)
- Code of practice and safety guide for safe use of fixed radiation gauges (RPS 13)
- Code of practice for radiation protection in the medical applications of ionizing radiation (RPS 14) and safety guides for radiation protection in diagnostic and interventional radiology, nuclear medicine and radiotherapy (RPS 14.1, 14.2 and 14.3)
- Safety guide for the management of naturally occurring radioactive material (NORM) (RPS 15)
- Safety guide for the predisposal management of radioactive waste (RPS 16)
- Code of practice and safety guide for radiation protection in veterinary medicine (RPS 17)
- Code of practice for radiation protection in the application of ionizing radiation by chiropractors (RPS 19)

2.1.2 Radiological Protection for Radiation Workers

An increase in a person's exposure to ionizing radiation, even at low doses, is assumed to increase the risk of harm to that person's health. As such, all radiation industries and facilities are required to implement a system of radiation protection which limits possible detrimental effects arising from occupational radiation exposure. This ALARA approach involves the design of processes in such a way as to minimise exposure and to ensure that occupational dose limits are met. Radiological protection is achieved through the following hierarchy:

- avoidance of exposure, where practicable;
- isolation of sources of radiation, where practicable, through shielding,
- containment and remote handling techniques;
- engineering controls, such as local exhaust ventilation to remove contaminants from the workplace environment;
- adoption of safe work practices, including work methods which make appropriate use of time, distance and shielding to minimise exposure; and
- where other means of controlling exposure are not practicable, the use of approved personal protective equipment.

ARPANSA has derived dose limits for ionizing radiation to be adopted nationwide as follows:

Table 2: Radiation Dose Limits

	Dose limit[1]	
Application	**Occupational**	**Public**
Effective dose	20 mSv per year, averaged over a period of 5 consecutive calendar years[2,3]	1 mSv in a year[4]
Annual equivalent dose in		
the lens of the eye	150 mSv	15 mSv
the skin[5]	500 mSv	50 mSv
the hands and feet	**500 mSv**	**-**

1 The limits shall apply to the sum of the relevant doses from external exposure in the specified period and the 50-year committed dose (to age 70 years for children) from intakes in the same period.
2 With the further provision that the effective dose shall not exceed 50 mSv in any single year. In addition, when a pregnancy is declared by a female employee, the embryo or foetus should be afforded the same level of protection as required for members of the public.
3 When, in exceptional circumstances, a temporary change in the dose limitation requirements is approved by the appropriate authority, one only of the following conditions shall apply: (a) the effective dose limit shall not exceed 50 mSv per year for the period, which shall not exceed 5 years, for which the temporary change is approved, or (b) the period for which the 20 mSv per year average applies shall not exceed 10 consecutive years and the effective dose shall not exceed 50 mSv in any single year.*
4 In special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year.
5 The equivalent dose limit for the skin applies to the dose averaged over any 1 cm^2 area of skin, regardless of the total area exposed.

Regulatory requirements are in place in all jurisdictions for controlling exposure to medical personnel. These are implemented by a well qualified workforce of medical and hospital physicists who interact well with each other through professional bodies.

Doses to radiation workers are measured either through thermoluminescent dosimeters or electronic personal dosimeters. ARPANSA provides a national dosimetry service for some 35000 radiation workers nationally on a cost recovery basis. Australian Nuclear Science and Technology Organisation (ANSTO) provides an in-house service for 850 radiation workers and Queensland Health provides a dosimetry service for some 5000 Queensland radiation workers. A variety of other commercial personal dosimetry service providers cater for an estimated 9000 other radiation workers. Calibrations of dosimeters through service providers are traceable to national standards. ARPANSA and ANSTO dosimetry services participated in the IAEA/RCA intercomparisons held under IAEA/RCA RAS/9/029.

Australia does not have a national register for occupational exposures and there are no current plans to establish one. Dose records are held by the operator and the dosimetry service provider and this data is reviewed by the relevant regulator. Individual monitoring for intakes of radionuclides is available from ANSTO and ARPANSA (for whole body monitoring and bioassay).

2.1.3 Radiological Protection for Radiation Area

Monitoring of workplace areas is required to be performed by the operator with regulatory inspectors having the capacity to check this. Commercial consulting services are also available to carry out such monitoring for operators who do not have the required in-house expertise. Radiological protection measures for specific radiation areas are implemented by the operators in order to comply with the relevant regulations.

Through their Radiation Health and Safety Advisory Council, ARPANSA have also identified the need to assess the radiation levels in workplaces not normally associated with radiation activities and to provide technical support. These include potential radiation exposure from:

- Residue Naturally Occurring Radioactive Minerals from historic mineral sands operations.
- Radioactive scale from off-shore oil and gas.
- Mineral processing activities where radiation levels are higher than background.
- Orphan sources which are discovered within the recycling industry.
- Elevated radon levels from decay of naturally occurring radioactive minerals

2.1.4 Radiological Protection for the Public

Radiological protection measures are implemented by the states, territories and federal government for members of the public as an inherent part of applying their regulations regarding general radiation safety. Dose limits for the public are to comply with those specified in ARPANSA's National Directory for Radiation Protection (see Table 2).

ARPANSA have carried out characterisation studies within Australia of radon and natural background to determine expected doses to the public. ARPANSA also assesses radiation doses to the Australian population from medical radiation practices through national surveys. Advice is provided to medical professionals, patients and the public on medical exposures and risks. Additionally, ARPANSA conducts a quality assurance test program to monitor the quality of radiopharmaceuticals and undertakes for the Therapeutic Goods Association (TGA) the evaluation of the chemistry, manufacture, quality control and radiation dosimetry aspects of new drug applications and variations to conditions of TGA registration.

The capability to monitor foodstuffs for radioactivity is available within Australia for specific potential threat situations. ARPANSA, as part of the Commonwealth Department of Health, is the national competent authority for dealing with such threats, for doing check monitoring and issuing guidance advice to all stakeholders.

2.1.5 Radiation Emergency Preparedness

The following organisations are responsible for managing and planning the response to emergencies that may involve radiation:

- National Warning Point – Attorney Generals Department Coordination Centre (AGDCC) , 24h/d
- National Competent Authority - Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) - on call
- Emergency Management Australia (EMA, part of the AGDCC) 24h/d
- Bureau of Meteorology - on call
- State and Federal Police (Victoria, New South Wales, Queensland, Northern Territory, South Australia, Western Australia, Australian Capital Territory, Tasmania, Commonwealth)
- State and Federal Combat Agencies (Fire, Ambulance, State Emergency Services etc.,)
- Australian Defence Force (ADF)

The following plans are in place in the event of a radiological emergency:

- Nuclear Powered Warship accident (OPSMAN1)
- Port Safety Plans/Visiting Ships Operations Orders
- Space debris re-entry (COMDISPLAN SPRED)
- Accident/misuse of Radioactive/Nuclear material and Radiological/Nuclear Terrorism

(COMDISPLAN)

- International Response under Convention for Requesting Assistance

2.2 Radiation Safety Management in Research Reactors

2.2.1 Radiation Safety Management System

Australia's only nuclear reactor (OPAL) is operated by the Australian Nuclear Science and Technology Organisation and is funded by the federal government. As such, ANSTO is regulated by ARPANSA and its safety management system must comply with their requirements. ANSTO is dedicated to implementing international best practice in this area and adopts the relevant recommendations given by the IAEA. ANSTO has adopted an ALARA approach to radiation exposure and have implemented a more stringent internal occupational dose limit of 15 mSv in comparison with the IAEA and ARPANSA limit of 20 mSv per year effective dose.

2.2.2 Radiological Protection for Radiation Workers

ANSTO designs and operates all processes involving radioactivity with the aim of keeping doses ALARA and within their internal dose constraint of 15 mSv per year effective dose. Radiation protection controls are implemented according to the hierarchy described in section 1.2. Processes involving radiation include radioisotope production, research, radioactive waste management and storage of radioactive materials. Dose rates are monitored both through use of area radiation monitors and through personal dosimetry. Health Physics Surveyors are employed to provide radiological advice to personnel, to give on the job monitoring during tasks and to assess the radiological status of work areas. Radioisotope production areas, reactor operations and waste management have on-call access to health physics support with some operations unable to be carried out without a health physics surveyor in attendance.

ANSTO provides an in house dosimetry service for 850 radiation workers which involves a whole body monitoring program for internal dose and external dose measurement using thermoluminescent detectors. Whole body monitoring (internal dose monitoring) is carried out three to four times a year for reactor operators, radioisotope production staff, radioisotope delivery drivers, handlers of nuclear fuel and waste management staff. External dosimetry data collected from thermoluminescent detectors is reviewed on a monthly basis by ANSTO's personal dosimetry service. Any anomalous or unusually high levels of effective dose are investigated to determine the cause of exposure. Through this process of review and investigation, improvements to practices and equipment are identified and implemented in order to prevent continued or potential abnormal high exposure. Radiation workers at ANSTO are also equipped with electronic personal dosimeters which are used to measure their cumulative dose during a certain task or over the course of the day and help them to manage their dose exposure. Urine sampling is carried out for personnel during specific operational campaigns involving exposure to tritium. Thyroid monitoring and urine sampling is carried out for personnel who are involved in the production of Iodine-131.

Radiation workers are equipped with the personal protective equipment (PPE) required for the particular work area (depending on its radiation classification) and for specific tasks. In classified radiation areas compulsory PPE include overshoes, overcoats, and safety shoes. For tasks involving radioactive contamination the PPE required may include gloves, disposable overalls, safety glasses, face shields, full face masks with filters and full suits with breathing air.

2.2.3 Radiological Protection for Radiation Area

Work processes and areas are designed to keep radiation exposure to a minimum. Where the potential for exposure to radiation or contamination still exists, shielding and mechanical ventilation are employed to minimise the dose received. Areas are classified according to the potential radiation and contamination level.

Table 3: Classification Levels for Radiation and Contamination Areas

Radiological Area Colour Code	Potential Radiation Exposure Levels (individual, effective mSv per year)	Removable Surface Contamination Levels (averaged over 2000 h per year)	Potential Airborne Contamination Levels (averaged over 2000 h per year)
RED	6 to 20	0.3 to 1 DL	0.3 to 1 DAC
BLUE	1 to 6	0.05 to 0.3 DL	0.05 to 0.3 DAC
WHITE	<1	< 0.05 DL	<0.05 DAC

Table 4: Maximum Permitted Activity in Contamination Areas in Terms of Annual Limits on Intake (ALIs)

Location	Nature of Operation		
	Volatile or dry and dusty	Slightly volatile or dry, non-dusty	Non-volatile wet operations
Red Contamination Area			
Open Room	10^{-3} ALI	10^{-1} ALI	10^{1} ALI
Fume Cupboard	10^{2} ALI	10^{3} ALI	10^{4} ALI
Glove-box	10^{4} ALI	10^{5} ALI	10^{6} ALI
Blue Contamination Area			
Open Room	10^{-4} ALI	10^{-2} ALI	1 ALI
Fume Cupboard	10^{1} ALI	10^{2} ALI	10^{3} ALI
Glove-box	10^{3} ALI	10^{4} ALI	10^{5} ALI
White Contamination Area Open Room	Not Permitted	Not Permitted	0.1 ALI

Local area radiation monitors are used within all 'Red' classified work areas and 'Blue' areas where higher than background radiation levels are to be expected. These monitors are configured to raise an alarm when an upper radiation set point has been reached to alert personnel to discontinue the process, make safe or evacuate. Red and Blue contamination classified work areas are also equipped with contamination detectors for checking personnel on exiting the area. All contamination and radiation monitors are calibrated annually by ANSTO's calibration services.

Dose and contamination surveys are carried out by health physics surveyors as scheduled and also at request. Items that are transferred from a Red or Blue classified area (radiation and/or contamination) to another building are monitored by health physics and a clearance certificate issued to advise the receiver of the item's dose, contamination level and any special handling requirements.

2.2.4 Radiological Protection for the Public

Through the safety assessment process (Safety analysis reports for facilities and safety approval submissions for new and ongoing processes) ANSTO addresses any radiological issues that may have an impact on the public. As such, processes and modifications are only allowed once the operator can prove the safety of their process/facility from the perspective of design, use of equipment, maintenance, operational and administrative controls in place.

The main ways in which members of the general public may be exposed to radiation is through:

- potential release of radionuclides into the environment from atmospheric discharges from stacks (tritium, volatile fission products, activation products and noble gases released from isotope production facilities, research laboratories and waste management areas)
- Discharge of low level liquid effluent via the Sydney Water Corporation sewer to the ocean.
- Radionuclide transport by surface/ground water and/or contaminated airborne particulate dispersion from buried waste in a small low level radioactive waste disposal site

Stack monitoring for radionuclides is carried out continually to determine compliance with the limits imposed by the regulator and to fulfil the duty to protect members of the public. A program of environmental sampling of air, ground water and sediments at various locations around the ANSTO site has been carried out for more than a decade and consistently demonstrates that ANSTO's activities have no impact on public radiological safety or the environment. Radioactivity discharge limits are set for liquid effluent to meet the WHO Guidelines for Drinking Water Quality (2004) for radioactive species at the point of the receiving sewage treatment plant (Cronulla). Waste water is analysed for gross alpha and beta radioactivity concentration and must comply with the derived limits (based on a dilution factor of 25 prior to the sewage plant) before it is released. Annual sampling at the sewage treatment plant and outfall has always shown that the levels of radioactivity detected are below those set in the WHO guidelines. The information collected from environmental monitoring is published annually and made available to the public and the regulator (ARPANSA).

2.2.5 Radiation Emergency Preparedness

ANSTO has Emergency Planning arrangements in place to enable effective management and response in the event of a radiation emergency. The five main components to the emergency planning arrangements include:

- Response plans
- Standing Operating Procedures (SOPs)
- Communication and consultation
- Testing and review
- Emergency response training

The response plan was developed by ANSTO's Quality, Safety, Environment and Radiation Protection section (QSERP) and is practised once every two years to ensure all participants are familiar with its contents, to test specific aspects and practise procedures associated with the plan.

ANSTO provides specific emergency response training to ANSTO's emergency response staff and includes regular workplace exercises focusing on various emergency procedures and response. The objective of these exercises is to continually improve ANSTO's emergency arrangements and to identify further emergency response training needs.

There are a number in plans in place which would come into effect in the event of a radiation emergency where there may be possible off-site consequences:

- Sutherland Shire Local Disaster Plan
- The Georges River District Disaster Plan
- NSW State Hazardous Emergency Sub-Plan

- NSW State Disaster Plan, etc.
- (ERNET/ENATOM/RANET)

In such an event ANSTO would continue to provide technical advice and assistance to the NSW authorities that would be in control.

2.3 Radiation Safety Management in Nuclear Power Plant

Radioactive waste in Australia is generated by research, industry, medical applications, research reactor operation and radiopharmaceutical production. Naturally occurring radionuclides (NORM) and technologically enhanced naturally occurring radioactive materials (TENORM) are produced in Australia by the mining, mineral sands processing and other resources sectors. Australia has no nuclear power plants.

Australia has a number of radioactive waste management facilities where radioactive wastes are held in storage and/or processed. The largest waste management facility is run by ANSTO for the processing of wastes arising from activities associated with its nuclear research reactor. Other small waste stores and processing facilities are managed by the Department of Defence and State governments (comprising of waste arising mostly from public hospitals). Radioactive waste management facilities in Australia range from custom built decontamination facilities and radioactive waste stores, such as those at ANSTO, to temporary storage facilities where radioactive material is held in transit. Current operational radioactive waste management facilities in Australia are listed in Table 3.2.

Table 3.2: Radioactive Waste Management Facilities

Location	*Main Purpose*	*Essential Features and estimated waste inventory*
ANSTO, Lucas Heights, NSW	Treatment and Packaging	Management of waste from research reactor operation, radiopharmaceutical production, research and development
ANSTO Lucas Heights, NSW	Storage	1620 m3 low level waste 417 m3 intermediate level waste
Mt Walton East Intractable Waste Facility, WA	Disposal	Near surface disposal of low level radioactive waste generated in the State of Western Australia
Woomera Protected Area, SA	Storage	Storage of low level and intermediate level waste owned by Department of Defence
Woomera Protected Area, SA	Storage	Storage of 2010 m3 contaminated soil owned by CSIRO
Esk Storage Facility, Qld	Storage	Storage of radioactive waste (sources and low volume material) generated in the State of Queensland.
Others	Storage	Over 100 locations around the country where low level, short-lived and/or long-lived intermediate level radioactive waste is stored

Australia is in the process of developing and implementing a National Waste Management Facility (NWMF) to safely manage radioactive wastes generated in Australia. On 25 February 2010 the Senate referred the National Radioactive Waste Management Bill 2010 for inquiry and report. The purpose of the Bill is to repeal the Commonwealth Radioactive Waste Management Act 2005 and to substitute a new process to select and establish a facility for managing, at a single site, radioactive waste arising from medical, industrial and research uses of radioactive material in Australia.

It is internationally accepted that centralised radioactive waste management facilities offer substantial safety and security benefits by minimising risk of accidental loss of control of radioactive waste, thereby protecting the community and environment from any adverse effects. The Australian Government has introduced legislation to repeal the *Commonwealth Radioactive Waste Management Act* 2005 and introduce the *National Radioactive Waste Management Bill 2010 (Bill).* The new legislation will restore procedural fairness rights for establishing a purpose built radioactive waste management facility.

The *Bill* will establish a facility to manage radioactive waste generated by Australia's medical, industrial, agricultural and research use of nuclear material and will ensure that the selected site undergoes full environmental, heritage and other approval processes. Currently Australia's radioactive waste is stored at more than 100 less than ideal sites around Australia. This approach will promote the consistent, safe and responsible management of radioactive waste, in accordance with Australia's obligations as a party to the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.*

The three sites selected by the previous Government on Defence land in the Northern Territory have been ruled out and there will be no pre-determined site outcome – the new Bill requires any site to be volunteered by landowners. In February 2009, Parsons Brinckerhoff finalised a series reports, on the preliminary site characterisation investigations for a radioactive waste management facility on previously identified sites in the Northern Territory.

2.3.1 Radiation Safety Management System

The radiation safety management system for handling wastes and managing waste processing operations would generally be covered within the facility radiation safety management system. There are however some additional considerations in relation to the classification of radioactive wastes based on their physical form, chemical nature and radioactivity. These waste classifications provide guidance as to what radiation safety measures are required for both processing and storage.

In April 2010, ARPANSA issued a Safety Guide on the Classification of Radioactive (RPS 20) waste to be adopted nationally in order to standardise the classification of radioactive waste with reference to the IAEA General Safety Guide, Classification of Radioactive Waste (No. GSG-1). Six classes of waste have been derived as the basis for the classification scheme:

- **Exempt waste (EW)**: Waste that meets the criteria for exemption from regulatory control for radiation protection purposes. Exemption activity concentrations and exempt activities of radionuclides are specified in Schedule 6 of the NDRP (ARPANSA 2010).

- **Very short lived waste (VSLW)**: Waste that can be stored for decay over a limited period of up to a few years and subsequently exempted from regulatory control according to arrangements approved by the relevant regulatory authority, for uncontrolled disposal, use or discharge. This class includes waste containing primarily radionuclides with very short half-lives often used for industrial, medical and research purposes.

- **Very low level waste (VLLW)**: Waste that does not meet the criteria of EW, but does need a moderate level of containment and isolation and therefore is suitable for disposal in a near surface, industrial or commercial, landfill type facility with limited regulatory control. Such landfill type facilities may also contain other hazardous waste. Typical waste in this class includes soil and rubble with low activity concentration levels. Concentrations of longer-lived radionuclides in VLLW are generally very limited.

- **Low level waste (LLW)**: Waste that is above exemption levels, but with limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near surface facilities. This class covers a very broad range of waste. Low level waste may include short lived radionuclides at higher activity concentration levels and long lived radionuclides, but only at relatively low activity concentration.

- **Intermediate level waste (ILW)**: Waste that, because of its content, particularly of long lived radionuclides, requires a greater degree of containment and isolation than that provided by near surface disposal. However, ILW needs little or no provision for heat dissipation during its storage and disposal. Intermediate level waste may contain long lived radionuclides, in particular alpha emitting radionuclides, which will not decay to an activity concentration acceptable for near surface disposal during the time for which institutional controls can be relied upon. Therefore waste in this class requires disposal at greater depths, in the order of tens of metres to a few hundred metres.

- **High level waste (HLW)**: Waste with activity concentration levels high enough to generate significant quantities of heat by the radioactive decay process or waste with large amounts of long lived radionuclides that need to be considered in the design of a disposal facility for such waste. Disposal in deep, stable geological formations usually several hundred metres or more below the surface is the generally recognised option for disposal of HLW.

For operational purposes, ANSTO has also adopted the following working definition described in IAEA Safety Series No. 111-G-1.1, Classification of Radioactive Waste 1994 (section 318):

- Low level wastes (liquids and solids) have a dose on contact < 2 mSv/h
- Intermediate level wastes (liquids and solids) have a dose on contact > 2 mSv/h. Shielding must be employed for all processes and storage facilities where intermediate level wastes are involved

For long term waste disposal purposes offsite (to the proposed Commonwealth Radioactive Waste Management Facility), the above definition does not apply and all wastes are to be classified and managed according to ARPANSA's system (RPS 20).

2.3.2 Radiological Protection for Radiation Workers

Refer to ANSTO Guide Docs

2.3.3 Radiological Protection for Radiation Area

Refer to ANSTO Guide Docs

2.3.4 Radiological Protection for the Public

Radioactive waste management controls and the control of radioactive discharges are in place in all jurisdictions to current international standards.

2.3.5 Radiation Emergency Preparedness

ARPANSA maintains two offices with Scientific (Melbourne) and Regulatory (Sydney) units. Radiation Emergency Planning is coordinated by the Health Physics Section of the Environmental and Radiation Health Branch, Melbourne. The coordination of Commonwealth response to State requests for radiation emergency support is through Emergency Management Australia (EMA).

In the event of a radiation accident or radiation emergency, and when requested by the responsible State or Commonwealth authorities, ARPANSA can provide Health Physics Advisors and Health Physics monitoring teams. In 1989, ARPANSA was designated jointly with the Peter MacCallum Cancer Institute as a Collaborating Centre for Radiation Protection and Radiation Emergency Medical Assistance (CRPREMA), and is a member of the WHO Radiation Emergency Medical Preparedness and Assistance Network. This role requires that ARPANSA assist in training and dissemination of information on response to radiation accidents and emergencies, as well as respond to WHO requests for assistance for radiation accidents and emergencies in neighbouring countries. (REAC/TS in the US is also a member of REMPAN.)

Through ANSTO, ARPANSA are part of the IAEA EMERCON Network for assistance in international response to radiation emergency. ARPANSA maintains an Australia-wide network of fallout monitoring stations as part of the Comprehensive Test Ban Treaty (CTBT) network of monitoring stations.

2. Bangladesh

2. Bangladesh

Part 1. Radiation Safety in RI Facilities

1.1 General

Bangladesh Atomic Energy Commission(BAEC) follows the IAEA Safety Series No 115 (1996), USNRC Code for radiation protection, the recommendations of the international Commission on Radiological Protection (ICRP) and the Nuclear Safety and Radiation Control Rules (SRO NO. 205 –Law/97). The overall safety objective is to protect operating personnel, society and the environment by establishing and maintaining an effective defence against radiological hazards. The safety objectives of the radiation protection policies are as follows:

- ❑ To ensure that the operation and utilization of nuclear/radiation facilities is justified under radiation protection consideration
- ❑ To ensure that during normal operation radiation exposure of site personnel and public remains below limits prescribed by national authorities and is kept ALARA

1.1.1 Legislative and Statutory Framework

The Regulatory Authority of Bangladesh is authorized for issuing rules and regulations and conducting licensing and supervisory processes for issuing licenses, and thereby regulating nuclear and radiation safety for siting, design, equipment manufacturing, construction, commissioning, operation and decommissioning of nuclear/radiological facilities. NSRCD is also responsible for the regulation of issues related to accounting and control of nuclear materials, radioactive substances and physical protection. The NSRCD is the competent authority for licensing shipments out of Bangladesh and giving consent to shipments into Bangladesh.

The basic legal and statutory framework for Nuclear Safety and Radiation Control is in place. The present legislative framework does not separate the regulatory functions from promotional activities of the BAEC and together with its NSRCD, the Commission performs both. A draft Nuclear Safety Law has been submitted to the Agency for comments and it is currently under the Agency's review (October 2008). It is expected that the draft Nuclear Law when promulgated will have full provisions for public and environmental radiological protection, although the regulations of public exposure is presently covered by an existing NSRC Rule-97.

1.1.2 Structure of Regulatory Authority

Structure of Regulatory Authority

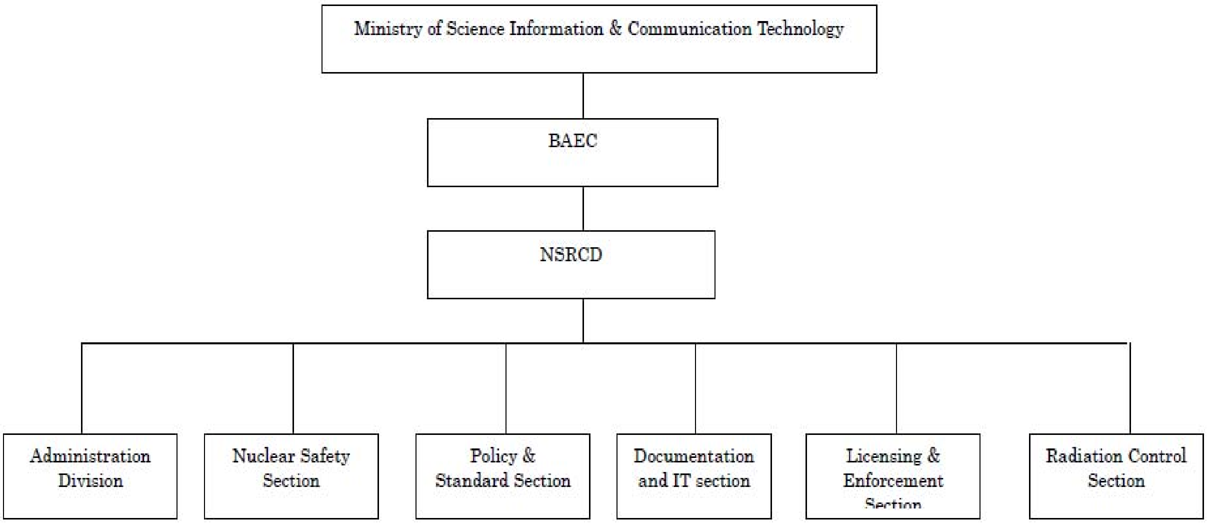


Fig.1: Structure of Regulatory Authority

1.1.3 Legal Background

National policy is to provide adequate protection for man and the environment against undue exposure to ionising radiation from radiation sources and radioactive wastes for the present and future generation. Nuclear Safety and Radiation Control Act 1993 was duly approved and enacted (1993) and the Regulations have been put into force (1997).

The following acts that address the basic nuclear activities have already been approved by the Government of Bangladesh. This act will establish the set up basic requirements for management of radioactive waste; define basic requirements, licensing procedures and responsibilities of different organizations involved in nuclear activities and related radioactive waste management.

- Nuclear Safety and Radiation Control Act 1993, Act No. XXI of 1993,
- Nuclear Safety and Radiation Control Rules – 1997 SRO. 205 – Law/97, Date: September 04, 1997

The Radiation Protection Regulations contains information on clearance and sets up clearance levels and limits for authorized discharges of radioactive substances from nuclear facilities. In addition, Nuclear Safety and Radiation Control Division (NSRCD) have prepared new rules for the 'Radioactive Waste and Spent Fuel Management – 2008, which is currently under the Agency's review.

1.2 Outline of Radiation Facilities and Radiation Sources

1.2.1 Number of Specialists and Workers in Related Organizations and Radiation Facilities including Related Facilities

Refer to the table 1.

Table 1: Number of specialists and workers in related organizations and radiation facilities

	Numbers (Installation/unit)	Approximate Number of specialist/worker
Diagnostic X-ray units	3800	5500
Research Reactor	1	20
Dental X-rays	150	-
Nuclear medicine departments	18	122
Radiotherapy facilities	12	100
Teletherapy	12	-
Brachytherapy	7	-
Industrial radiography facilities	14	-
Industrial or research irradiators	3	-
Nuclear gauges	38	-
Well-logging devices	7	-
neutron generator	1	2
Radioisotope production unit	1	12
Tandem accelerator	1	15
Beach sand mineral processing plant	1	10
Waste storage facility	1	19
Research laboratories	11	-
Linear Accelerator	13	20

1.2.3 Activity and Number of Radiation Sources and Generators

Refer to the following table 2-5.

Table 2: Nucleonic Gauge practices

Sl. No	Source/Machine	Activity	Units
01	^{241}Am	50 mCi – 03 Ci	18
02	^{60}Co	10-50 mCi	04
03	^{137} Cs	20-500 mCi	06
04	^{90}Sr	25 mCi each	10
05	^{85} Kr	50 mCi – 01 Ci	08
06	Am-Be	10- 50 mCi	08
07	^{55}Fe	100 mCi	01
08	^{63} Ni	200 mCi	01

Table 3: Nuclear Well-logging Practices

Sl. No	Source	Activity	Units
01	Am-Be	20μCi- 20 Ci	12
02	^{137}Cs	50 mCi- 02 Ci	07
03	^{232} Th	0.23 μCi	02
04	^{226}Ra	2.5 μCi	02
05	^{60}Co	01- 2.5 μCi	30

Table 4: Industrial Radiography practices

Sl. No	Source	Activity	Units
01	^{192}Ir	45 – 102 Ci	09
02	^{137}Cs, for controlling X-ray Crawlers	20 mCi each	04
03	Industrial X-ray Machines	upto 300 kVp	07

Table 5: Nuclear Medicine Facility

Sl. No.	Source	Activity
01	^{125}I	02μCi – 02mCi
02	^{131}I	20 – 200 mCi
03	^{99m}Tc	100 – 405 mci
04	^{90}Sr	55mCi each – 13 units
05	^{137}Cs	11 μCi – 345 mCi
06	^{32}P	10 – 100 mCi, 3 units
07	^{67}Ga	10 – 50 mCi, 3 units
08	^{201}Tl	10 – 20 mCi, 3 units
09	^{186}Re ^{90}Yt, ^{133}Xe, ^{51}Cr, ^{57}Co, ^{58}Co, ^{60}Co, ^{153}Sm	

1.3 Education and Training

BAEC regularly arranges 3 months long Basic Nuclear Orientation Course for its newly recruited scientists. This course covers the fundamentals of the all areas of BAEC programs. Short duration specialized courses involved lectures, practical classes, workshop, seminar, conferences etc. are arranged. In addition, GOB or other agencies like IAEA, MEXT, DAAD, Colombo Plan, ICTP and other international organizations also provide the training for BAEC Scientist.

The training programmes for the radiation protection and management are provided by the nuclear safety and radiation control division (NSRCD) for the RCO's, radiation protection management staff, other facility personnel.

1.3.1 RI Usage

- **Production of radioisotopes**: (e.g.^{99m}Tc,^{131}I)
- **Agriculture**: ^{65}Zn, ^{32}P, ^{54}Mn, ^{3}H, ^{35}S and ^{14}C
- **Research:** ^{137}Cs,^{60}Co,^{226}Ra,^{241}Am,^{131}I,^{90}Sr,^{22}Na,^{192}Ir, ^{152}Eu etc.
- **Industrial Radiography practices:** ^{192} Ir, ^{137}Cs
- **Nuclear Well-logging Practices**: Am-Be, ^{137}Cs, ^{232}Th, ^{226}Ra, ^{60}Co
- **Nucleonic Gauge Practices:** ^{241} Am ^{60}Co, ^{137}Cs, ^{90}Sr, ^{85} Kr, Am-Be, ^{55} Fe, ^{63} Ni
- **Nuclear Medicine Facility:** ^{125}I, ^{131}I, ^{99m}Tc, ^{90}Sr, ^{137}Cs, ^{32}P, ^{67}Ga, ^{201}Tl, ^{186}Re ^{90}Yt, ^{133}Xe, ^{51}Cr, ^{57}Co, ^{58}Co, ^{60}Co, ^{153}Sm

1.3.2 Radiological Protection

The legislative basis for radiation protection in Bangladesh consists primarily of the President's Order No.15 of 1973 establishing the Bangladesh Atomic Energy Commission (BAEC); the Nuclear Safety and Radiation Control Act No.21 of 1993; and the Government Order HM/hospital-1/ap-2/2001 issued on 01/12/2001 transferring the control of x-ray machines from the Ministry of Health and Family Welfare to the Bangladesh Atomic Energy Commission (BAEC). The regulatory function is exercised by the Nuclear Safety and Radiation Control Division (NSRCD), which is an integral part of the BAEC. The Nuclear Safety & Radiation Control (NSRC) Act of 1993 and the NSRC Rules–1997, (SRO NO-205-Law/97) stipulate that licensees engaged in activities involving normal exposure or potential exposure are responsible for the protection of the employees from occupational exposure. The provision of individual monitoring services is mandatory. A national system (logistics and/or technical capabilities) for monitoring the levels of radioactivity in foodstuffs and selected commodities before they are traded exists.

1.4 Standardization on Radiation and Radioactivity

Standardization and Calibration of radiation measuring instruments and dosimeters for performance tests are carried out using SSD laboratory at AERE, Savar. The Calibrated instruments and sources traceable to a primary standard laboratory. Participation in the IAEA intercomparison programs largely contributed to the improved accuracy and reliability on radiation and radioactivity measurement.

Part 2. Status of Radiation Safety Management

2.1 Radiation Safety Management in various RI Usage

The operating organizations establish and implement a radiation protection programme to ensure that all activities involving radiation exposure are compliance with regulatory requirements.

2.1.1 Radiation Protection Programme

The operational radiological safety programme of the research reactor and other nuclear/radiation facilities are carried out following the IAEA/ NSRC regulation. Bangladesh

Atomic Energy Commission (BAEC) ensures the safety and radiation protection of man and the related environment through the following radiological protection services:

- Radiation/contamination survey of all potentially radioactive/contamination areas
- Personnel monitoring of all radiation workers: TRF, casual workers and visitors
- Classification of supervised and controlled areas
- Environmental monitoring of all work places where air-borne radioactivity is likely to be generated
- Records keeping pertaining to all kinds of monitoring
- Safety evaluation of radiation workers and assessment of radiological risks
- Approval of activities, which involve actual or potential exposure to radiation or release of radioactive material to the environment
- Regular calibration of radiation monitoring instruments and records keeping
- Formulation of safety procedures for the safe handling of radioactive materials and radiation sources
- Safe management of radioactive waste
- Control over the internal movement of radioactive materials to and from the TRF radiation areas
- Advice on matters related to radiation protection
- Medical services
- Training

To ensure that accidents are generally prevented, the legal dose limits for both occupationally exposed personnel and the general public, as mentioned in the NSRC Rules 1997 are described in the table below:

Table 6: Effective dose and annual dose limit for occupational worker and general public

Application	Dose limits	
	Occupational workers	General public
Effective dose	20 mSv per averaged over five consecutive years	1 mSv in a year
Effective dose	50 mSv in any single year	5 mSv in any single year, in special circumstances, provided that the average dose over five consecutive years does not exceed 1 mSv/yr.
Annual equivalent dose to The lens of the eye The skin The extremities	 150 mSv 500 mSv 500 mSv	 15 mSv 50 mSv 50 mSv

2.1.2 Radiation Emergency Preparedness

The Nuclear Safety & Radiation Control Division (NSRCD) in cooperation with BAEC's Health physics and radiation-monitoring laboratories has been assigned to provide expertise and services in radiation protection. Capabilities for regular training of emergency personnel are being developed under national emergency plan. However, some capabilities have already been developed through training of relevant manpower in home and abroad. A draft national radiological plan is currently under review. One national committee, two subcommittees and one local subcommittee have been formed to perform responsibilities during radiological emergency.

2.2 Radiation Safety Management in Research Reactors

The operational radiological safety programmes of the research reactor are carried out following the IAEA/NSRC regulation. All radiation surveys are carried out by group member of radiation protection and RCO (Radiation Control Officer) maintain proper record.

2.2.1 Radiological Protection for Radiation Worker, Radiation Area, and Public

Assessment and control of radiation exposure to occupational workers and the public are performed under the ERM program. Radiation measurement for TRF worker is currently carried out by TLD techniques on a quarterly basis. All TLD's are checked/measured for evaluation of dose level for all occupational workers at TRF. Pocket dosimeters are also used if high dose rates are probable.

- The frequency of radiation surveys are determined by RCO depending on the nature and scale of operations carried out in the area
- Area in which radiation sources are used or stored interim storage room, heat exchange room, ion exchange resin bed, primary pump room, decay tank entrance door, fresh fuel storage room, reactor control room, reactor hall, reactor hall, reactor top, neutron spectrometry laboratory, tangential beam port area, piercing beam port, radial beam ports, rabbit room, etc. are monitored in regular intervals.
- A high-resolution gamma spectrometry system is used to analyze food and environmental samples.
- The gaseous radioactive effluents from TRF discharged through the stack are monitored before discharging to atmosphere

[Access control and zoning]

Areas where potential radiological risks from radiation or contamination are designated as control areas, which are further, classified as radiation area, contamination area or both. Areas in which sealed radiation sources are used or stored and radiation generating apparatus are in operation classified as radiation zones. Similarly, the areas in which unsealed radioactive materials are handled designated as radiation and contamination zones.

Supervised areas are any areas where occupational exposure conditions need to be kept under review even though specific protective measures and safety provisions are not normally needed.

All controlled areas are marked with appropriate warning signs in order to indicate the presence of ionising radiation or radioactive contamination or both. All the person entering the controlled areas are required to wear radiation personnel monitoring devices such as TLD's or pocket dosimeters and protective clothing.

On account of external and internal radiation risks the areas have been declared controlled/supervised areas:

Location	Designated Areas
Reactor top	Controlled area
Reactor Hall	Controlled area
Control room	Supervised area
Public gallery	Supervised area
Reactor Manager Office	Supervised area
Laboratory room	Supervised area
Staff Sitting room	Supervised area
Senior reactor operator sitting room	Supervised area
Officers sitting room	Supervised area
Spare parts store room	Supervised area
Neutron spectrometer lab	Supervised area
Staff sitting room (Ground floor)	Supervised area
Health physics control room	Supervised area
Rabbit room (ground floor)	Controlled area
Fresh Fuel storage room	Controlled area
Radioactive waste storage room	Controlled area
Heat exchanger room (ground floor)	Supervised area
Primary pump & decay tank room	Supervised area
Stack (Ground floor)	Supervised area
Stack (1st floor)	Supervised area
Stack (2nd floor)	Supervised area
Stack (3rd floor)	Supervised area

Table 7: Location of radiation control and supervised area at TRF

2.2.2 Radiation Emergency Preparedness

The availability of the resources and tools required for responding to the emergencies has been ensured. The personnel are being trained continuously through testing of the emergency plans and procedures, taking part in the emergency exercises and publishing the appropriate information. As a result of the feedback of the experiences gained during the exercises, the emergency plans are being reviewed and improved. A complete organisatioal infrastructure of radiation emergency preparedness is in the development process.

2.3 Radiation Safety Management in Nuclear Power Plants

Currently, there is no power reactor in Bangladesh. It has one 3 MW TRIGA Mark II research reactor at Savar site.

2.4 Radiation Safety Management in Radioactive Waste Management

❑ **General Safety Provisions for Radioactive Waste**

In Bangladesh, radioactive wastes generated mainly from activities of research reactor operation, radioisotope production, nuclear medicines, industrial applications and other nuclear researches. These wastes are classified into low level radioactive waste and intermediate level radioactive waste. Criteria used to define and categorize radioactive wastes bases on the classification system as recommended by the IAEA. All radioactive wastes, including disused sealed sources, are kept to a minimum, adequately processed, stored or disposed of under regulatory control.

❑ Radiation Protection Policy

During all operation states, the main aim of radiation protection is to avoid any unnecessary exposure to personnel and to keep unavoidable exposure as low as reasonably achievable (ALARA). The radiation exposure of site personnel and members of the public conforms to the requirements of relevant authority (Rules).

For accident conditions the radiological consequences are mitigated by appropriate engineered safety features, by accident management procedures and by the means provide in the emergency plan.

Operating organization is responsible for

a) Appropriate control of radiation doses to persons resulting from the operation.
b) Appropriate control of the amounts of radioactive substances released to the environment from the facility and off – site radiation dose levels.
c) Preparations for the management of on-site emergencies and co-operation with appropriate authorities during off - site emergency

The radiation protection programme includes adequate administrative measures, which take account of the design provision for:

a) Restricting the exposure of site personnel and of the general public within, established limits and the ALARA concept.
b) Ensuring that there is sufficient and appropriate instrumentation and equipment for personnel monitoring and protection.
c) Ensuring that there is on site radiological monitoring and surveying.
d) Ensuring that there is on - site co operation between the radiation protection staff and operating staff in establishing operating and maintenance procedures when radiation hazards are anticipated and direct assistance will be provided when required.
e) Providing for environmental radiological surveillance
f) Providing for decontamination of personnel equipment and structures
g) Controlling compliance with applicable regulation for the transport of radioactive materials.
h) Detecting and recording any release of radioactive material
i) Recording the inventory of radiation sources.
j) Providing adequate training in radiation protection practices.

All facility personnel are individually responsible for putting into practice the exposure control measures within their area of activity, which are specified in the radiation protection programme. Consequently, particular emphasis is given to all facility personnel to ensure that they are fully aware of both the radiological hazards and the protective measures available. Special attention is given to the fact that, personnel at the facility may include persons not permanently working there (e.g., experimenters, trainees, visitors and outside workers).

The operating organization verifies by means of surveillance, inspection and audits, that the radiation protection programme is being implemented and that its objectives are achieved, and undertakes corrective action if necessary.

If reference level is exceeded, the operating organization investigates the matter for the purpose of taking corrective action.

All personnel who may occupationally be exposed to significant levels of radiation have their exposure measured, recorded and assessed as determined by the relevant authority and this record is available to the regulatory body or to any other body designated by the national regulations.

If the limits for either personnel exposure or radioactive release are exceeded, the regulatory body and/or relevant authority informs in accordance with the requirements.

The radiation protection programme provide for the medical surveillance, the personnel who may be occupationally exposed to significant radiation doses. The legal dose limits for both occupationally exposed personnel and the general public are described in the table below:

Application	Occupational	Public
Effective dose per year	20 mSv (averaged over defined period of 5 years)	1 mSv (averaged over any consecutive years 5mSv
Annual equivalent dose in the lens of the eye	50 mSv in any single year	15 mSv
Annual equivalent dose to extremites (hand or feet) or the skin	500 mSv	15 mSv

Table 8: Effective dose and annual dose limit for occupational worker and general public

❑ Personal Monitoring

The essential aim of radiological protection is to prevent injury from ionizing radiation. It's basis respects for the recommended maximum permissible doses, but also calls for systematic observation to detect any radiation or irradiation effect. Radiation measuring devices (e.g., pocket dosimeter, TLD for individual radiation measurement) are worn by the facility personnel. Gamma spectrometry and radiation detectors system are also available in this unit for determination of the presence and quantity of radioactivity.

❑ Area Monitoring

For administrative purposes, disposal to the environment during routine operation is limited to clearance level for all radioisotopes.

It is the policy of CWPSF operation group does not to release radioactive material above naturally existing amounts to any stream or ground water under normal operation conditions. The content of radioactivity in the treated wastes is checked to determine the concentration of radioactivity.

The solid wastes are collected and located on controlled area of the CWPSF for accumulation of clean and low - level contaminated waste.

Air sampling of site are taken weekly by health physics staff and the results are recorded. All equipment and areas are monitored by group member of radiation protection and reported to RCO for proper record keeping.

There Gamma Area Monitoring System is used for monitoring of radiation level in various parts of operation area. Each detector has a Geiger Muller detector as radiation sensor. The following is a list of equipment available area monitoring:

a) Portable survey meters
b) Portable air sampler
c) Geiger Muller Counter
d) Portable gamma analysis
e) Portable Dose - rate meter

❑ Environmental Monitoring

Air samples are collected and analysed in several locations within CWPSF, AERE and evaluation of radioactivity in these samples is done in regular basis. Background radioactivity around the setting locations of CWPSF, AERE are measured and evaluated every month.

❑ Emergency Preparedness

The operating organization is developing the capabilities for protection of the public and the environment by establishing policies, strategies and programme involving radiation exposure and radiological consequences due to accident conditions.

3. China

3. China

Part 1. Radiation Safety in RI Facilities

1.1 General

1.1.1 Legislative and Regulatory Framework

The legislative framework in China regarding radiation safety is composed of national laws, administrative regulations, and department rules.

The existing national laws applicable to the field of nuclear safety and radiation safety are:

1) The Law of the People's Republic of China on Environmental Protection;
2) The Law of the People's Republic of China on Prevention and Control of Radioactive Pollution; and
3) The Law of the People's Republic of China on Environmental Impact Assessment

The Law of the People's Republic of China on Environmental Protection was promulgated in 1989 by the Standing Committee of the National People's Congress. It is a specific law applicable to protecting and improving accessible environment, preventing and controlling pollution, protecting health of people, and advancing social progress. The Law of the People's Republic of China on Prevention and Control of Radioactive Contamination was promulgated in 2003 by the Standing Committee of the National People's Congress. This law is applicable to the prevention and control of environmental pollution that are caused by the discharge of gaseous, liquid and solid wastes in the context of nuclear energy expansion, nuclear technology applications, mining of uranium/thorium resources and ores associated with radioactivity, so as to attain the goals of preventing and controlling radioactive pollution, protecting the environment and health of people, and accelerate the development and peaceful use of nuclear energy and nuclear technology.

1.1.2 Regulatory Body

In China, the independent regulatory bodies which are relevant to radiation safety are Ministry of Environment Protection (MEP(NNSA-National Nuclear Safety Administration)), Ministry of Health and Ministry of Public Security.

❑ **MEP/NNSA Responsibilities**

MEP (NNSA) undertakes the overall regulation of the country-wide prevention and control of Radioactive Pollution, through review and authorization, supervision and inspection, and supervisory monitoring of the activities associated with license holders. Thus it can be ensured that the license holders assume the responsibility of safety and conduct activities in compliance with relevant laws and regulations. MEP (NNSA) is principally responsible for:

1) Drafting and establishing policy, strategy and regulations relevant to nuclear safety, radiation safety, prevention and control of radioactive pollution, and coordinating development and publication of relevant standards;
2) Licensing and regulating of nuclear safety, radiation safety and prevention and control of radioactive pollution;
3) Investigating and tackling nuclear safety accident and radiation safety accident, in cooperating with other relevant organizations in providing guidance on, and supervision of the preparation

and implementation of NPP emergency plan, and working with other relevant organization in participating with nuclear accident emergency through the conciliation and resolution of the dispute relating to nuclear safety;

4) Conducting review, authorization, supervision and inspection of environmental impact assessment;
5) Supervisory monitoring the discharge of radioactive effluents and radiation environmental release; and
6) Planning and coordinating relevant scientific research and promoting dissemination of relevant knowledge.

❑ **Ministry of Health**

The main responsibilities of the Ministry of Health

1) Developing health related regulations and standards for radiological workers;
2) Supervising the doses that may be received by the radiological workers;
3) Reviewing and authorizing occupational health/hygiene assessment; and
4) Organizing the radiological injury diagnosis and treatment and the medical rescue in the case of nuclear and radiation accident.

❑ **Ministry of Public Security**

The Ministry of Public Security is principally responsible for investigating and recovering the lost radioactive sources, and for the security of road transport of radioactive materials.

❑ **Functions of China Atomic Energy Authority**

In addition to the forgoing mentioned regulatory bodies, the China Atomic Energy Authority (CAEA) is one of the primary governmental agencies relevant to radiation safety, with the following functions:

1) To research and draft out policies and regulations for peaceful utilization of atomic energy in China;
2) To research and establish developing program, planning, and nuclear industry standard for peaceful utilization of atomic energy in China;
3) To organize demonstration, review and approval of relevant science and technology research project on peaceful utilization of nuclear energy in China; be in charge of surveillance and coordination of the implementation of science and technology projects;
4) To be in charge of control of nuclear materials and physical protection of nuclear installations;
5) To be in charge of review and management of nuclear export;
6) To be in charge of communication and cooperation in nuclear energy field among governments and also among international organizations; take part in the IAEA and its related activities on behalf of Chinese government;
7) To undertake emergency management of state nuclear accidents and lead on organizing the National Coordinating Committee for nuclear Emergency, be in charge of developing, preparing and implementing national nuclear accident emergency plan;
8) To be in charge of the decommissioning of nuclear installations and the treatment of radioactive waste.

1.2 Outline of Radiation Facilities and Radiation Sources

1.2.1 Authorization

All radiation sources-related production, sale, transfer, use, import, and export shall be subjected to the licensing system. MEP(NNSA) and the bureaus of environment protection at provincial level, observing principles of categorizing radiation sources and regulations in this respect, separately exercise rights of approval and documentation.

The categorization of radiation source in China is principally equivalent to the IAEA's categorization. Based on the potential hazards on human and environment, radiation sources are divided into five categories. For organizations that produce radioisotopes or sell and use category sources, MEP(NNSA) takes direct responsibilities of reviewing, approving and granting licenses. Authorities concerned at provincial level grant licenses for the rest of radioactive sources.

1.2.2 Workers and Specialists in Radiation Facilities

1.2.2.1 Radiation Workers

The number of people working with radiation related industry in China is difficult to correctly define, according to an incomplete statistics, 300 thousand people are engaging in the utilization of nuclear technology.

1.2.2.2 Radiation Protection Supervisors

The MEP(NNSA) is the government authority responsible for radiation safety. The MEP(NNSA) has six regional branches in Shanghai, Shenzhen, Chengdu, Beijing, Lanzhou and Dalian, respectively, which are responsible for routine supervision of nuclear safety and radiation safety in designated areas. In order to fulfill a better implementation of regulatory functions, MEP (NNSA) set up a Nuclear and Radiation Safety Center as technical support and guarantee for itself. An expert panel concerning nuclear safety and the environment was set up to provide technical support in aspects of drafting nuclear safety and radiation safety laws and regulations, decision-making, technical development, technical review and supervision. MEP (NNSA) has nearly 1000 staff in total now.

In order to ensure and maintain the capability of regulatory staff, it is required that the staff shall meet the follow conditions:

1) Have a bachelor's degree or above or at the same educational level;
2) Have gained more than 5 years of practical experiences or more than 3 years of experiences in nuclear(radiation) safety management, being able to fulfill the task of nuclear(radiation) safety supervision under the rule of relevant law and regulations independently, and be able to make correct judgment and write qualified report;
3) Be familiar with national nuclear (radiation) safety regulations and complying with the relevant national laws and regulations; and
4) Be honesty, just, devoted and modesty.

1.2.2.3 Activity of Radiation Sources and Number of Generators

In China, application of sealed sources started in the 1930's. Documentation has shown that the earliest radioactive source found in China is radium needles used in a hospital in Beijing. With the dramatic expansion of nuclear technology and the increasing development of economy, in particular since the 1980's, the use of sealed radioactive sources is rapidly expanding in China. According to an incomplete statistics, the number and quantity are increasing at 10% rate per year in the recent years. As of December 31, 2006, the total number of the producers, vendors and users of radioisotopes amount to about 13051 across the country, with more than 140,000 of sealed sources involved in total.

1.2.4 Recent Movement Concerning Radioisotope Sources

1.2.4.1 Develop Conditioning Capability for Spent Radioactive Source

Spent radioactive sources are currently held in the provincial nuclear application wastes storage facilities and in the centralized radioactive source storage facility or at user's premises. These radioactive sources have not been conditioned into a stable form, which occupy large storage space and pose high potential risk. China is making effort to establish a research and development base to develop radioactive source conditioning technology as soon as possible for the purpose to improve the safety of radioactive source storage. At the same time, China is exploring options for disposal of spent radioactive sources, it is expected to seek a long term solution for spent radioactive sources. .

1.2.4.2 Promote Disposal of LILW

In accordance with the *Law of the People's Republic of China on Prevention and Control of Radioactive Pollution*, China is organizing to develop the siting program for solid radioactive waste disposal. This will help analyze the demands for solid LILW disposal in a comprehensive manner and direct the development trend of solid LILW disposal and promote the development of regional disposal site for LILW.

1.2.4.3 Promote Minimization of Radioactive Waste

One of the principles and objectives for radioactive waste management is to control the generation of radioactive waste so as to achieve the minimization of radioactive waste in China. The expansion of nuclear power in China raised a high requirement for safety of radioactive waste management. As a result, facilitation of radioactive waste minimization is a sustainable work Chinese government faces. Compared with advanced countries, there are still larger potentials to reduce waste generated at NPPs. However, the minimization of radioactive waste is a combined effort balancing factors of technology, safety and economy. China will take more action in controlling generation of waste, upgrading management, introducing advanced waste reduction technology, promoting specialization and socialization in radioactive waste treatment service.

1. 3 Education and Training

1.3.1 The Law Concerning Prevention of Radiation Hazards Due to Radioisotopes, etc.

Under Article 28 of Regulations on Safety and Protection against Radioisotope and Ray-generating Installations, any undertakings who produce, distribute and use the radioisotope and ray-generating installations shall provide training in nuclear safety and protection knowledge to the workers who is directly associated with production, distribution and use of them. Examination shall be given to the trainee. The worker who does not passed the given examination is not fit the job post with radiation safety related responsibility. The training program, in conjunction with training materials, was developed by the MEP in such a way as to have an enhanced training management and consistent training and examination requirements. Training organizations have been accredited with whole process supervision being provided of training and examination.

1.3.2 The Nuclear Reactor and Fuel Law

Recruitment, training and re-training of nuclear facility operational personnel and authorization are subject to the nuclear safety guideline "Staffing, Recruitment, Training and Delegation at NPPs".

As required by the relevant regulations, guidelines, and standards, the requirements for post qualification is defined, on the basis of the post-specific task analysis, and the training and retraining program and procedures are developed and implemented. The personnel working in nuclear facilities can carry out the relevant post with responsibility only after appropriate training, qualification examination, and acquirement with post qualification certificate or authorization granted.

Validity period management is applied to the qualification and authorization for nuclear facility personnel. After expiration of effective period, the extension and renewal of qualification certificate shall be made in accordance with the post-specific requirements. Furthermore, additional training and re-training are needed to ensure for the personnel to meet the post-specific requirements.

With the expansion of nuclear power production in China, systematic training approach is being drawn on at nuclear facilities. Training demand analysis is based on the actual work conditions. With focus on the safe operation of nuclear facilities, different types of training and technical support activities are carried out in so far as to continue to raise the level of knowledge and competence of nuclear facility' personnel. Training resources are optimized through standardizing teaching material preparation. Trainer management and cultivation are strengthened by many approaches. The internal and external evaluation and feedback are conducted to continue the improvement of the existing training system.

1.3.3 Examples of Education and Training

In order to raise the quality of the technical staff for nuclear safety related activities, Chinese government, in November 2002, issued the Temporary Regulations on Registration qualifications for Nuclear Safety Engineer under which the occupational qualification system was established for the technical staff working on the key nuclear safety related posts who are providing nuclear safety related technical services for the nuclear energy and nuclear technology applications. It was issued consistent with the relevant provisions of the Law of the People's Republic of China on Prevention and Control of Radioactive Pollution to enhance the management of the key posts with nuclear safety related responsibility, ensure nuclear and radiation environmental safety, and maintain national and the public's interests. Subsequently, Nuclear Safety Engineer Registration Management Rules was issued in 2004, and the Temporary Regulations on Continued Education of Registered Nuclear Safety Engineer was issued in 2005.

Country-wide examination is sponsored annually for applicants for registration qualification after being given systematic training and qualification certification. The subjects to be examined cover nuclear safety related laws and regulations, nuclear safety related comprehensive knowledge, nuclear safety related practices and nuclear safety case analysis. Qualification Certificate of the People's Republic of China for Registered Nuclear Engineer is granted to the qualifier after his or she passed the given examination. The validity period of a registration is 2 years. Continued educational regime is performed for the registered nuclear safety engineers.

The occupational scope of a registered nuclear safety engineer covers review of nuclear safety case, supervision of activities affecting nuclear safety, manipulation and operation of nuclear facilities, quality assurance, radiation protection, radiation environmental monitoring, and other nuclear safety closely related fields prescribed by the MEP(NNSA) .

1.4 Standardization on Radiation and Radioactivity

In China, standard is one part of the legislation and regulation. Chinese government has attached high degree of importance to the legislation and regulation of nuclear and radiation activities, thus leading to the continued improvement of the legislation and regulation system. In 1960, the Regulation on Health and Protection for Work with Radioactivity was promulgated. Subsequently in 1974, Regulation on Radiation Protection（GBJ8-74）was issued. In 1979, the Law of the People's Republic of China on Environmental Protection (for trial) was promulgated for implementation, stipulating that the design, construction and operation of a main project must be simultaneous with those of the facilities used for preventing pollution and other public hazards. In 1986, the State Council issued the Regulation on the Safety Control for Civilian Nuclear Installations, establishing the nuclear facility licensing system, and setting up independent regulatory body for nuclear facility safety. In 1989, the State Council issued the Regulations on Safety and Protection of Radioisotope and Ray-generating Installations, stating that licensing system shall be applied to the production, distribution and use of radioactive sources and the recovery and storage of disused radioactive sources. Various administrative departments under the State Council relating to health, environmental protection and public security shall apply phased regulation to the radiation protection in the production, distribution and use of radioisotopes. The environmental protection competent authority under the State Council is responsible for the regulation of the recovery and decommissioning of radioactive sources. In 1992, the State Council approved and circulated the Environmental Policy on LILW Disposal in China (State Council [1992]45), which strongly boosts the matters relevant to radioactive waste disposal. In 1993, the State Council issued the Regulations on Accidental Emergency Management at Nuclear Power Plant, setting out the policies, strategies and measures to be adhered to in the event of an emergency. In 2003, the Law of the People's Republic of China on Prevention and Control of Radioactive Pollution was promulgated for enforcement. It defines that the environmental protection competent authority under the State Council has the overall responsibilities for the country-wide prevention and control of radioactive pollution by virtue of the relevant national laws and that other administrative departments under the State Council shall implement their allocated duties in this regard. In 2004, the State Council caused the Regulations on Protection against Radioisotope and Ray-generating Installations of 1989 to be revised, and renamed Regulations on Safety and Protection of Radioisotope and Ray-generating Installations. It lays out that the previous by-stage, multi-sector regulatory approach was changed to a unified regulatory system by the environmental protection competent authority of radioactive sources. In 2002, the Basic Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (GB18871-2002), a Chinese Standards, was issued.

Part 2. Status of Radiation Safety Management

2.1 Radiation Safety Control in RI facilities

2.1.1 Radiation Safety Control System

In 2005, the State Council issued the Regulations on the Safety and Protection of Radioisotopes and Ray-generating Installations (the State Council Order No. 449). These regulations, fully observing requirements stated in the IAEA Code of Conduct on the Safety and Security of Radioactive Sources and the Basic Safety Standards on Ionizing Radiation Protection and radioactive Sources(Chinese Standards GB18871-2002), have constructed a spectrum of regulation mechanism. These include:

a) Practicing a licensing system abided by organizations producing, selling, or using radioactive sources;
b) Full-traced control over applications of radioactive sources;
c) Reviewing and documentation of radiation-related transfer, export and import;
d) Documentation of sources applications in different locations from originally assigned places;
e) Specifying the procedures of retrieving disused radioactive sources to manufacturers.

MEP(NNSA) supervises and administers the safety and security of radioisotope and radioactive equipments throughout the country in centralized manner, including the practicing and monitoring of foresaid systems, construction of information system for monitoring and controlling radioactive sources, management of training radiation workers and monitoring dose information to persons exposed to radiation, response to emergencies, and inspection of radiation safety and security.

MEP(NNSA) takes direct responsibilities of reviewing, approving and granting licenses for Category sources.

The provincial government authorities take responsibilities for the rest categories of radioactive sources.

For local environment authorities (at level of city or county), special offices or technicians are assigned to control and manage the applications of nuclear technologies within their jurisdiction.

MEP(NNSA) is responsible for establishing an information management system regarding the production and use of radioisotope. Since 2004, MEP(NNSA) has commenced to localize IAEA's Radioactive Source Information System(RAIS), and now this system has been put into operation throughout China.

2.1.2 Radiation Protection of Workers

In accordance with China's laws and regulations, those organizations which produce, sell or use radioisotope and radioactive equipments shall monitor radiation dose exposed to those staffs who directly involves in activities of producing, selling or using those radioactive isotopes or devices , and give the staffs occupational physical examinations, establish files of personal radiation dose and occupational health caring.

As regulator, the environmental protection authority is free from involving in tasks of monitoring personal radiation dose, nevertheless, the licensed organizations are required to file personal radiation dose documents and give an annual report to authorities granting the license. By this mean, the authorities will be promptly informed with that if the safety and protection of radiation work sites meets the requirements.

2.1.3 Radiation Protection of Working Area

According to China's regulation, obvious radioactive sign should be set at the workplace in which radioisotope or ray-generating installations are produced, sold, used or stored, the radiation protection facilities, necessary safety interlock and alarming devices should be set up at the entrance. Safety measures to prevent mis-operating and unexpected radiation exposure for the employee or the public should be taken.

The requirements for the monitoring of the workplace are consistent with the IAEA BSS in China. Program for the monitoring of the workplace under supervision should be established, maintained and kept. The nature and frequency of monitoring workplace should be determined according to the radiation level and the potential exposures, to enable: i) evaluation of the radiological conditions in all workplace; ii) exposure assessment in controlled areas and supervised areas and iii) review of the classification of controlled and supervised areas. The program for monitoring of the workplace shall specify: i) the quantities to be measured; ii) where and when the measurements are to be made and at what frequency; iii) the most appropriate measurement methods and procedures; iiii) reference level and the actions to be taken if they are exceeded.

2.1.4 Public Radiation Protection

In China, The dose limits required by the standards for public exposure is as the followings:

1) An effective dose of 1 mSv in a year;
2) In special circumstances, an effective dose of up to 5 mSv in a single year provided that the average dose over five consecutive years dose not exceed 1 mSv per year;
3) An equivalent dose to the lens of the eye of 15 mSv in a year;
4) An equivalent dose to the skin of 50 mSv in a year.

The registrants and the licensees are responsible for any public exposure which is delivered by the practice or source. The responsibilities are as the followings:

1) To establish protection and safety policies and organizational arrangements in relation to public exposure in fulfillment of the requirements of the standards;
2) Take measures to ensure the optimization of the protection of members of the public, and the limitation of normal exposure of the relevant critical group, which is attributable to such sources, in order that the total exposure be not higher than the dose limits for member of the public;
3) To ensure the safety of such sources, in order that the likelihood of public exposure be controlled in accordance with the requirements of the Standards;
4) To provide suitable and adequate facilities, equipments and services for the protection of the public;
5) To provide appropriate protection and safety training to personnel having functions relevant to the protection of the public;
6) To provide appropriate monitoring equipment and surveillance programmes to assess public exposure ;
7) To keep adequate records of the surveillance and monitoring ;
8) To establish emergency plans or procedures;
9) To ensure the optimization process for measures to control the discharge of radioactive substances from a source to the environment.

2.1.5 Emergency Action

According to the nature, severity, controllability and impact extent of a radiation accident, they are classified into exceptionally serious radiological accidents, major radiological accidents, serious radiological accidents and ordinary radiological accidents, with exceptionally serious radiological accidents as the most serious and ordinary radiological accidents as the least.

The MEP is responsible for emergency response to radiation accidents, and for investigation and classification of the accident. For this reason, Radiation Accident Emergency Plan is specially established. Under the *Council of State Decree 449*, the environmental protection agencies of the people's governments at or above county-level should work with the agencies responsible for public security, health and finance at the same level to make joint effort to prepare radiation accident emergency plan within their own administrative areas. The plan is subject to approval of county-level people's governments to ensure their legality and validity and should make them available to the public in an appropriate form.

The license holder shall prepare emergency plan for its facility based on potential accident risk and make emergency preparedness.

Once a radiation accident occurs, the holder of radiation safety license shall initiate emergency plan that has been prepared in advance and take emergency measures to check the effectiveness of the measures taken from time to time. Within two hours after an accident occurring or being discovered, report shall be made to the agencies responsible for the environment, health and public security. After receiving such a report, the agencies should dispatch personnel to the accident site to conduct emergency fieldwork in a way consistent with the provisions, and at the same time report the information to their respective upper level competent agencies in a prescribed way. The personnel that have arrived at the accident site should carry out their own respective responsibility through taking effective measures, controlling and eliminating accidental impacts. In the case of an exceptionally serious radiological accident or a major radiological accident, the people's governments at the level of province, autonomous region and municipality directly under the State shall report to the State Council not later than 4 hours after the accident occurs.

2.2 Radiation Safety Management in Nuclear Facility (Nuclear Power Plant, Research Reactor, Radioactive Waste Treatment Facility)

2.2.1 Radiation Safety Management System

A wide spectrum of laws, regulations and national standards are promulgated in China to ensure the achievement of the goals of radiation protection. On 8 June 2003, the Standing Committee of the National People's Congress promulgated the Law of the People's Republic of China on Prevention and Control of Radioactive Pollution, laying down prevention and control of radioactive pollution as follows:

1) The operator of a nuclear facility shall be responsible for the prevention and control of radioactive pollution arising from such a facility and subject to the regulatory control of the competent authority of environmental protection and other relevant agencies, and take the liability of radioactive pollution arising from such a facility;
2) The operator of any nuclear facility shall monitor the types and concentrations of radionuclides in the surrounding environment and the quantity of radionuclides in effluents from such a facility, and report the monitoring results to the competent authorities of environmental protection both under the State Council and at the provincial level;
3) The operator of any nuclear facility shall make the effort to reduce the radioactive waste generation as low as reasonably achievable. Release of gaseous and liquid radioactive wastes into the environment shall be consistent with national standards on radioactive pollution prevention and control, and the quantitative results of release shall be reported to the competent authorities of environmental protection.

Any nuclear facility is required to set dose limits as management goals under the GB18871-2002 taking account of economic and social factors, which should be lower than the relevant national limits. The GB18871-2002 requires that release of radioactive materials into the environment shall be controlled in such a way to determine the important pathways through which the public are exposed to radioactive material and that the impacts upon the human and the public shall be assessed. The GB18871-2002 also sets up the following individual dose limits:

-------Occupational exposure

(1) Effective dose of 20 mSv per year is prescribed by regulatory body, averaged over defined 5 year periods, rather than any traceable average;

(2) The effective dose should not exceed 50 mSv in any single year;

(3) Annual equivalent dose for Lens of the eye is 150 mSv;

(4) Annual equivalent dose for hands and fee is 500 mSv;

-------Public exposure

(1) Annual effective dose limit is 1 mSv

(2) In special circumstances a higher effective dose value of 5 mSv could be allowed in a single year, provided that the average over defined 5-year periods does not exceed 1 mSv per year;

(3) Annual equivalent dose for lens of the eye is 15 mSv;

(4) Annual equivalent dose for skin is 50 mSv.

2.2.2 Radiological Protection for Radiation Worker

According to the monitoring results of occupational exposures, the average annual dose equivalent to workers in the operating NPPs in China is far below the national limits given in standards, as shown in the following Table 1.

NPP	Year	Annual average individual effective dose (mSv)	Annual maximum individual effective dose (mSv)	Annual collective effective dose (Man.Sv)	Normalized collective effective dose (Man.mSv/GWh)
Qinshan NPP	2007	0.650	8.450	0.997	0.450
	2008	0.153	3.577	0.149	0.057
	2009	0.336	4.257	0.453	0.192
Guangdong Daya Bay NPP	2007	0.378	9.476	1.053	0.068
	2008	0.307	5.988	0.826	0.051
	2009	0.278	5.240	0.715	0.044
Qinshan Phase II NPP	2007	0.347	8.164	0.785	0.088
	2008	0.300	4.881	0.588	0.059
	2009	0.345	7.899	0.710	0.071
Guangdong LingAo NPP	2007	0.456	8.533	1.231	0.083
	2008	0.600	12.169	1.772	0.116
	2009	0.502	10.568	1.531	0.099
Qinshan Phase III NPP	2007	0.277	5.900	0.572	0.050
	2008	0.364	9.102	0.788	0.070
	2009	0.327	6.415	0.748	0.064
Tianwan NPP	2007	0.136	2.693	0.327	0.033
	2008	0.209	3.460	0.557	0.040
	2009	0.244	3.200	0.548	0.038

Table 1: Monitoring results of occupational exposures

2.2.3 Radiation Area Management

Principles and requirements of radiation protection were provided for by national nuclear safety regulatory bodies in a wide spectrum of regulations governing the siting, design and operation of nuclear facilities at any stages:

1) At the stage of siting, the public and the environment should be protected from excess radiation exposure from emerging radioactive accidents, simultaneously with due account being taken of normal release of radioactive materials from NPPs;
2) Full consideration should be given to radiation protection requirements, such as optimized facility deployment, installation shielding, in such a way to make the activities and occupancy time of persons within radiation areas as less as possible;
3) Taking necessary measures to reduce quantity and concentrations of radioactive materials within plant area or released to the environment;
4) Taking into careful consideration possible accumulation of radiation level with time within occupancy area in such a way as to as less radioactive waste as possible to be generated;
5) Carrying out, on the part of operating nuclear facilities, assessment and analysis of radiation protection requirements and their implementation, making and implementing radiation protection programs to ensure the implementation of such programs and the verification of their goal achievement, and if necessary taking necessary corrective actions; and

6) Making and implementing, by radiation protection functional departments, radioactive waste management programs and environmental monitoring program to assess environmental impacts of radioactive release.

The Technical Policies Governing Several Important Safety Problems in Design of Newly Built NPPs was issued in August 2002, where nuclear safety analysis should be accomplished in designing NPPs to assess the possible doses to both NPP's workers and the public and potential environmental consequences. Various measures are required to be taken for controlling radiation exposure and reduce possibility of an accident.

2.2.4 Radiation Protection for Public

The Regulations on Radiation Protection for NPPs GB6249-86, clearly sets out effective dose equivalent to any adult individuals of the public arising from released radioactive materials into the environment from NPPs and the annual release limits of airborne and liquid radioactive effluents:

1) Effective dose equivalent to any adult individuals of the public arising from a NPP should be less than 0.25 mSv;
2) In addition to meeting the above provisions, the airborne and liquid radioactive effluent from a PWR NPP should be also less than the control values listed in the following Table 2.

Table 2: Annual discharge limits under operational conditions of a PWR Nuclear Power Plant (Bq)

Airborne radioactive effluent			Liquid radioactive effluent	
Noble gas	Iodine	Particle (half-life≥8d)	Tritium	other
2.5×10^{15}	7.5×10^{10}	2.0×10^{11}	1.5×10^{14}	7.5×10^{11}

Monitoring was made in the surrounding environment in provinces where China' NPPs are located. The results show that the discharged quantities of effluents in operational NPPs caused the maximum individual doses to the public in the proximity far lower than national limits.

Environmental monitoring program was developed by nuclear facilities for key nuclides, exposure pathways (transfer) and key populations as defined in the environmental impact report with a view to carrying out environmental radioactivity monitoring to ensure compliance with the provision of the relevant national laws and regulations, satisfaction with radioactive waste discharge limits and protection of the public from radiation impacts arising from nuclear facility operation. Environmental radioactive monitoring data shall be used to assess and analyze the validity of controlling radioactive material release into the environment, the public exposure from nuclear facility' effluent, long term trend in variation in environmental radioactivity, migration and dispersion of radioactive material in the environmental media and the reality of environmental model used for establishing authorized limits.

Environmental radioactive monitoring includes pre-operation monitoring, routine environmental radiation monitoring, radioactive effluent monitoring and meteorological monitoring.

Pre-operation monitoring means a two-year long survey of radioactive background and ocean ecology through which the information on key nuclides, key exposure (transfer) pathway and key populations can be obtained. The investigated media comprise air, surface water, groundwater, terrestrial and marine organisms, foods, soils among other things. Environmental gamma radiation level is investigated within 50 km of the proposed sites with others within 20 km of the proposed sites. What to be analyzed and measured includes environmental radiation level and radionuclides released from nuclear facilities. Before operation of NPPs in China, environmental radioactivity backgrounds are measured and the results preserved in such a manner as to ensure the representative of environmental monitoring extent and frequency that meet the relevant requirements.

Routine environmental radiation monitoring means that as much optimization as possible is achieved by nuclear facilities through making full use of pre-operation survey information on the premise to meet the needs of environmental assessment. Environmental monitoring focuses on what is deemed to be maximum risks to the key populations.

Radioactive effluent monitoring refers to the monitoring of gaseous and liquid radioactive effluents after nuclear facilities come into operation, involving total quantity and concentrations of nuclides released and the main nuclides to be analyzed. Monitoring results show that the quantity of radioactive effluents discharged is not in excess of national limits.

Meteorological monitoring aims to atmosphere diffusion monitoring. Meteorological monitoring programs have been prepared with the aim of making continuous monitoring of wind direction, velocity and air temperature, precipitation and air pressure at varying heights above ground at the typical selected locations. In addition, lines of communication are established between NPPs with meteorological observatory stations in provinces where they are situated so as to obtain the needed meteorological data.

Accident emergency monitoring means the environmental emergency plan prepared by NPPs prior to their operation, where derived intervention levels are provided for in order to assess monitoring results and decide whether or not to take necessary action as early as possible.

NPPs are equipped with radiation monitoring meters, radiation surveillance meters, contamination monitoring meters, air sampler and environmental media sampler among others, with regular test and calibration. All emergency equipment is, as required, tested for reliable use.

Assessment of public dose and environmental impact is performed at NPPs based environmental monitoring data. Accumulated gamma radiation monitoring data at the plant boundary are used, together with data in respects of atmosphere fly dust, terrestrial organisms, soils, water quality and other environmental media, to assess the dose equivalent to the public and environmental impact arising from the operation of NPPs under normal and abnormal conditions

Effective environmental monitoring and assessment have been completed by NPPs under the auspices of NNSA. The measurement and analysis of samples from biology, air, soils and ocean in the surrounding environment show that NPPs have caused no adverse impacts on the environment.

2.2.5 Nuclear Emergency Response

Three-level emergency organizational system which has been established in China, which consists of national nuclear emergency organization, provincial emergency organizations (including autonomous region, municipality directly under central government where nuclear facilities are located) and the nuclear facility’s emergency organizations.

National Nuclear Accident Emergency Coordination Committee (NNAECC) organizes and coordinates the country-wide nuclear emergency management arrangement. National Nuclear Accident Emergency Office (NNAEO) is the management body for country-wide nuclear accident emergency arrangements

If necessary, the State Council shall lead, organize and coordinate country-wide nuclear accident emergency arrangements.

The MEP (NNSA) executes independent supervision of NPPs’ nuclear accident emergency arrangements, and overseeing the development and implementation of NPP nuclear accident emergency plan.

The competent authorities of environmental protection, health, army and other related agencies shall make every effort to implement nuclear accident emergency response arrangement within the scope of their responsibilities.

Nuclear accident emergency committees of provincial governments where nuclear facilities are located are responsible for nuclear accident emergency arrangements within their administrative areas.

Nuclear accident emergency organizations of nuclear facilities have the following responsibilities:

1) Enforcing national regulations and policies on nuclear accident emergency arrangements;
2) Preparing onsite nuclear accident emergency plan and making nuclear accident emergency arrangements;
3) Determining nuclear accident emergency classification, commanding nuclear accident emergency response actions;
4) Timely notifying information on nuclear accident situation to the higher competent authorities, the MEP (NNSA) and the agencies designated by provincial governments and making suggestions on initiating off-site emergency actions and protective actions; and
5) Assisting and helping the agencies designated by provincial governments in making nuclear accident emergency arrangements.

The following four emergency classes are used in China, in order of increasing severity.

1) Emergency standby: Certain types of special conditions and external events that could endanger the safety of nuclear facilities are expected to have occurred. Nuclear facility emergency personnel are in standby and some of the offsite emergency organization may be notified;
2) Plant emergency: Radiation consequences is only limited to part of in-plant area. In this case, onsite personnel may take actions under emergency plan and relevant offsite emergency organizations may be notified;
3) Plant area emergency: Radiation consequences are only limited to in-plant area. In this case, onsite personnel put into action and offsite emergency organization may receive notifications, also with some have potential to take actions; and
4) Offsite emergency: Radiation consequences are expected to have exceeded plant boundary. Onsite and offsite personnel start to take actions, and onsite and offsite emergency plans start up.

When in the emergency standby situation, emergency organization of a nuclear facility shall timely report to higher competent department and MEP (NNSA) and to nuclear accident emergency committee of the province where such nuclear facility is located where appropriate. When any releases of materials are expected to be in process or have occurred, plant emergency or plant area emergency shall be initiated timely where appropriate and shall report to the higher competent department, the MEP (NNSA) and provincial accident emergency committee.

When radioactive materials are expected to be in process or have dispersed to outside the plant area, suggestions shall be made on entering into plant area emergency situation and taking protection actions. After receiving notification on accident, provincial nuclear accident emergency committee shall take emergency countermeasures and prompt actions and report timely to national nuclear accident emergency committee. Determination to enter into offsite emergency situation is subject to approval from the NNAECC. In some special conditions, provincial nuclear accident emergency committee can determine to enter into offsite emergency situations prior to approval and then report timely to the NNAECC.

When entering into an offsite emergency situation, the NNAEO, MEP (NNSA) and other agencies involved shall dispatch persons in a timely manner to the field and provide guidance to the nuclear emergency response actions.

4. Indonesia

4. Indonesia

Part 2. Status of Radiation Safety Management

2.1 Radiation safety management in Radioactive Waste Management

2.1.1 Radiation Safety Management System

Radioactive waste management technology center (RWMTC) at BATAN Serpong is responsible on managing any kinds of radioactive wastes generated by all radiation and nuclear facilities in Indonesia. In Serpong, the wastes mostly come from research reactor, chemical processing facilities including radioisotope and radiopharmacy production facilities, and fuel element and radiological laboratories.

Radioactive waste management technology center (RWMTC) is a centralized facility at Serpong site for solid and liquid waste treatment. Solid radioactive wastes collected in standard 100 liter drums from the different source are brought to RWMTC at Serpong site. They are segregated into combustible and non-combustible, and compressible and non-compressible types. The low active combustible wastes are incinerated and the compressible ones are compacted in 200 liter drums. Non-combustible and non-compressible wastes are packed into 200 liter concrete drums and stored in an interim storage. Liquid waste transported from generating facility to RWMTC through mobile tank for evaporation and/or chemical treatment. Sludge generating from evaporation or chemical chemical treatment and ash from incineration treatment are cemented in 200 liter standard drums. Liquid radioative effluent below clearance levels is discharged to Cisalak river.

2.1.2 Radiation Safety Survrilliance

RWMTC is designed to provide adequate radiological safety for operating staff, members of the public and the environment. Contamination control is applied by zoning policy, and suitable protective clothing is provided at appropriate locations. Liquid effluent generated from facility operation is discharged by pipelines through integrated waste control (IWC/PBT). Ventilation system is also designed so that the facility areas are kept under negative pressure. The exhaust air is discharged to atmosphere through a bank of high efficiency particulate air (HEPA) filters.

2.1.2.1 Area Monitoring

The radiation fields of all working areas including those outside the waste processing facility are monitored routinely. Working areas are also checked for radioactive contamination by swiping (smear tests), with special attention given to areas like corridors, worker rooms, etc. Location where radiation field is excessive are identified and classified. Adequate shielding is provided for equipments which show high dose rates. Occupancy in high radiation field areas is controlled by the system of special work permit (SWP). Area radiation monitors with alarm setting are installed at few locations in the facilities. A routine air sampling programme is in place, employing discontinuously operated air samplers at fixed location, and by batch air samplers during routine and specific operations.

2.1.2.2 Personnel Monitoring

Personnel monitoring for external exposure is routinely carried out using thermo luminescent dosimeters (TLD). In addition, digital personnel dosimeters are used for immediate assessment of radiation dose. Average exposure per worker in 2009 is less than 5,0 % of the national annual dose limit, and the maximum individual annual dose around 8.5 % of this limit, i.e. 20 mSv.

Monitoring for internal contamination to radiation workers at Serpong Nuclear Area are carried out through bioassay and in-vivo counting. Bioassay by urine analysis is carried out once a year as routine, and more frequently in case of suspected internal contamination. In-vivo counting, for estimation of gamma radionuclides is carried out for certain workers potentially expected contaminated, has revealed no occurences of internal contamination in 2009 at Serpong.

2.1.2.3 Effluent Monitoring

Liquid effluent from Serpong Nuclear Facilities is collected in a pond and released by RWMTC. Before discharging through river, the liquid effluent is analyzed to determine radionuclide concentrations and their chemical and physical forms, and then compared with the appropriate environmental radioactivity level standards. Environmental monitoring carried out every 3 months on Cisadane river. Analysis results of effluent samples has revealed that ^{60}Co and ^{65}Zn in the liquid effluent. Most of the effluent is generated by the Serpong Research Reactor.

2.1.2.4 Monitoring Public Exposure

Surface water from Cisadane river and other environmental components are regularly monitored for their radioactivity concentration. Estimated maximum possible radiation exposure of member of public due to consumption of foodstuff and occupancy of bank areas (critical group), is estimated to be negligibly low when compared to recommended annual dose constraint of 300 Sv for public. Monitoring results showed that there was no increase in radiation dose in the environment, only the background radiation dose from terrestrial exposure and cosmic ray.

2.1.2.5 Environmental Monitoring

Monitoring of environment around the facility is carried out by background radiation survey, and analysis of ground water and surface soil samples. Any abnormal increase in radiation field is investigated for its causes, and corrective actions taken. Samples of ground water and surface soil from around RWMTC are collected with a defined periodicity and analyzed for radionuclide quantification.

2.1.2.6 Emergency Preparedness

RWMTC is part of the Serpong Nuclear Area Emergency Preparedness and Response Arrangements, so that the emergency preparedness refers to emergency preparedness programmes of Serpong Nuclear Area.

5. Japan

5. Japan

Part 1. Radiation Safety in RI Facilities

1.1 General

1.1.1 Legislative and Regulatory Framework

The basic law on the utilization of nuclear energy in Japan is the Atomic Energy Basic Law (AEBL) that was established in 1955. The objectives of the law are quoted as "to secure future energy resources, achieve progress in science and technology, and promote industry, by encouraging research, development, and utilization of nuclear energy, and thereby contribute to the improvement of the welfare of human society and the national living standard." The basic policy here is prescribed as follows: "The research, development and utilization of nuclear energy shall be limited to peaceful purposes, on a basis of ensuring priority to safety, and performed on a self-disciplined basis under democratic administration, and the results thereof shall be made public and actively contribute to international cooperation."

In order to attain these objectives and achieve the basic policy, the law prescribes the following:

- Establishment of the Atomic Energy Commission (AEC) and the Nuclear Safety Commission (NSC), and their duties, organization, administration, and authorities
- Regulations on the nuclear fuel materials
- Regulations on the construction, etc. of reactor facility.
- Prevention of radiation hazards

The law also prescribes the assignment of these matters to the respective laws. Major laws established for the purpose of providing safety regulations on the utilization of nuclear energy and related laws include "the Law for the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (the Reactor Regulation Law)", "the Electricity Utilities Industry Law," "the Law Concerning Prevention from Radiation Hazards due to Radioisotopes, etc. (the Radiation Hazards Prevention Law)" and "Medical Care Law, etc." Also included are "the Basic Law for General Emergency Preparedness," "the Special Law of Nuclear Emergency Preparedness (the Special Law for Nuclear Emergency)," "the Law for Technical Standards of Radiation Hazards Prevention" and "the Specified Radioactive Waste Final Disposal Act," etc.

1.2 Regulatory body

The mandate of the regulatory bodies is to ensure public safety through securing safety of nuclear facilities, and their obligations are to implement the above-described legislative and regulatory framework. The regulatory bodies are responsible for conducting regulatory activities prescribed in the Reactor Regulation Law, the Radiation Hazards Prevention Law, etc. on the basis of the Atomic Energy Basic Law. Their organizations and assigned obligations are clearly defined in their respective establishment laws, and their financial resources are covered by the national budget.

The Minister of Economy Trade and Industry (METI) serves as the competent minister for safety regulation on activities concerning utilization of nuclear energy, and Nuclear and Industrial Safety Agency (NISA) administers the regulatory activities as a special organization for METI. The Minister of Ministry of Education, Culture, Sports, Science and Technology (MEXT) serves as the competent minister for the safety regulation over the nuclear utilization associated with science and technology and the utilization of radioisotopes (except medicines, etc.), etc., and the Science and Technology Policy Bureau (STPB) administers the regulatory activities. The Minister of Ministry of Health, Labor and Welfare (MHLW) governs the safety regulation concerning medical facilities as the competent minister, and the Pharmaceutical and Food Safety Bureau (PFSB) and the Health Policy Bureau (HPB) administer the regulatory activities.

Regulatory body	Assigned Facilities and Activities
NISA (Nuclear and Industrial Safety Agency) / METI (Minister of Economy Trade and Industry)	Activities for utilization of nuclear energy. Namely, nuclear power reactor facilities and related nuclear fuel cycle facilities
STPB (Science and Technology Policy Bureau), MEXT (Ministry of Education, Culture, Sports, Science and Technology)	Utilization of nuclear power for science and technology, and utilization of radioisotopes etc. (except for medical supplies etc.). Namely, test and research reactor facilities, facilities handling radioisotopes, etc.
HPB (Health Policy Bureau) and PFSB (Pharmaceutical and Food Safety Bureau), MHLW (Ministry of Health, Labor and Welfare)	Activities at facilities for medical treatment and medical cares. Namely, manufacturing, handling, storage and disposal of radiopharmaceuticals.

Table 1: Regulatory bodies and Assigned Facilities and Activities

These regulatory bodies have clearly defined duties on safety regulation, and their independence is ensured both in legislation and in substance.

The NSC, consisting of members whom the Prime Minister appoints with consent of the Diet, observes and audits activities of these regulatory bodies (Regulatory Review), and establishes the basic policy for safety regulations therefore the consistency among the regulations is maintained. The consistency of the technical standards for prevention of radiation hazard is discussed at the Radiation Review Council under the MEXT.

Reference: Government of Japan, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, National Report of Japan for the Second Review Meeting Oct. 2005.

1.3 Outline of Radiation Facilities and Radiation Sources

Laws and Ordinances apply uniformly regardless of the nature of the establishment. It is appropriate to think of them as stipulating the minimum standards that the establishments and the radiation workers should observe, and, accordingly, each establishment, while of course meeting the legally prescribed standards, should implement radiation control appropriate for its own activities.

The Law Concerning Prevention of Radiation Hazards was drafted and modified in line with recommendations of the ICRP, its provisions on radiation control are not significantly different from those in other countries.

The purpose of the Law Concerning Prevention of Radiation Hazards is to prevent radiation hazards to radiation workers and the public and to protect the environment when radiation or radioisotopes are used. In order to attain this purpose, the Law provides for the regulation of facilities (requirement for facilities) and for the regulation of people's actions, etc. (for requirement for actions).

1.3.1 Authorization

Prior to the use of radiation or radioisotopes, permission by or notification to the Minister of Education, Culture, Sports, Science and Technology (MEXT) is required.

(1) Permission: The use of generators, unsealed radioisotope sources and sealed radioisotope sources more than 1,000 times of the lower Activity Limits. The disposal of radioisotope wastes.

(2) Notification: The use of sealed radioisotope sources less than 1,000 times of the lower Activity Limits. The sale of radioisotope sources.

(3) Notification of Certification Equipments: The use of ECD, etc. which receive the design certification beforehand.

The number of users by category of organizations permitted by and notified to MEXT since 1959 when the Law was enforced is shown in Fig.1.

The use of radiopharmaceuticals is regulated by the Medical Service Law. The number of users of radiopharmaceuticals is shown in Table 2.

Fig.1: Number of users by category of organizations permitted by and notified to MEXT

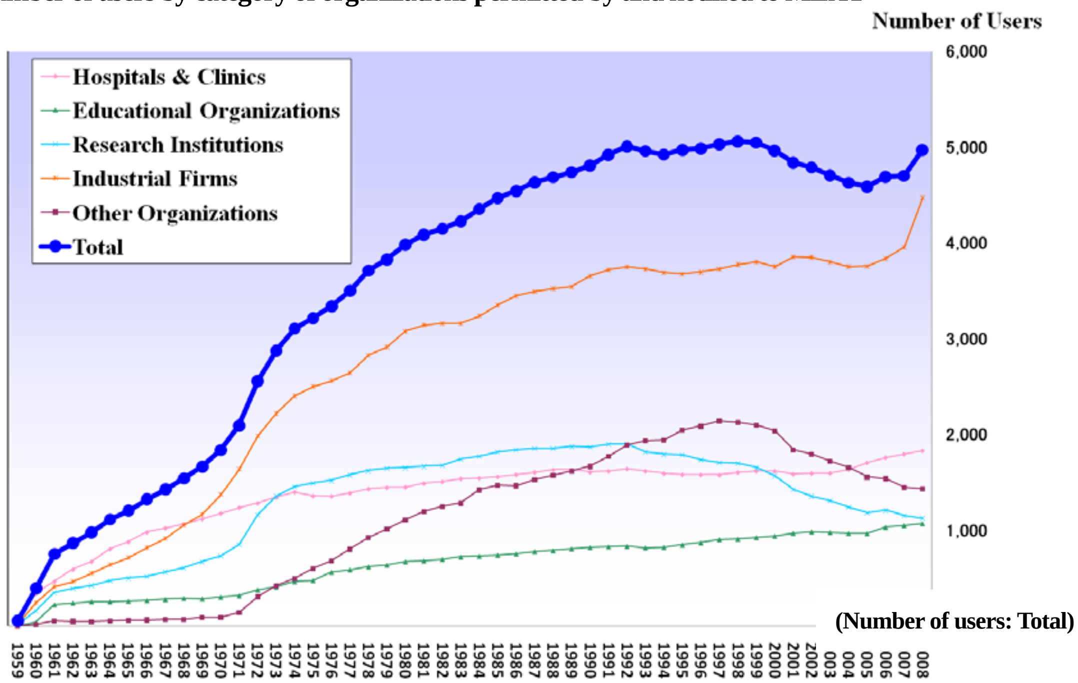


Table 2: Number of licensed hospitals and clinics for using radiopharmaceuticals

Year	2004	2005	2006	2007	2008
Hospitals & Clinics	1,266	1,280	1,301	1,297	1,293

1.3.2 Workers and Specialists in Radiation Facilities

1.3.2.1 Radiation Workers

Those who are given permission to use, or who submit a notification on the use of radioisotopes or radiation, must comply with a series of standards for safety control, in order to prevent radiation hazards.

Specific standard apply to workers who enter controlled areas: Education and training, measurements of personal dose and medical examinations. The round number of radiation workers including x-ray device handlers is shown in Table3.

Table 3: Round number of radiation workers (including x-ray device handlers, 2009)

Organization	Number
Medical	256,000
Research and Education	59,000
Industry	62,000
Total	377,000

1.3.2.2 Radiation Protection Supervisors

In order to conduct appropriate and thorough radiation safety control at an establishment, it is necessary to have a management structure or mechanism in place that is responsible for radiation protection control within the establishment. In such a situation, the radiation protection supervisor is playing the key role. Radiation protection supervisors are people responsible for supervising efforts to prevent radiation hazards. They are appointed at any establishment where radiation or radioisotopes are handled in the course of using, selling, leasing, or disposing of them.

To be qualified as a radiation protection supervisor, a person must complete required training courses and pass a national examination. There are three classes of radiation protection supervisors – first class to third class. Which class is required by a particular establishment depends on the kind and level of radiation or radioisotopes handled. Moreover, Radiation protection supervisors must attend seminars, etc., an on-going basis, in order to always have the latest information in the field of radiation protection.

Contents of the National Examinations and the Regulatory Training Courses for radiation protection supervisors are shown in Tables 4 and 5 respectively. The National Examinations for radiation protection supervisors (first class) is shown in Fig. 2.

Table 4: National examination for radiation protection supervisor

Class	Days	Subjects	Sbject Items
First	2	6	Law, Physics, Chemistry, Biology, Measurements and safety control for radiation protection
Secoud	1	3	Law, Safety control techniques for radiation protection (1) and (2)
Third	-	-	No Examination

Table 5: Regulatory training course for radiation protection supervisor

Class	Days	Enforcement Organization	Remaks
First	5	JRIA and JAEA	
Secoud	3	NUSTEC	
Third	2	JRIA and NUSTEC	No Examination

JRIA: Japan Radioisotpe Association
JAEA: Japan Atomic Energy Agency
NUSTEC: Nuclear Safety Technoligy Center

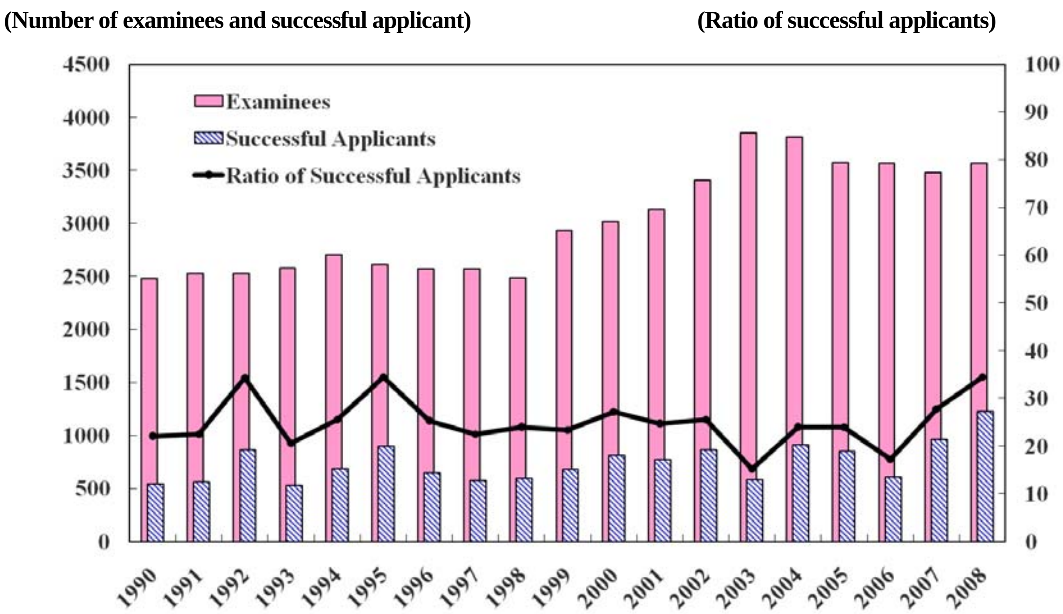


Fig.2: National examinations for radiation protection supervisors (First class)

1.3.3 Activity of Radiation Sources and Number of generators

Amounts of major unsealed radioisotopes, major sealed radioisotopes and major radiopharmaceuticals, distributed by Japan Radioisotope Association are shown in Figs. 3, 4 and 5 respectively. Number of radiation generators given permission to use by MEXT is shown in Table 6.

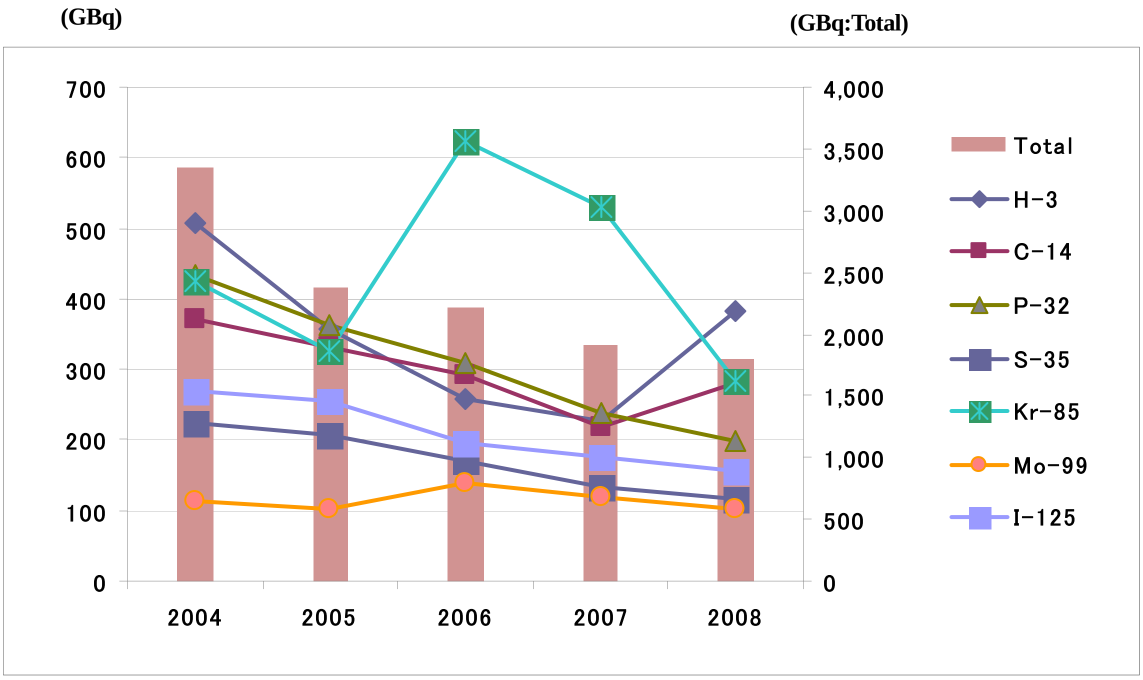


Fig.3: Amounts of major unsealed radioisotopes distributed by JRIA

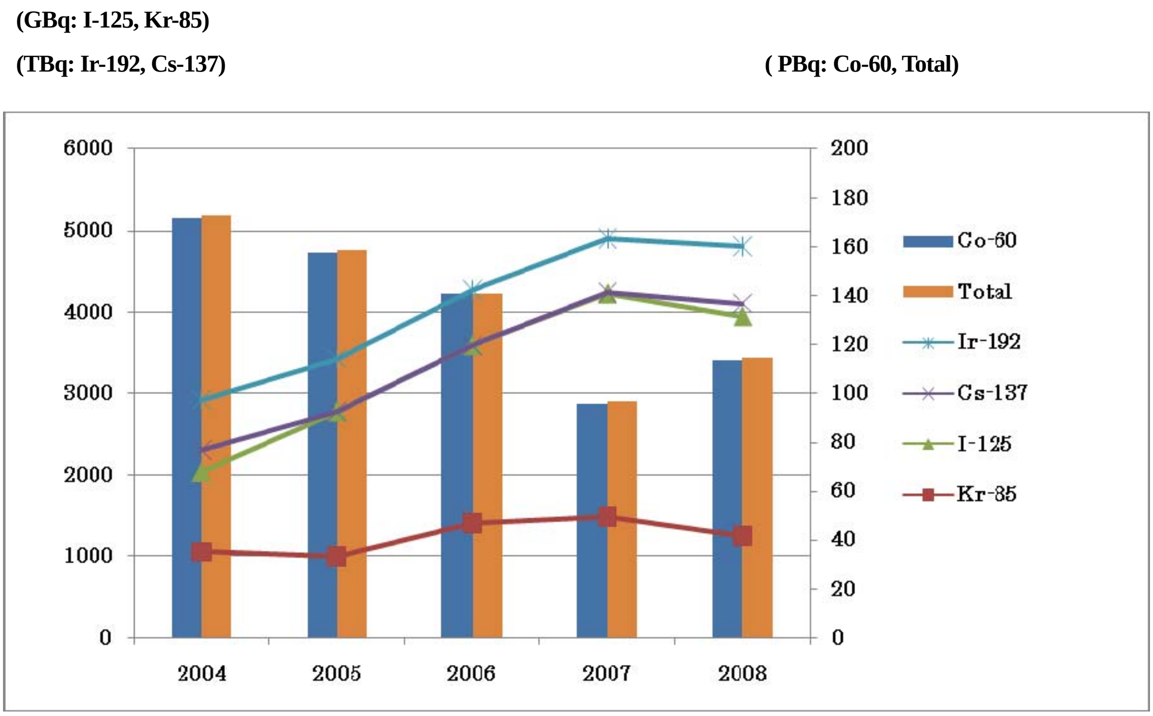


Fig4: Amounts of major sealed radioisotopes distributed by JRIA

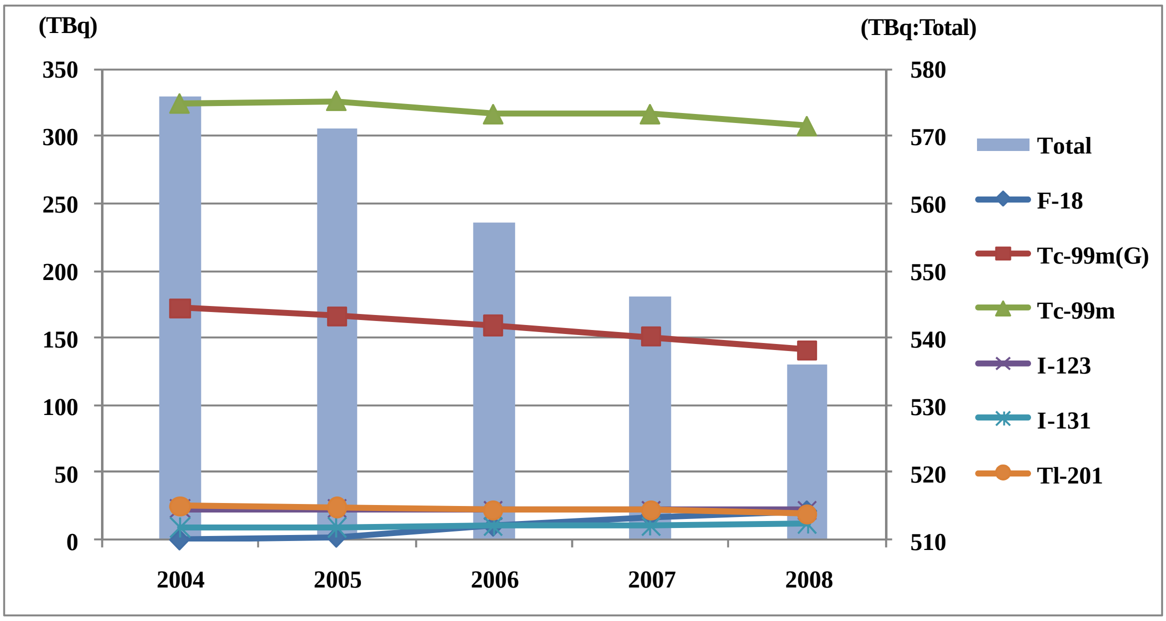


Fig.5: Amounts of major radiopharmaceuticals distributed by JRIA

Table 6: Number of radiation generators permitted by MEXT

(2008)

Generator	Number
Cyclotrons	198
Synchrotrons	28
Synchrocyclotrons	2
Linesr Accelerators	1,042
Betatrons	4
Van de Graaff Accelerators	40
Cockcroft-Walton Accelerators	82
Transformer-type Accelerators	17
Microtrons	19
Plasma Generators	1
Total	1,433

1.3.4 Recent Movement Concerning Radioisotope Sources

1.3.4.1 Sealed Radioisotope Sources Registration System

Registration of sealed radioisotope sources was tightened on the basis of the Law Concerning Prevention of Radiation Hazards according to the Code of Conduct (IAEA). On-line computer system for sealed sources registration was introduced and started operation in MEXT from 2009. Input of the more detailed information on sealed source was obliged to make.

1.3.4.2 Disposal of Radioisotope Wastes

Facilities for disposal of radioactive wastes from the operation of the Nuclear Power Plants were operated at Rokkasho site by Japan Nuclear Fuel Limited from 1992. Implementing organization for disposal of radioisotope wastes from radioisotope utilization decided to be Japan Atomic Energy Agency (JAEA). The disposal plan is covering all radioisotope waste from institutes, universities, hospitals, etc. Planning for the construction of disposal facilities by JAEA is in progress.

1.3.4.3 Clearance Regulation of Radioisotope Wastes

Clearance regulation system already established with Nuclear Reactor Regulation Law by the Ministry of Economy, Trade and Industry. The clearance regulation is applying to metal and concrete arising from decommissioning of the Nuclear Power Plants. Some metal materials were already recycled according to the clearance regulation. On the other hand, MEXT decided a similar clearance regulation system with the Law Concerning Prevention of Radiation Hazards. This clearance regulation is applying widely not only to metal and concrete but also to other solids arising from radioisotope utilization and activation by generators. Amendment and enforcement of this clearance regulation is scheduled in 2010 and 2011, respectively.

1.4 Education and Training

1.4.1 The Law Concerning Prevention of Radiation Hazards Due to Radioisotopes, etc.

Radiation users shall give radiation workers education and training, (1) prior to their first entering in controlled areas; and (2) at least once a year thereafter (re-education). By the re-education, radiation workers obtain the latest knowledge on regulations, radiation effects, and techniques for safe handling, as well as have an opportunity to regularly reaffirm the importance of safe handling.

Radiation users shall give inexperienced radiation workers shall give knowledge listed in the Table 8, and minimum education time for each item is clearly determined by the law. Sometimes OJT (on-the-job-training) or special curriculum of practical training is prepared depending on the situation of radiation usage in each facility for more effective education.
Table 7 Items and minimum time on education and training for radiation workers, determined by the Law Concerning Prevention of Radiation Hazards Due to Radioisotopes, etc

Table 7: Items and minimum time on education and training for radiation workers, determined by the Law Concerning Prevention of Radiation Hazards Due to Radioisotopes, etc.

Items for education	A	B
Effects of radiation on human body	30 min	30 min
Safe handling of radioisotopes and radiation generators	4 hrs	1.5 hrs
Laws and ordinances on prevention of radiation hazards by radioisotopes and radiation generators	1 hr	30 min
Local radiation protection rules in the facility	30 min	30 min

A: Radiation workers

B: Workers who do not enter controlled areas

1.4.2 The Nuclear Reactor and Fuel Law

For users of special nuclear materials (SNM, defined by the law), users shall give the workers additional education. The education items and frequency shall follow the local rule of each facility. The education items shall include;

- Laws and ordinances on the Nuclear Reactor and Fuel Law
- Structure of, specification of, and how to handle, the related facilities and instruments
- Radiation management
- How to handle contaminated materials
- Emergency action
- Nuclear security including physical protection, etc.

Minimum time for this education item is not determined by the law.

1.4.3 The Labor Standards Law

When a new worker is employed, the employer shall give the worker education for safety and his health concerning his work operations, following the Ordinance of the Ministry of Health, Labor and Welfare. In addition, when a worker is to be involved in several special operations designated by the Ordinance of the Ministry of Health, Labor and Welfare, the employer shall give the worker the special education for safety and his health concerning the related operations, following the Ordinance. Works on transparent photographs and movies using X ray generators, and works in nuclear fuel facilities or nuclear reactors are included in the special operations.

1.4.4 Examples of Education and Training

1.4.4.1 Nuclear Power Plant

- Fundamental and practical knowledge (5 hours)
  1) Nuclear fuel materials, spent fuel, or materials contaminated with them
  2) Works and operations in nuclear reactor facilities
  3) Structure of, specification of, and how to handle, the related facilities and instruments
  4) Effects of radiation on human body
  5) Laws and ordinances on the Nuclear Reactor and Fuel Law
- Practical skills (2 hours)
  1) Works and operations in nuclear reactor facilities and handling of equipment relating to the facilities
- Overall practical education (OJT) (10 days)

1.4.4.2 University (users of radioisotopes, accelerators, and X ray generators)

- Knowledge of radioisotopes and their utilization (90 min)
- Laws and ordinances (2 hours)
- Radiation measurements (60 min)
- Effects of radiation on human body (60 min)
- Local radiation protection rules in the facility (30min)
- Practical trainings using radioisotopes with low activity (OJT) (3 hours)

1.5 Standardization on Radiation and Radioactivity

Radiation safety and radioactive waste management must be based on the reliable and precise measurement of the quantities associated with ionizing radiation such as dose (Sv) and radioactivity (Bq). For radiation safety, various dose meters are being used such as electric or passive dosimeters for personal dose and survey meters for ambient dose. Dose meters must be calibrated regularly and always must show a right value in order to ensure the safety and security of the people related to ionizing radiations. Measuring instruments such as ionization chambers, scintillation counters and semiconductor detectors are important in radioactive waste management, which need to be calibrated using reference radioisotope sources. Normally calibrations are performed by calibration laboratories, where measuring devices are relatively calibrated by reference instruments. These reference instruments are in turn calibrated by reference instruments with higher accuracy (lower uncertainty). The chains of the relative calibrations never loop to avoid circular reference and end up to the reference instruments with highest accuracy, called national standards. From the viewpoint of accuracy and reliability in measurement, it is essential to calibrate measuring instruments and secure the traceability of measurement to national standards.

In Japan, national standards on ionizing radiation are maintained and provided at the National Metrology Institute of Japan (NMIJ)[1] in the National Institute of Advanced Industrial Science and Technology (AIST). Table 1 shows the national standards on ionizing radiation and primary instruments used in absolute measurement of each quantity. Accuracy and worldwide consistency of the national standards were verified by participating about 100 times in the international key comparisons organized by the Consultative Committee for Ionizing Radiation (CCRI) of the International Committee of Weights and Measures (CIPM) in the International Bureau of Weights and Measures (BIPM) as well as the Technical Committee for Ionizing Radiation (TCRI) in the Asia Pacific Metrology Program (APMP). The results of these comparisons are documented in the BIPM web page[2]. The national standards are being operated with the quality management system conforming to ISO/IEC 17025 (General requirements for the competence of testing and calibration laboratories) and peer-reviewed by experts from major foreign national metrology institutes every four years. The calibration certificates issued on these standards can be accepted worldwide within the range specified in the Calibration and Measurement Capabilities (CMCs)[3] in the framework of the CIPM Mutual Recognition Arrangement (CIPM-MRA).

With regard to the traceability of measurement, the measurement act introduced the Japan Calibration Service System (JCSS) in 1993, consisting of the national standards provision system and the calibration laboratory accreditation system. In the national measurement standards provision system, the Ministry of Economy, Trade and Industry (METI) designates national primary standards and NMIJ calibrates the reference standards of accredited calibration laboratories (i.e. secondary standards) with national primary standards. In the calibration laboratory accreditation system, calibration laboratories are assessed and accredited as accredited calibration laboratories to meet the requirements of the measurement act, relevant regulations and ISO/IEC 17025. Calibration laboratories are also required to

1 http://www.nmij.jp/english/
2 http://kcdb.bipm.org/AppendixB/
3 http://kcdb.bipm.org/AppendixC/

periodically take assessment as well as proficiency testing. Calibration certificates with a JCSS symbol issued by accredited calibration laboratories assure the traceability to National Measurement Standards as well as a laboratory's technical and operational competence and are acceptable in the world through the MRA of the International Laboratory Accreditation Cooperation (ILAC) and the Asia Pacific Laboratory Accreditation Cooperation (APLAC).

Table 8: Quantities and primary standard instruments for the national standards on ionizing radiation in Japan

Air kerma, Exposure (X, γ-ray)
10-50 kV (Low), 30-300 kV (Medium),
20-25 kV (Mammography): Free air ionization chamber
Co-60, Cs-137: Graphite wall cavity chamber
Absorbed dose (β-ray)
Sr-90/Y-90, Kr-85, Pm-147: Extrapolation chamber
Fluence (neutron)
Thermal: Gold foil activation
144 keV, 565 keV: Hydrogen proportional chamber
2.5 MeV, 5.0 MeV, 8.0 MeV: Thick radiator detector
14.8 MeV: Associate alpha particle counting
Am-Be, Cf: Standard Am-Be source
Emission rate (neutron)
Am-Be, Cf: Standard Am-Be source
Radioactivity, Emission rate (α, β, γ-ray)
Radioactive nuclides (74 species): $4\pi\ \beta$-γ coincidence counter

Part 2. Status of Radiation Safety Management

2.1 Radiation Safety Control in RI facilities

2.1.1 Radiation Safety Control System

There are about 4,900 RI facilities (Research laboratories of universities or companies, nuclear medical facilities etc.) in Japan.

Those facilities are required to calculate whether dose in controlled area or in boundary of plant, concentrations of air discharged and liquid effluent from the facilities is respectively lower than dose reference, concentration reference required by the law to submit applications and documents to concerned government ministries before operating the facility.

The facilities are required to record and check the measurement results during practical operation with radiation monitor such as gas monitor. Therefore, almost all of RI facilities in Japan employ radiation control systems as below to simplify management and to perform automation of data storage of measurement results etc.

Radiation safety control system is employed in combined with the following systems in accordance with intended use.

a. Radiation Monitoring System (Fig.6)

Radiation monitoring system consists of area monitor that monitors dose equivalent dose in controlled area and room gas monitor that monitors radioactive concentration in operating room. Also, a gas monitor that monitors radioactive concentration of gas discharged form facilities to the public, and liquid monitor that monitors radioactive concentration of effluent.

Since the latest radiation monitoring system has been computerized, the each monitor is centrally controlled by the central monitor (computer) which automatically creates daily, monthly and yearly reports or the trend graphs of the alarm settings or measurement data according to the control levels. (Fig.7).

Fig.6: Configuration of Radiation Monitoring System

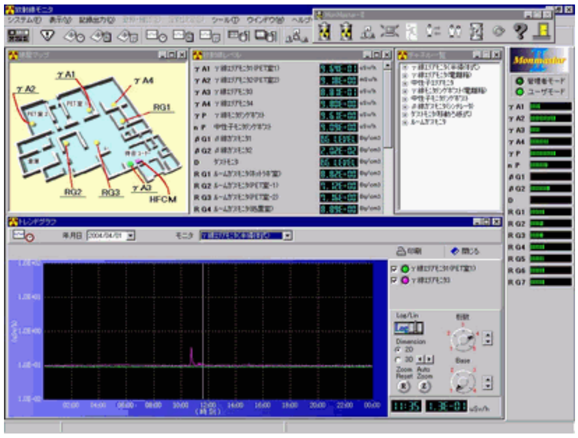


Fig.7: System Control Screen

b. RI Liquid Effluent Control System

RI liquid effluent control system is installed to control discharged water from those facilities. The system automatically controls and remotely monitors storage, decay, and dilution of RI effluent.

By interfacing with radiation monitoring system, many of those facilities perform automated effluent sampling and control radioactive concentration in the effluent using liquid monitor in accordance with the amount of water in storage tank.

c. Access Control System

Access control system automatically restricts access of qualified personnel that access to RI facilities and controls access records by ID card (magnetic/contactless Felica etc.) or biometrics (finger prints/vein) authentication.

Generally, the system permits only access of authorized personnel to the controlled area of RI facilities. Accessible area or time can be selected for each qualified radiation work personnel with the system.

At the time of exit from controlled area, each personnel checked with a hand foot monitor can exit from controlled area if contamination isn't detected.

The system is used in combination with limit switches of doors or key switches for personnel access check in the facilities where interlock is required and is also used as a part of an interlock system to prevent equipment from starting when personnel are in the specified areas of accelerator facilities, etc.

The central monitoring system generates daily, monthly, and yearly reports as well as displaying lists of personnel who are currently in the controlled area.

Internal exposure evaluation of personnel can be calculated by checking the data of personnel working in controlled area and their access time in controlled area on specified date and time. Also, contamination or a loss of radiation sources can be determined with data traceability of the system.

d. Unsealed Radioisotope Stock Control System

Unsealed Radioisotope Stock Control System is mainly used in RI facilities because the system unifies the managements of a series of the purchase, acceptance, storage, utilization, storage and disposal, and delivery of unsealed radioisotopes waste for unsealed radioisotopes in compliance with laws.

At the time of purchasing or acceptance, the system easily checks that purchased or accepted quantities are within regulated quantities (maximum quantities per day, 3 months or year) for the storage and specifies by whom, when, where the each source is used and quantity of each used source, residual quantity of sources and what container the waste is in, which allows the RI facility manager to easily generate control reports in compliance with laws (Fig.8).

Recently, stock check system using the RI stock list, noncontact IC tag and handy terminal is introduced (Fig.9). The system is useful for daily source control as well as periodic stock control because the system cuts the stock check time (check for loss of stock).

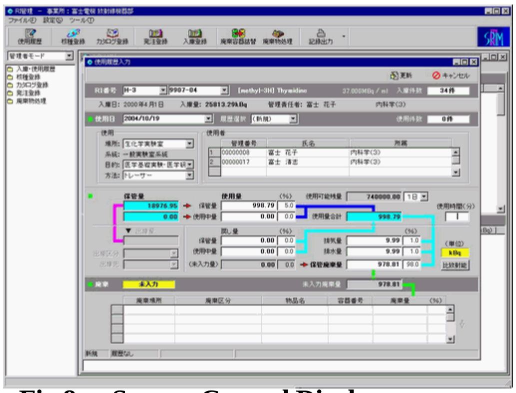


Fig.8: System Control Display

Fig.9: Stock Control System

e. Personal Dose Control System

Personal Dose Control System is to rationalize the evaluation of effective dose at the plant. Measurements of personal dosemeter and periodic health check-up can be input in the system. By interfacing with the access control system, the personnel who have not taken the periodic health check-up and those who have exceeded dose limit can be detected so as to disable them to enter the access control area.

In addition, personal dose control system applying the electronic dosemeter, which is also used as a dosemeter for evaluation at nuclear power plant etc., has started to become widely used.

2.1.2 Radiation Protection of Worker

Radiation Protection for the radiation work personnel is provided by the evaluation of external exposure dose using personal dosemeter (It is measured and evaluated every month with glass badges and other method. It is generally outsourced.) and by the periodic health check-up set forth by law, in order to check that the total amount of external and internal exposure dose does not exceed yearly effective dose limit. However, these methods merely check whether to have been exposed or not after the occurrence. It is important to emphasize the radiation protective measures within work area for reduction of exposure more assertively.

Therefore, employment of aforementioned personal dose control system using the electronic dosemeter is also effective so that plant manager can take appropriate measures by detecting radiation exposure promptly.

2.1.3 Radiation Protection at Work Area

Environmental monitoring is conducted for radiation protection at work area by the following methods. The monitoring is required to conduct in order not to exceed the monthly-base limit in compliance with laws and regulations. The monitoring is conducted by Manager, but mostly it is outsourced.

2.1.3.1 Measurement of Airborne Radioactive Concentration

Airborne Radioactive Concentration is measured by filtering method with movable dust sampler. It is for internal exposure evaluation of worker, and is implemented in a room where has a possibility the worker would inhale the RI such as rooms using RI. Especially for highly concentrated RI, room gas monitor or iodine monitor is may installed for real-time monitoring of airborne radioactivity

2.1.3.2 Surface Contamination Measurement

Surface Contamination is measured by direct measurement method with smear method or survey meter. It is required to measure contamination monitoring room which is entrance of the restricted area, room using RI and disposal work room.

Measurement points are determined, focusing on points with high chance of contaminations such as tables, hoods, floor around sink or on highly used point as entrance of each operating room. Hand foot monitor detects floor surface contamination by measuring personnel with slippers on, so that contamination status is immediately recognized.

If any contamination was detected, decontamination of the floor is performed, or preventive measure of spread out of the contamination would be taken immediately. Some facilities provide measurement results to users to draw attention on a regular basis.

2.1.3.3 Measurement of Leak Dose Equivalent Rate

Leak Dose Equivalent Rate is measured by ionization chamber or scintillation survey meter.

It is required to measure operational, storage and disposal facilities, and at boundary of controlled areas and site.

Area monitor is installed in possible points with maximum dose equivalent rate, large fluctuation in dose, in locations where personnel stay most of time or boundary of controlled area. In many cases, the area monitor conducts real-time monitoring of dose rate by communicating with radiation monitoring system.

2.1.4 Radiation Protection of the Public

2.1.4.1 RI Usage Facilities etc.

Dose criteria (levels of radiation or concentration of radioisotopes in air or surface) in controlled areas as well as the concentration limits for the releases and discharges of effluents from radioisotopes are stipulated and prescribed in the existing rules and regulations. For the protection of the general public against exposure to radiation, the law requires the use of appropriate material and thickness for shielding to achieve the desired dose limits for the general public. Other requirement specified in the law is for radioisotopes (RI) facilities to establish an exclusion boundary area (reasonable distance from public domain) including the residential area for RI facilities workers, with an effective dose level which is defined not to exceed 250 uSv/3 months.

2.1.4.2 Medical Sector

Guidelines (residual radioactivity and dose rate) and safety instructions related to release of patients administered with after therapy with unsealed radionuclides, brachytherapy are established for the safety of the family, patient comforters and carers ,and the general public.

2.1.4.3 Scrap and Metals, etc

Now that the scrap metals are distributed worldwide by cross border trade, not only workers engaged in ironworks and in metal production industries but also general public will be exposed in radiation from recycled products including orphan sources mixed in scrap metals. Thus, the government’s customs agency installs radiation monitors at the points of entry and exit of the shipping ports, scrap metal companies install radiation monitors in a yard entrance so as to ensure that every truck carrying scrap metals are properly monitored for orphan sources and radioactively contaminated scrap metals.

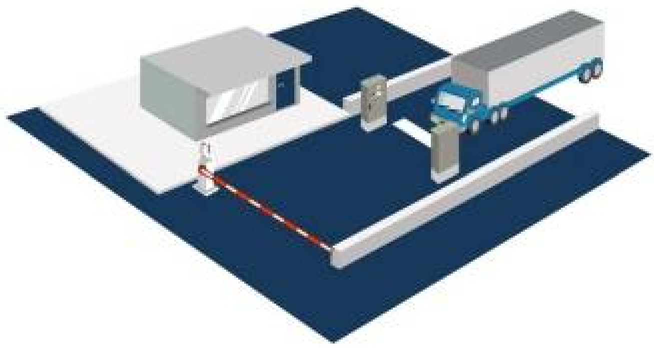


Fig. 10: Image of truck radiation monitor

2.1.5 Radiation Emergency Response

2.1.5.1 Definition of Accident (emergency situation)

A radiation accident is a situation caused by an unexpected event that deviates from a normal operation of facilities and workflow such as out of regulatory control of radiation source. This accident can be caused by earthquake, fire and other hazards/disasters (flood and power failure etc), deliberate offense like theft and pilferage, and machine failure.

Measures in case of accidents and emergencies are defined by the regulations of the Ministry of Education, Culture, Sports, Science and Technology(MEXT) and the Ministry of

Health, Labour and Welfare(MHLW) and other government agencies. Should these events occur, the employer is required to report promptly to a jurisdiction ministry and a related organization.

2.1.5.2 Examples of Accidents while Using RI at a Nuclear Medicine Facility and Transporting (emergency situation)

The examples here include the following situations:

a) There is a possibility of fire and catch fire
(vaporization and evaporation of radioactive materials)
b) There is a difficulty to immediately stop irradiation due to damage of shielding materials for external radiation caused by hazards such as earthquake while irradiating.
c) Radiation Source has fell off from its container
d) There is inability to store the radiation sources into their container caused by breakdown of remote devices.
e) A radiation source is missing due to theft/ loss
f) The local exhaust ventilation system or the emission source enclosure system does not function properly due to faults or damage.
g) A great deal of radioactive substance has leaked, spilled or been scattered.

2.1.5.3 Where to report

The place to report varies according to jurisdiction or cases. The example includes Ministry of Education, Culture, Sports, Science and Technology(MEXT), Jurisdiction labor standards office, police station, fire department, Ministry of Land, Infrastructure, Transport and Tourism, Public health department, and National Personnel Authority.

2.1.5.4 Medical Examination etc. (Ordinance on Prevention of Ionizing Radiation Hazards)

The employer shall immediately have those workers falling under any one of the following categories receive the medical examination or treatment by a medical doctor, and also report to the head of relevant labor standards office.

- Those who were in the zone when an accident occurs.
- Those who have exposed effective dose or equivalent dose over the limit
- Those who accidentally inhaled or orally took in a radioactive materials.
- Those whose contamination level of their bodies cannot fall below one ten by means of washing and so on.
- Those whose wound is contaminated

2.1.5.5 A case that you find radioactive materials (response to accidents regarding orphan sources)

Based on the Radiation hazards prevention law, a permission or notification is required if you wish to use over a certain amount of radiation materials. MEXT requests on their website and other media to report if unapproved radioisotopes materials or those suspected were found and also warns against touching or moving them without discretion.

The followings are to be checked by MEXT if a radioactive material has been reported.

[Items to be reported]

a) Name and contact details of reporter
b) Time when it was found
c) Place where it was founded
d) State and label of the matter found etc.
e) Approximate dimension, weight, and quality of the material
f) Dose rate, radiation survey meter or measuring instrument, and measurement method
g) Situation around the found place (if there is a house or not etc.)

2.1.5.6 Preparation of radiation emergency response manuals

In RI Application facilities, radiation emergency response manuals and check lists are prepared and disseminated among the workers in case that an accident occurs. The following cases are considered in these manuals and check lists.

a) Fire
b) Earthquake
c) Ambulance vehicle needed
d) Radiation exposure (lose of radiation sources, continuous irradiated state due to equipment failure, inadvertent external exposure, internal exposure, and body contamination)
e) Expansion of contamination of unsealed sources （gas, dust, and liquid）
f) Loss or theft
g) RI outside their control found
h) Accident during transportation
i) Communication system and contact information （in and out of the facilities）

2.2 Radiation safety management in Research Reactors

2.2.1 Radiation Safety Management System

The safety management system in research reactors is regulated in the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors of Japan as well as Nuclear Power Plants. The radiation safety procedures are ruled in the inside-rule of every facility, but much simple relative to those of NPPs.

The radiation safety management at the reactor facility consists of the management of radiation workers, radiation control of working area, control of contamination level on carry-out goods and control of radioactive discharge (gas and liquid) to the environment.

2.2.2 Radiation Protection for Radiation Worker

The reactor room is designated as controlled area and is equipped with some radiation protection apparatuses and instruments, such as radiation monitors (Gamma and Neutron), survey meters (Gamma, Neutron, Beta etc.) and radioactive air concentration monitors. The air pressure of reactor room is kept in lower level than outside so that radioactive materials cannot flow out to the general area. For most research reactors, the criticality monitoring is not necessary except some of the special types of critical assembly facilities. Access control of workers is a little bit strict and all the workers who are going into the reactor room are registered during their stay in the room. When they exit from the reactor room, radioactive contamination of the body or carry-out goods and exposures of workers are checked and the exposure value would be reported if it is over the recording level.

All the radiation workers have to wear an experimental or working suit and safety shoes to avoid contamination of their own bodies and clothes. The radiation workers also must wear either one or two types of personal dosimeters to measure and record their exposure values. Direct reading personal dosimeters are useful for their exposure control by themselves. The radiation and air contamination (dust or gas) monitoring apparatuses are often used to observe the status of the working area. If the air contamination level is exceeded a designated criterion, appropriate radiation protection measures, such as wearing air mask, etc. are conducted. When work finished, survey checks on surface contamination are made with survey meters for workers, tools and floors.

2.2.3 Radiological Protection for Radiation Area

Radiation and air contamination levels at the working area are continuously watched by the radiation protection officers using monitors and recorded with the electric devices. And, when something unusual happened, the radiation protection officers would notify the situation to the workers and take any protection measures, if necessary. Figure 11 shows an example of the air contamination monitoring at controlled area.

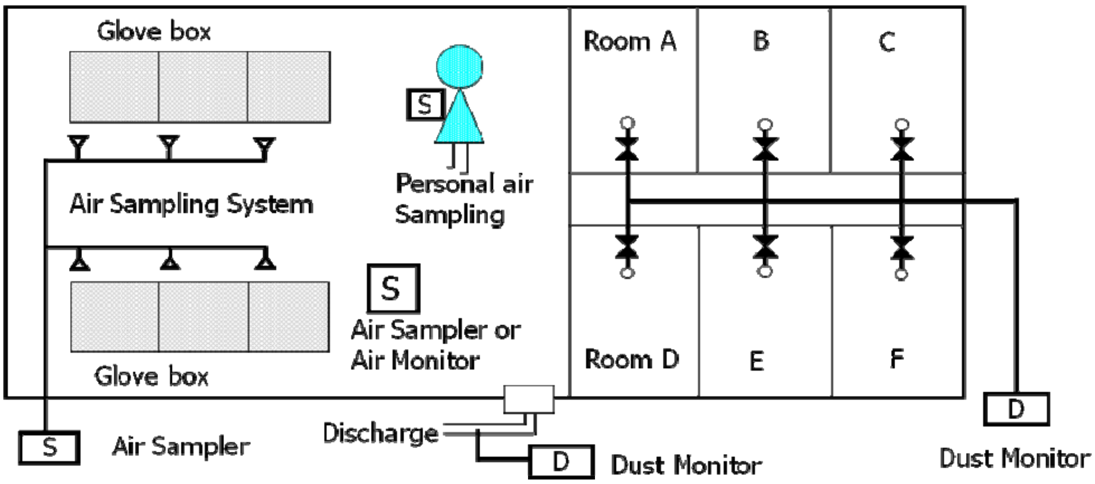


Fig. 11: An Example of Air Contamination Monitoring at Controlled Area

The control of discharge of radioactive materials to general environment is also quite important for research reactors. The total amount of radioactive discharge is limited in the inside-rule of each facility, but the actual amount of discharge is quite smaller than the limited value. For some research reactors, main radio-nuclides in the air waste are Ar-41 and Tritium (H-3) produced in the surrounded air or water. The fission products, such as I-, Xe-, etc., are discharged in the air quite a little from general water-cooling type research reactors. Figure 12 shows an example of the air monitoring system of research reactor facility. The radioactivity level in the air is watched all the time with dust or gas monitors. Dust and volatile materials are also sampled with air filters and the filters are measured with suitable radioactivity measurement devices such as, Ge detectors and/or gas flow counters, for detailed investigation of radioactive air concentration level.

The liquid waste from the controlled area is once stored in a disposal tank at each facility and then checked its radioactive concentration level by sampling. If the value of radioactive concentration in the liquid waste is less than a designated level, the liquid waste is discharged into the sea. If the value is exceeded the level, the waste is transferred to the disposal treatment facility and stored.

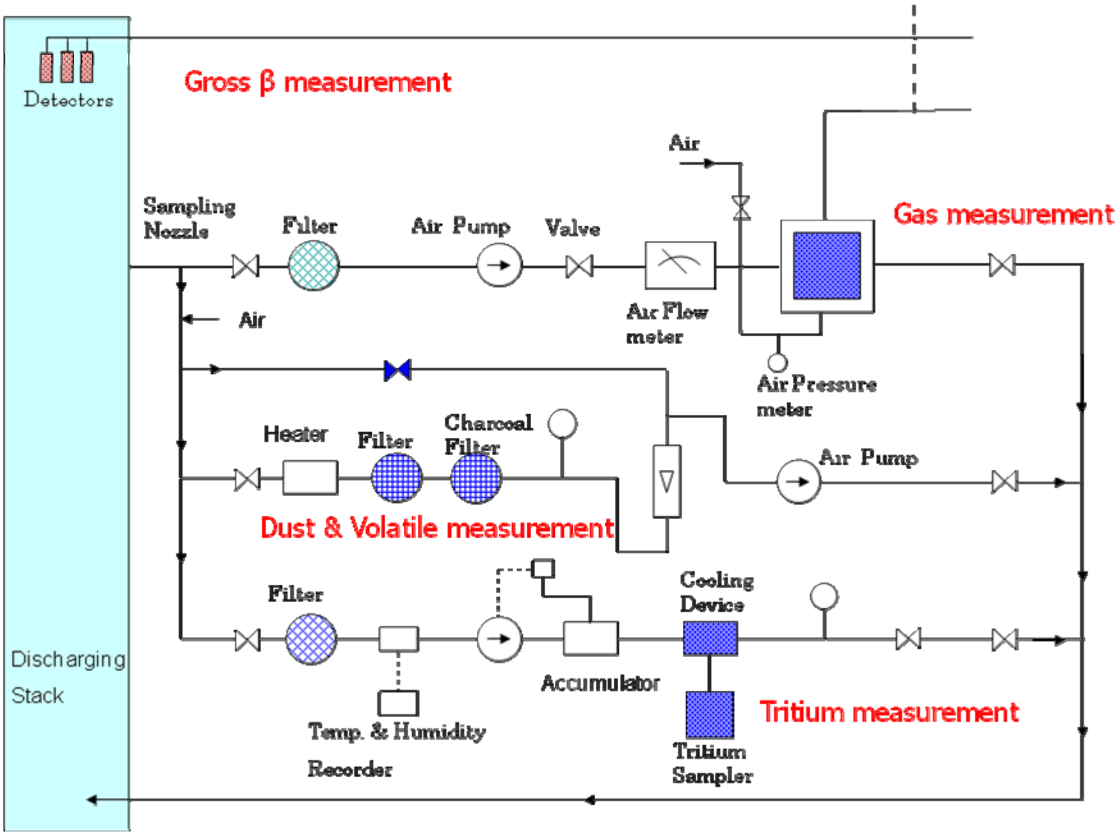


Fig. 12: An example of monitoring system for airborne radioactive waste at research reactor facility

2.2.4 Radiological Protection for the Public

The exposure of public people is evaluated by the calculation using the amounts of discharged air and liquid radioactive materials. And all the amounts of discharged radioactive materials and evaluated dose values of the public are reported to the Government and the local governments. In addition, most of the organizations that operate research reactors set up the environmental measurement apparatuses, such as monitoring stations or monitoring posts, inside and outside of the site, and they are keeping observation on radiation level and others all the time.

2.2.5 Radiation Emergency Preparedness

In emergency situations, such as fire, earthquake or any troubles inside the facility, all the members of the facility will gather immediately at any time and engage in the recovery work. The training on emergency preparedness is also conducted once or twice a year to keep workers' motivation in good condition.

2. 3 Radiation Management in Nuclear Power Plants

2.3.1 Radiation Safety Management System

Nuclear power plants construct radiation safety management system with the director at the top. Fig.13 shows an example of the system.

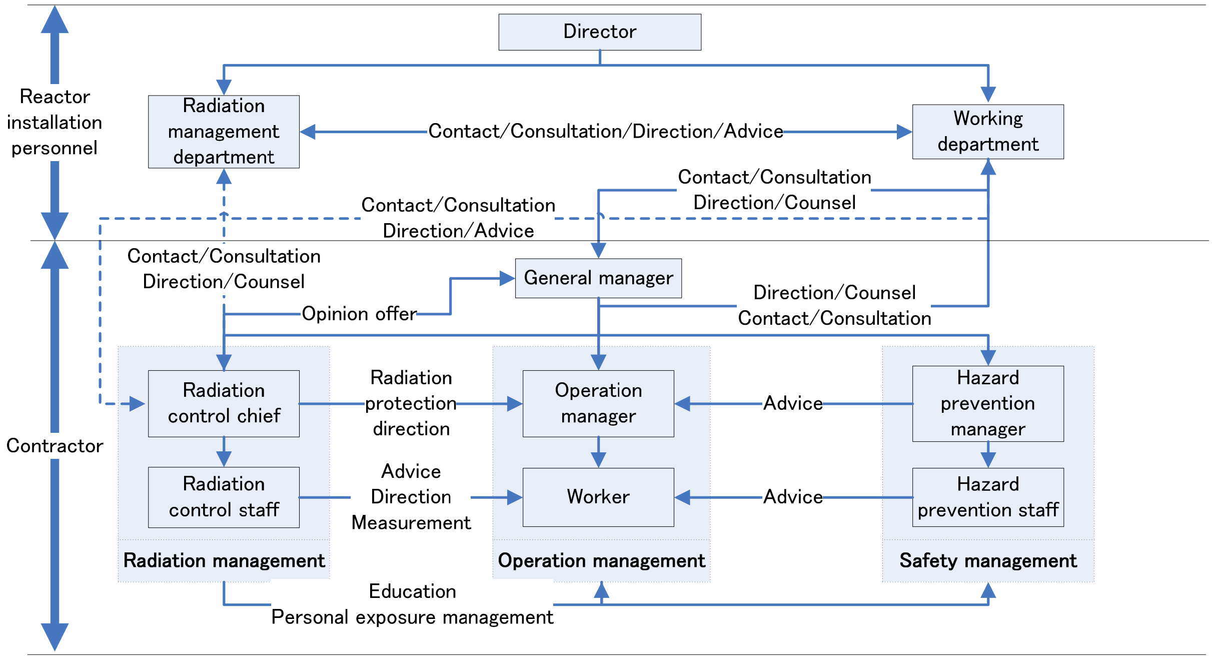


Fig.13: Radiation Safety Management System

2.3.2 Radiological Protection for Radiation Worker

In nuclear power plants, the amounts of doses for radiation workers are managed to keep the legal dose limits, 100 mSv for 5 years and 50 mSv for one year, as well as the planned doses which are directed every work. In this way, we try to aim at the doses as low as reasonably achievable (ALARA).

People who work in radiation-controlled areas are supposed to register as “Radiation Workers”. At the time of registration, they are required the past doses, the results of medical examinations by doctors, the records of education such as knowledge about radiation and rules for radiation works and so on. Only after the above confirmation, they can work in radiation-controlled areas.

After the registration, they undergo periodical medical examinations, external dose checks by electronic type pocket dosimeter or glass badge and internal dose checks by whole body counters. Then the total amounts of personal exposure doses are notified to them respectively.

The Radiation Dose Registration Center for Workers (RADREC) collects personal dose records for radiation workers periodically. Therefore their dose records are centralized and managed uniformly, even if they work in other places. This system is called “Radiation Dose Registration and Management System” (Fig.14). For each person, Radiation Dose Record Booklet (Radiation Passport) is issued by agencies authorized by the RADREC. The booklet contains necessary information about radiation protection management such as bearer’s identification, historical exposure results, educational records and so on.

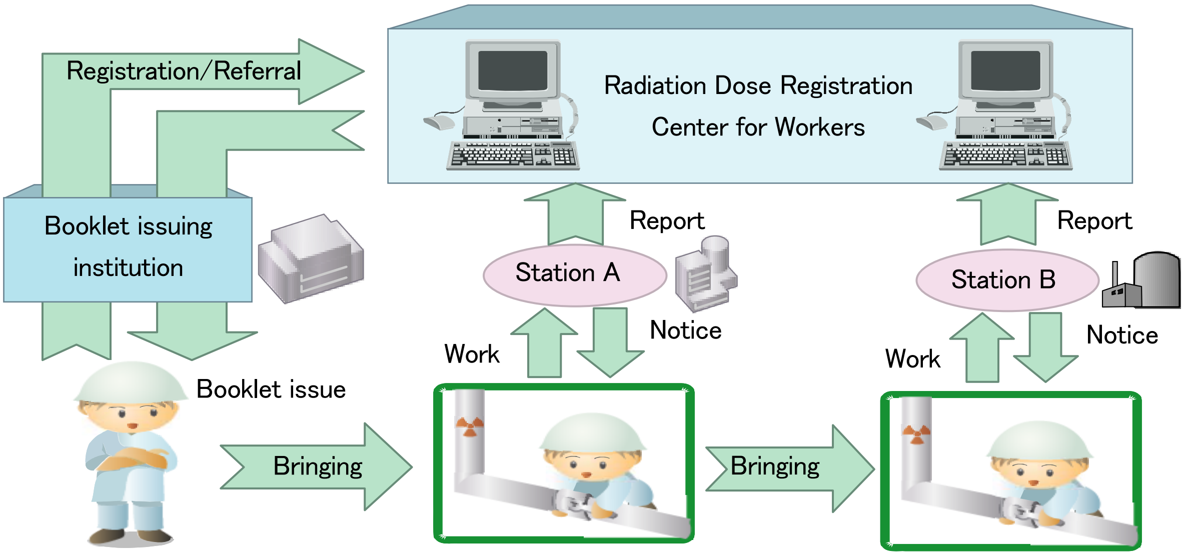


Fig.14: Radiation Dose Registration and Management System

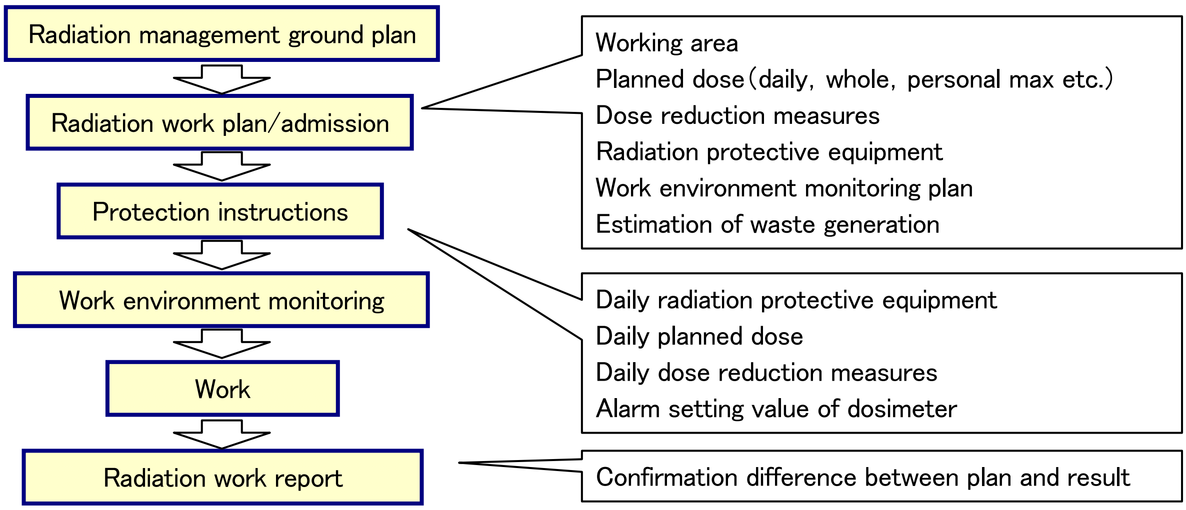


Fig.15: Radiation Work Flow (From plan to report)

Fig.15 shows the radiation work flow. By each step, PDCA (Plan-Do-Check-Action) has been repeated conventionally to reduce exposure dose.

2.3.3 Radiation Area Management

We prevent unnecessary exposures by setting radiation-controlled areas where a total effective dose from external radiation or radioactive materials in air and surface density of radioactive materials is exceed or suspected to exceed the legal limits. For figuring out the dose rates in the radiation-controlled areas, we settle radiation monitors. And then, continuous measurements and monitoring are conducted. To understand the contamination conditions, we also measure and watch the concentration of radioactive materials on the surface of the structural objects or in the air. According to the dose rates and contamination levels, we divide the radiation-controlled areas into some categories by using walls and fences with signs.(Fig.16)

In order not to bring out radioactive materials from radiation controlled areas, we are supposed to change into special clothes and shoes etc. in the radiation-controlled areas which have probability of contamination. And we are also supposed to take contamination tests for goods and body surface to make sure of no contamination when we exit from the radiation-controlled areas.

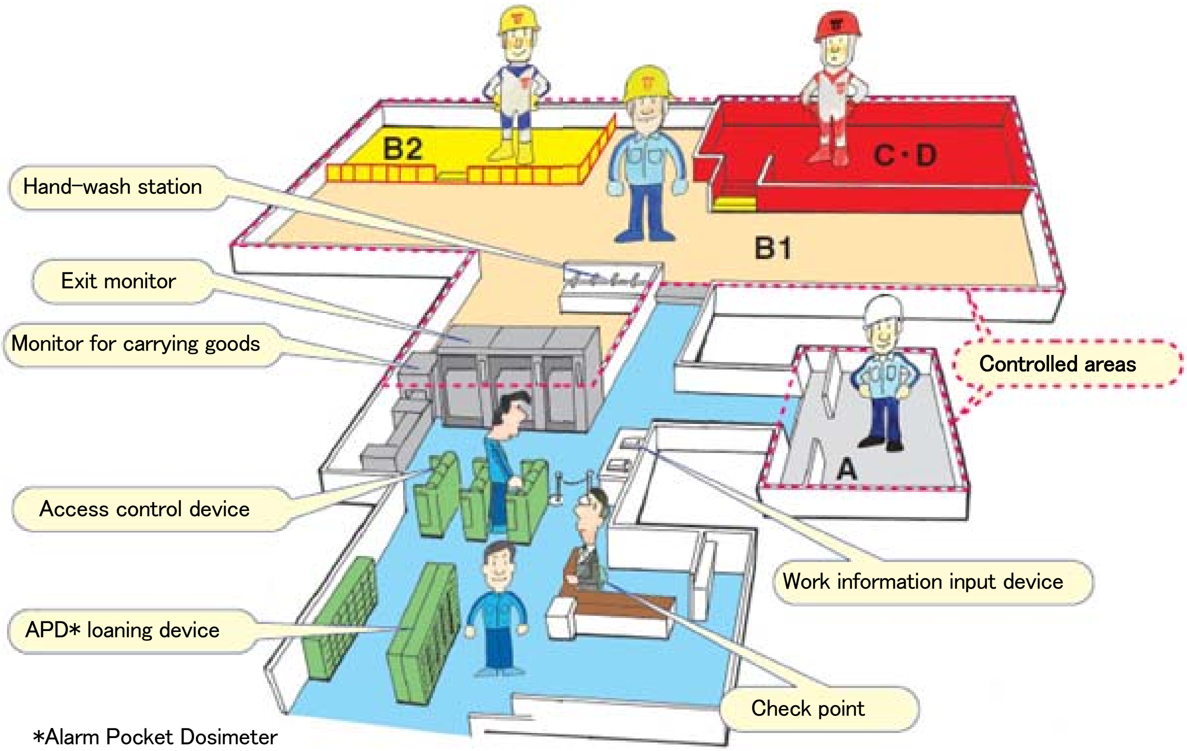


Fig.16: Divisions of Areas inside the Radiation-controlled Areas

2.3.4 Radiological Protection for the Public

2.3.4.1 Regulation and Guideline

(a) During normal operation

Annual dose limit (1mSv/y) for the public is prescribed by the regulation as shown in Table 1 to ensure the protection of the public against radiation from nuclear power stations in Japan. This is based on ICRP recommendation in 1990.

To allow compliance with the regulation with wide margins, a dose target (50μSv/y) for the public is prescribed by guideline. This is a target value for the public dose due to the radioactive materials released from nuclear power stations. And this is a criterion to judge that releases reduction systems are arranged so as to keep doses to the public as low as reasonably achievable (ALARA).

A dose target (50μGy/y) for the public due to radiation from the nuclear power station is provided in a Nuclear Energy Special Committee report.

(b) Under accident condition

To protect the public from significant radiation effects, dose criteria for postulated nuclear power station accidents are also stipulated in the guidelines in view of reactor site suitability and design adequacy.

As criteria for reactor site suitability, the target values of individual dose and population dose for severe accidents and hypothetical accidents are established as shown in Table 9. The severe accident is defined as an accident that is less likely to occur. The hypothetical accident is defined as an accident that is unlikely to occur from a technical viewpoint.

On the other hand, as criteria for design adequacy, the target value of dose is established for the design basis accident.

Table 9: The dose limits for the public in the Japanese regulation and guidelines.

Type				Dose criterion
Regulation (limit)		Annual dose		1 mSv/y
Guideline (target values)	During normal operation	Annual dose for release of radioactive materials		50 μSv/y
		Annual dose for radiation from facilities		50 μGy/y
	Under accident condition	Design basis accident	Effective dose	5 mSv
		Severe accident	Whole-body dose	0.25 Sv
			Thyroid dose (child)	1.5 Sv
		Hypothetical accident	Whole-body dose	0.25 Sv
			Thyroid dose (adult)	3 Sv
			Population dose	20000 man·Sv

2.3.4.2 Nuclear power plant design

(a) Policy of radiation safety design

Releases reduction systems, radiation protection equipments, and radiation monitoring and sampling systems are provided at nuclear power stations to establish radiation safety for public and radiation workers. The releases reduction systems and the radiation protection equipments are designed based on the ALARA concept, with specifications for reducing release or exposure dose to a level as low as reasonably achievable. Judging ALARA approach is accomplished by compliance with the dose target based on the guidelines.

In case of an abnormal event, the systems and the equipments are designed to achieve "shutdown of the reactor," "cooling of the reactor," and "confinement of radioactive materials". They are also laid out to attain habitability in the control room and the technical support center to allow operational actions. Furthermore, the releases reduction systems and the radiation shielding facilities are provided to ensure compliance with the dose targets by the guidelines during the abnormal condition.

(b) Radiation protection design

(i) Releases reduction systems

Releases reduction systems are designed so as to store radioactive gaseous waste emitted as a result of the degassing process of the reactor coolant, to monitor the concentration of radioactive materials and to release the waste gas after its radioactivity is sufficiently reduced.

The ventilation systems are intended to remove radioactive materials from the exhaust generated in radiation controlled areas by using iodine filters or high-performance particle filters. The systems also monitor concentrations before releasing waste gas.

Reactor coolant, equipment drains, floor drains and effluents from hand-washing, laundry, and hot shower systems are to be filtered, demineralized and concentrated by the evaporator. This is to ensure that the concentration of radioactive materials in the liquid waste is sufficiently reduced. Afterward the liquid waste is diluted and released after checking the concentration of radioactive materials. Concentrated liquid waste generated from the evaporator is to be solidified. The miscellaneous solid waste and the spent exhaust filters are to be compressed for volume reduction. The low level spent resin, the low level concentrated liquid waste, and combustible miscellaneous solid waste are incinerated for volume reduction. These solid wastes are put in drums separately for temporary storage. Storage capacity for the high level spent resin is secured to store the resin generated throughout the plant life.

Releases mitigation systems corresponding to postulated events are provided so as to keep doses below the target levels for site suitability and design adequacy. Moreover, event mitigation manuals have been developed with the aim of reducing the amounts of releases under severe accidents.

(ii) Shielding facilities

In Japan, since it is difficult to secure a sufficiently large site for a nuclear power station, it is critical to reduce radiological effects on the public to as low as reasonably achievable by thoroughly shielding radiation from facilities. In reactor facilities, the shielding designs of the containment vessel, turbine system (BWR), and waste disposal and storage facilities are important. For reactor auxiliary buildings, reasonable shielding designs are implemented by optimizing equipment layouts.

Currently, large components are being replaced for facility maintenance after about 20 years of operation.

Accordingly, additional waste storage facilities to store large-size radioactive waste arising from the replacement are being built with a satisfactory shielding design that eliminates the harmful effects of radiation on the public.

(iii) Radiation monitoring systems

In operating reactor facilities, monitoring systems are designed to ensure that the amounts of releases are below the prescribed releases targets for gaseous and liquid waste. At the same time, these systems are intended to perform sampling and measurement before releasing waste. Depending on the monitored level, the effluents can be returned to the radioactive material processing systems as necessary.

Furthermore, dose rates in the vicinity of the plant and the concentration of radioactive materials in environment (samples) are measured so as to monitor the impact on the environment.

To detect any anomaly at a nuclear power station as soon as possible, and to prevent any abnormal release of radioactive materials, radiation monitors for leakage detection are installed in the systems of reactor coolant, main steam, waste treatment, and ventilation.

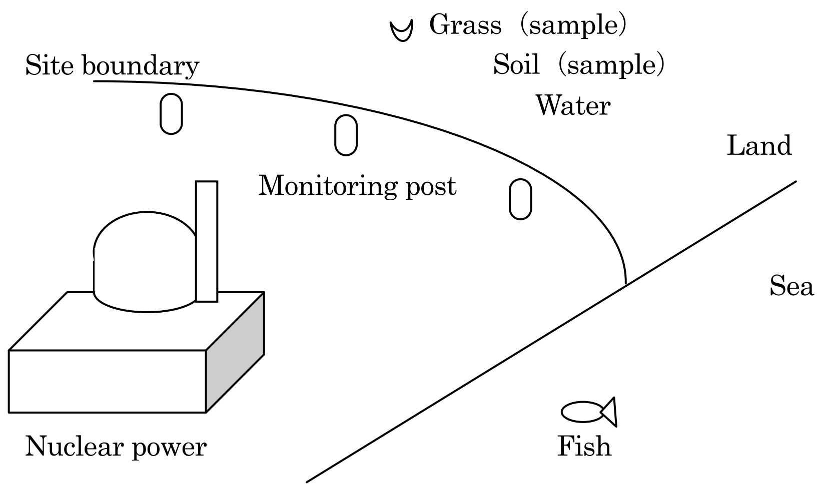


Fig. 17: Environmental monitoring and sampling during normal operation

2.3.5 Radiological Emergency Response

2.3.5.1 Legislation and guidelines

Following the critical accident at the reprocessing facility in Tokai-mura (Japan) in September 1999, the Special Law of Emergency Preparedness for Nuclear Disaster was enacted in December of the same year, whereby a disaster prevention scheme at the time of emergency at a nuclear installation was established.

The law clearly defines the duties of the nuclear operator in case of emergency, obligation to notify an abnormal event, declaration of a nuclear emergency, mechanisms for setting up Nuclear Emergency Response Headquarters and Local Nuclear Emergency Response Headquarters, and the roles of an Off-site Center.

An abnormal event should be notified when the dose rate near the site boundary reaches 5 μSv/h or if the event may develop into a nuclear emergency involving the activation of the emergency core cooling system (ECCS). A nuclear emergency is declared when the dose rate near the boundary of the plant site reaches 500 μSv/h or if the event has evolved into the loss of all reactor shutdown functions.

In the wake of the Three Mile Island reactor accident in 1979, emergency preparedness guidelines were established in 1980 under the Basic Law for Emergency Preparedness, and they were revised in May 2000. They clearly define technical elements in nuclear emergency activities as well as tasks to be fulfilled in the aspects of emergency monitoring, emergency preparedness, emergency exposure medical treatment, and so on.

2.3.5.2 Nuclear disaster emergency countermeasures

Upon notification of an abnormal event at a nuclear power station from the operator according to the Special Law, an Off-site Center will be set up.

As the event progresses, the central government declares a nuclear emergency, which prompts organization of Nuclear Emergency Response Headquarters within the government, Local Nuclear Emergency Response Headquarters at the Off-site Center, and a Joint Council for Nuclear Emergency Response.

The central government, local government, police, fire defense authorities, self-defense forces, operator, and experts will be summoned to take part in disaster response countermeasures in multiple functional groups under the leadership of Joint Council for Nuclear Emergency Response.

The central government is now implementing the technical assistance necessary for developing a system in which the government participates in the prediction and countermeasures management of the accident progression. This includes ascertaining the abnormal state of the reactor facility based on online information from the nuclear power station, operates a system that predicts the evolution of the event, predicts radiation exposure effects resulting from released radioactive materials in the vicinity of the site using local meteorological information on the basis of the SPEEDI system, and issues evacuation advisories to the local residents in an appropriate manner if necessary. Additionally, to establish a thorough preparedness structure in case of nuclear disaster, nuclear emergency response drills are regularly conducted jointly by the central government, local governments, operators, and other parties concerned to make sure that the communication system, command system, decision-making process, evacuation process, and roles and functions of individual participants work effectively.

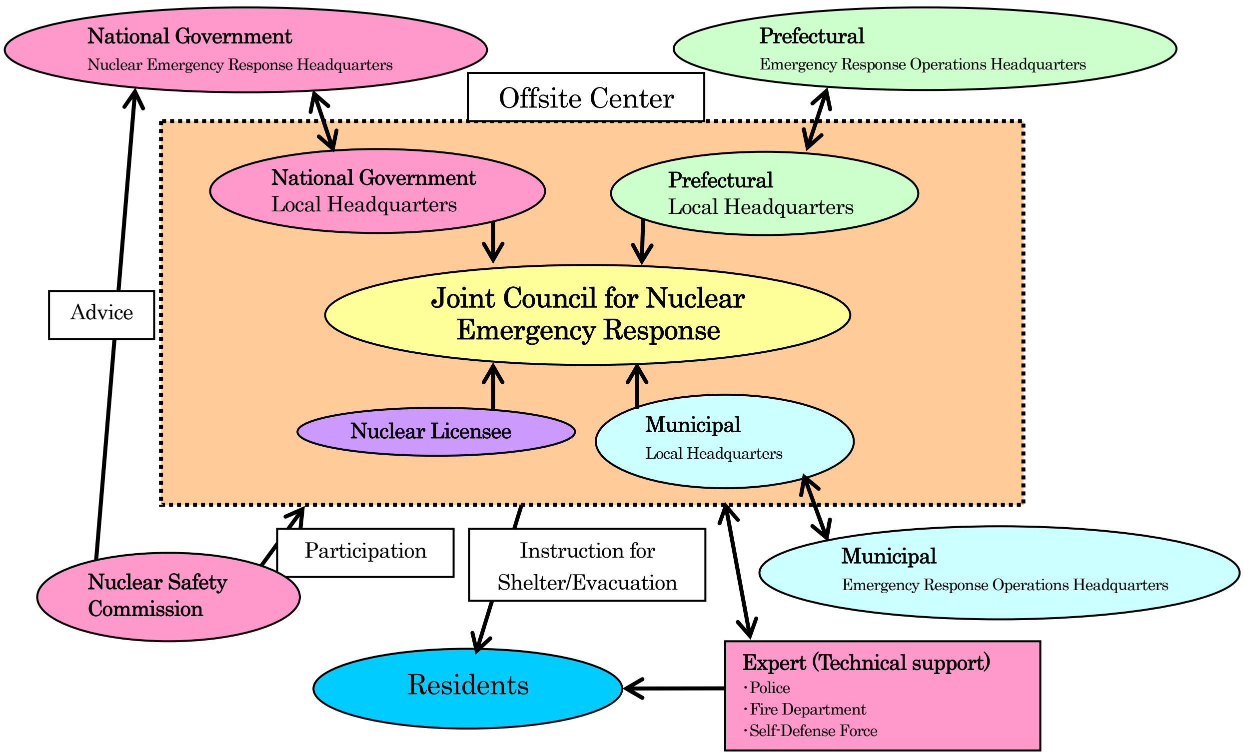


Fig. 18: Emergency Preparedness Organization

2.3.5.3 Response to a radiation accident

Possible radiation accidents at nuclear power stations include excessive exposure and radioactive contamination at times of patrol inspection during operation, radioactive equipment inspection as part of periodical inspection, and handling of spent resin, spent filters, and other radioactive waste.

To prevent these radiation accidents, radiation measurement and contamination inspection are performed in advance, as necessary; work plans are prepared and planned doses are preset for radiation work; and activities are performed under radiation control.

Importantly, education and training sessions and mockup tests are conducted in pursuit of high safety awareness and reduced exposure time.

In case a radiation accident occurs, the top priority is placed upon the safety of humans and lifesaving. If there is critical contamination or exposure, treatment by physicians is mandatory. In the meantime, the plant manager and workers around the accident site should be notified of the occurrence of the accident, and measures necessary for preventing expansion of the accident or spread of contamination must be put in place.

2.4 Radiation Safety Control at the Radioactive Waste Treatment Facility (Regarding Radiation Safety Control of the Low-Level Radioactive Waste Disposal Facility)

2.4.1 Radiation Safety Management System, Radiological Protection for Radiation Worker, and Radiological Protection for Radiation Area

Radiation safety control applied at Japan Nuclear Fuel Ltd. (JNFL) 's Low -Level Radioactive Waste Disposal Center which is located at Rokkasho-Mura, Aomori Prefecture, is different from the one applied to nuclear power plants , and has a special feature that its method is changed gradually in accordance with the attenuation of radioactivity of radioactive waste. This is described as the "Phased Management".

❑ **Regarding Waste Packages**

At present, there are two facilities at the Low-Level Radioactive Waste Disposal Facility at Rokkasho, namely, No. 1 Disposal Facility and No. 2 Disposal Facility, where two different types of waste packages are buried. In No.1 Facility, such liquid waste as water used in rinsing the floor of nuclear power plants is evaporated, concentrated and solidified, which is then put into drums after being homogenously solidified by cement, asphalt or plastic. Waste packages disposed in No. 2 Disposal Facility consist of metal（pipes and plates etc） and concrete scraps produced as result of periodic inspection works. These are cut, compacted or dissolved as necessary, and are placed in drums and solidified with mortar.

Among waste packages to be disposed, there is incongruity in radiation levels in each waste package, but the level is below the upper limit of concentration defined by law, which fact is confirmed before transportation from nuclear power plants, and on each waste package, signs indicating it as radioactive waste and identification number are shown. Upon arrival at Rokkasho Disposal Facility, Government confirmation that each package conforms to technical standard required by law regarding its outward appearance and identification number is given before being disposed.

The principal technical standard for waste package consists of the following:

1. That the waste is solidified inside the package
2. That the waste does not exceed the maximum radioactive concentration
3. That there is sufficient strength
4. That signs and identification numbers are place.

❑ **Regarding the disposal facility**

Waste packages are placed inside the disposal facility (pit) made of reinforced concrete.

When fixing waste packages inside a pit, attention should be paid so as to balance the concentration and types as facility as a whole, by not placing waste packages extremely close to the type other than that which is solidified by cement.

Waste packages, when confirmed upon reception, do not need to be verified package by package after their disposal, since radioactive waste in principle attenuates according to its half-life, and since, for dose evaluation of the general public, control is done as a disposal ground as a whole.

After waste packages are fixed fully inside a pit, spaces between the drums are filled in with mortar, and further, a cover made of reinforced concrete is placed over the entire disposal facility, shielding radioactive waste completely. The entire facilities is covered with water-impervious Bentonite clay. This is then covered with original soil、which is planted with grass, and this will remain a controlled site for approximately 300 years.

- ❑ **Regarding Phased Management**

Next, "Phased Management" means that the waste disposal facility is managed by changing method into three phases as follows:

At the First Phase, where the radiation level at the start of burial is not sufficiently low, by means of artificial barriers such as concrete pits and drums, waste packages are shielded so that they do not leak radiation and radioactive material.

At the Second Phase, upon completion of the First Phase, radioactivity becomes low after the passage of certain time period, stabilizing measures of the surrounding soil is effected, since it becomes possible to restrain the transfer of radioactive material sufficiently by means of the surrounding soil even if the disposal facility is deteriorated.

At the Third Phase, upon completion of the Second Phase, when radioactivity declines sufficiently after the passage of certain period, the situation becomes safe enough only by interdicting digging. After 300 years, the radiation level of the waste packages becomes very low, which means safe enough so that no regulation shall be applicable for the waste packages as radioactive material.

Fig. 19: Attenuation by aging of total radioactivity

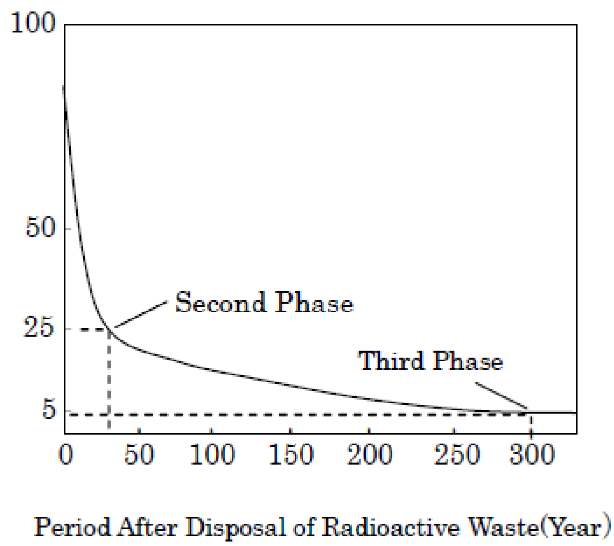


Table 10: Way of Thinking of Phased Management

<table>
<tr><th></th><th>1st Phase</th><th>2nd Phase</th><th>3rd Phase</th></tr>
<tr><td>Scheduled Period</td><td>Time elapsed after initial disposal
No.1:30-35 years
No.2:25-30 years</td><td>Time elapsed after 1st Phase:30 years</td><td>Time elapsed after 1st Phase:300 years</td></tr>
<tr><td>Purpose</td><td>Containment within disposal facilities</td><td>Prevention of transfer using disposal facilities and cover soil</td><td>Prevention of transfer primarily through cover soil</td></tr>
<tr><td rowspan="3">Control Management</td><td colspan="3">・Establishment of disposal maintenance area, monitoring of waste burial, restoration of cover soil
・Environmental monitoring</td></tr>
<tr><td colspan="2">・Establishment of supervised area
・Monitoring of density of radioactive substances in groundwater
・Drainage of water, supervisory facilities water drainage</td><td rowspan="2">・Restrictions on excavation, etc.</td></tr>
<tr><td>・Monitoring for any leakage
・Repairs of disposal facilities, etc.</td><td>・Monitoring of leakage conditions</td></tr>
</table>

❑ **Regarding Measures for reducing occupational exposure**

Both Measures relative to facility and measures relative to management are undertaken. Following measures relative to facility are undertaken:

- Shielding, in accordance with the area of access by workers.
  Design criteria for shielding are as follows:

Table11: Design Criteria for Shielding

Areas		Dose Rate Equivalent (μSv/h)
Outside of Radiation Controlled Area		≦ 6
Inside Radiation Controlled Area	・48 hours entry /week	≦ 10
	・24 hours entry/week	≦ 20
	・10 hours entry/week	≦ 50
	・1 hour entry/week	≦ 500
	・Entry normally unrequired	＞ 500

The actual thickness of the shielding wall is 20cm～90 cm for the Control Building.

For the Disposal Facility, shielding is by concrete of approximately 50 cm.

Further, after fixing the drums in pits, by placing a temporary cover of 50 cm thickness, exposure from the pit opening is reduced.

・Crane for the handling of waste packages and inspection equipment of waste packages are automated and remote controlled.
・Entry-exit Control Units and Radiation Measurement Equipment are installed for the management of occupational exposure .

Table12: Measures for Radiation Protection Equipment

Items	Example of measures
Shielding	Thickness of concrete of the Facility ・Control Building （Principal Parts） Approx. 20～90cm ・Disposal Facility Approx. 50cm
Remote Controlled Automated	Various cranes Inspection Units for Waste Package
Radiation Control Facility	Access Control Facility Radiation Measurement Units, etc.

As measures from the management point, following are undertaken:
・Unitary management of Company employees and subcontractors' personnel by professionalization of Radiation Management Sector.
・Limiting access by establishing "Radiation Controlled Area"
・Access control of workers entering "Radiation Controlled Area".
・Personal dose control of workers.
・Radiation protection education to workers.
・Radiation work management such as monitering of dose rate in work area.

These measures are basically similar to those implemented at nuclear power plants.

❑ Regarding the evaluation of environmental impact

(Radiation protection of the general public)

Considering the impact on the environment by leakage of radioactive material from the Disposal Facility, it is important that there should not be harmful impact on human environment through groundwater.

The place where the Disposal Facility is located in Rokkasho, an impermeable bedrock called the "Takahoko Layer" is distributed along fairly shallow spot of several meters from the land surface, so that the groundwater is flowing mainly near the surface only. Further, since the landscape is a plateau surrounded by rivers and marshes, the groundwater consists mainly of rainwater which has seeped slowly into underground, so that we can say that this is an area where the groundwater is not abundant.

Since waste packages are placed in pits made of concrete, where the paces inside the pit are filled by mortar, and pits are surrounded by soil mixed with bentonite, it should be noted that sufficient measures are taken against the groundwater. Also, even in unlikely cases of the groundwater seeping into the Disposal Site, since water seeping through the surrounding porous concrete can be drained without reaching the waste packages until the Second Phase, it is unthinkable that the radioactive material can easily leak out of the Disposal Facility.

Table 13: Ground Water at the location of the Disposal Facility/Safety of locating below Ground Water

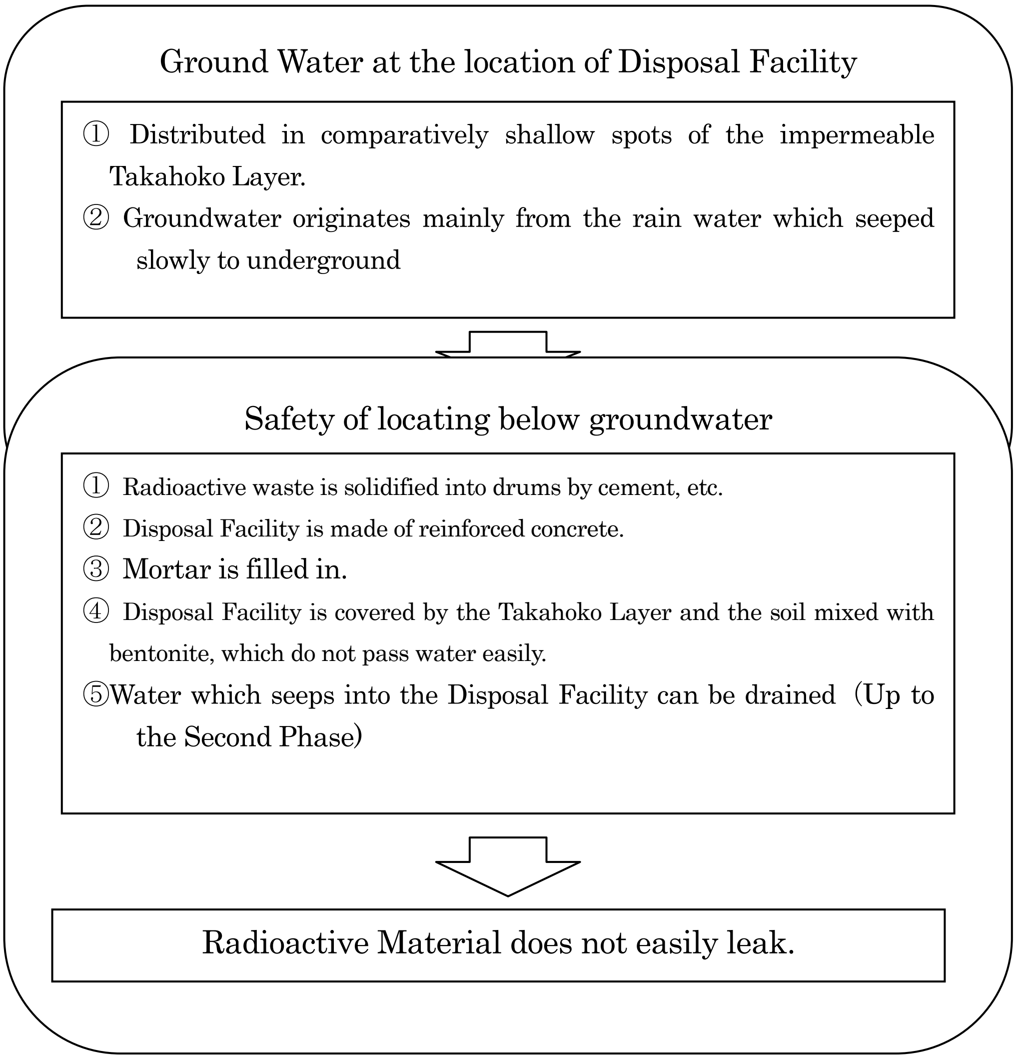


Table14： Comparison of Water Permeability Factor

Division	Water permeability Factor (cm/S)
Quarternary	Approx. 10^{-4}
The Takahoko Layer	Approx 10^{-5}
Bentonite Mixed Soil	Approx 10^{-7}
Concrete	Approx 10^{-10}

However, assuming the worst case of radioactive material leaking prematurely, evaluation of impact on in-taking maritime products from the marsh which is the ultimate reaching point of ground water is being undertaken.

Condition of evaluation is maximum 0.075 micro Sv per year, upon estimating the premature deterioration of the Disposal Facility, the routes through which marsh products are eaten, namely: from the groundwater to the stream to the marsh, from the marsh water to marsh products. This is well below the yearly dose criteria of 0.10 micro Sv which is a provisional target.

Dose equivalent evaluation is undertaken on assumption that the marsh water near the Disposal Facility may be used for drinking by the general public or for the cattle, after the expiration of the management period (300 years). This evaluation result shows that even taking into account, the cases of intake through various route, the dose equivalent is 0.13 micro Sv/year, which is so small that no impact is at all likely.

Table 15: Dose Equivalent Evaluation for eating maritime products

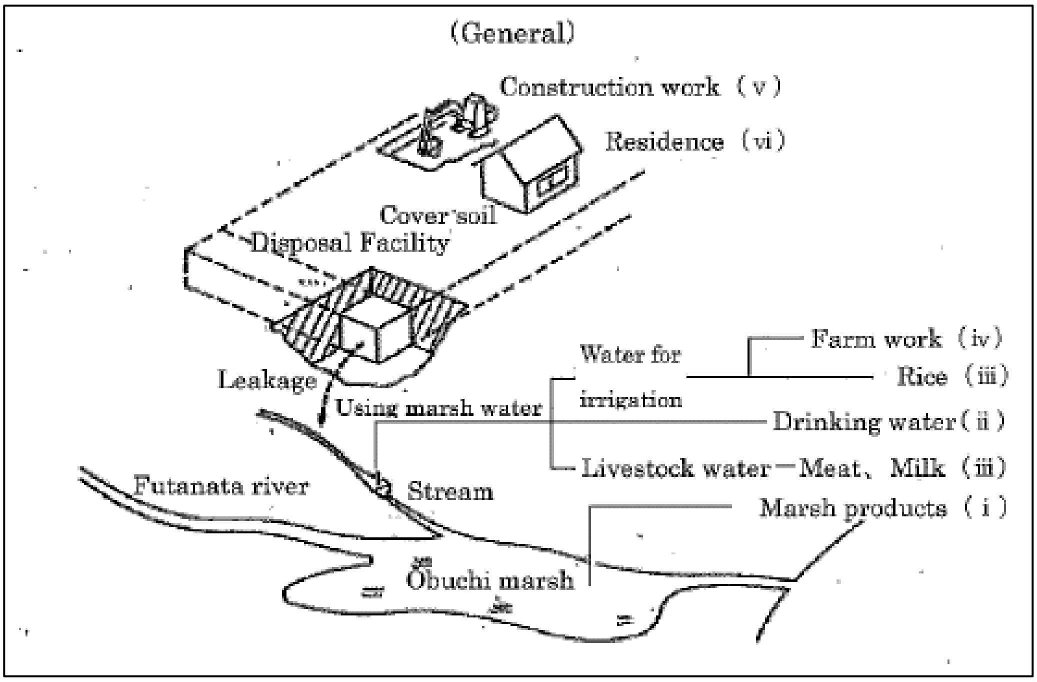
Condition for evaluation	Premature deterioration of Disposal Facility ↓ Carried by groundwater to marshes Marsh water to marsh product Eating marsh products daily & continuously
Result of evaluation	Max. 7.5×10^{-3} mSv/ y
Impact on maritime products	Sent to the sea from Obuchi Marsh ↓ Big volume of diluted water Impact can be fully ignored

Table 16：Evaluation Result After Expiration of the Management Period(General)

Unit(mSv/y)

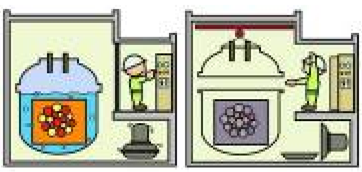
Evaluation Route of Dose Equivalent	Dose Equivalent	Judgment Dose
(i) Internal Exposure due to eating marsh product	Approx.7.5×10^{-5}	0.01 m Sv/y defined in "the Basic Way of Thinking" as a provisional target (For reference) Natural radiation Approx.1mSv/Year
(ii) Internal Exposure due to drinking marsh water	Approx.1.3×10^{-4}	
(iii) Internal Exposure due to eating dairy products produced by using marsh water	Farm products Approx. 9.1×10^{-5} Dairy Products Approx. 2.9×10^{-5}	
(iv) External & Internal Exposure due to farm work using marsh water for production	Approx. 5.5×10^{-5}	
(v) External & Internal Exposure for construction works of housing	Approx. 8.3×10^{-5}	
(vi) External & Internal Exposure due to residence in the area	Approx. 0.0015	

Fig. 20: Evaluation Result after Expiration of the Management Period

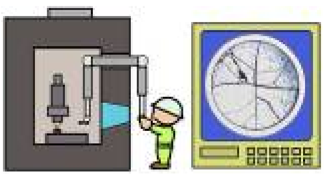


2.4.2 Radioactive Waste Management in the Research Facilities

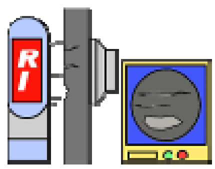
In the research facilities, radioactive waste is generated from research reactors, hot laboratories, nuclear fuel laboratories, radioisotope laboratories, accelerators, facilities modification and decommissioning, etc. This kind of waste includes various sorts of materials and radio activities.



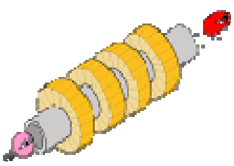
Operation & Maintenance



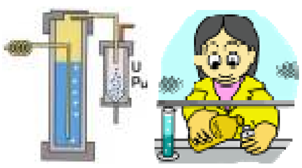
Post Irradiation Examination



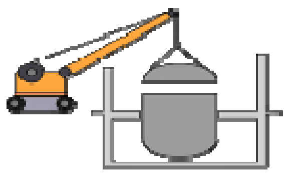
Application Research



Accelerator Operation



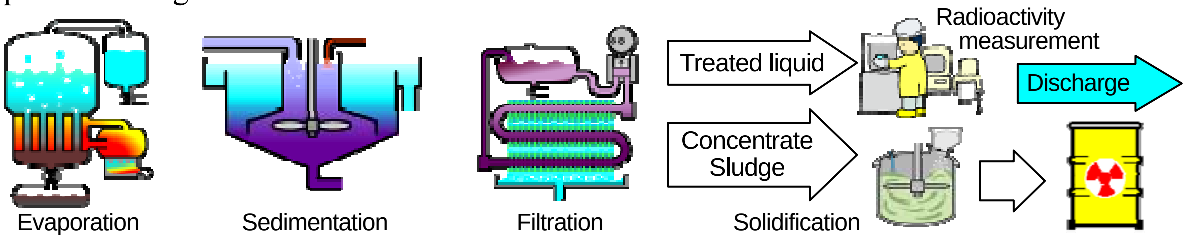
Radiochemical Experiment



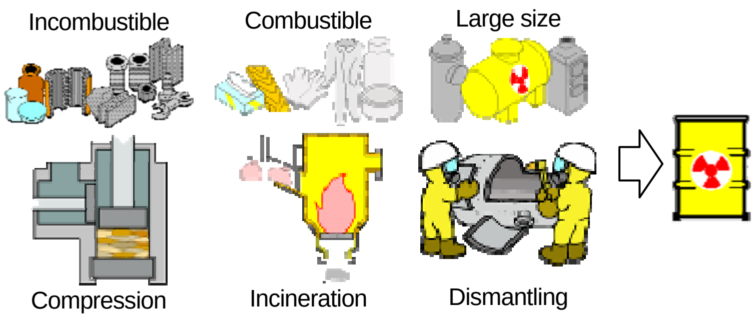
Modification & Decommissioning

Gaseous waste is treated at the generating facilities by filtration, dilution, decay, etc. After that, it's discharged under the radiation monitoring into the atmosphere.

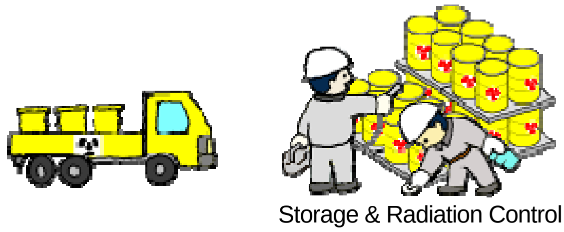
Liquid waste which radioactivity concentration is less than discharge standard is discharged into environment. Other liquid waste is treated at the liquid waste treatment facilities. Then concentrate and sludge are solidified into a container (drum), and treated liquid is discharged into environment.



All of solid waste is transported to the waste treatment facilities. Incombustible waste is compressed, combustible waste is incinerated, and large size waste is cut and sorted. Then these are packed into containers. High radiation dose waste is handled in the shield cell and packed into a shield container.



The waste packed into the container is stored in the storage building. These waste packages are checked on a periodic basis and maintained in safe condition.



6. Malaysia

6. Malaysia

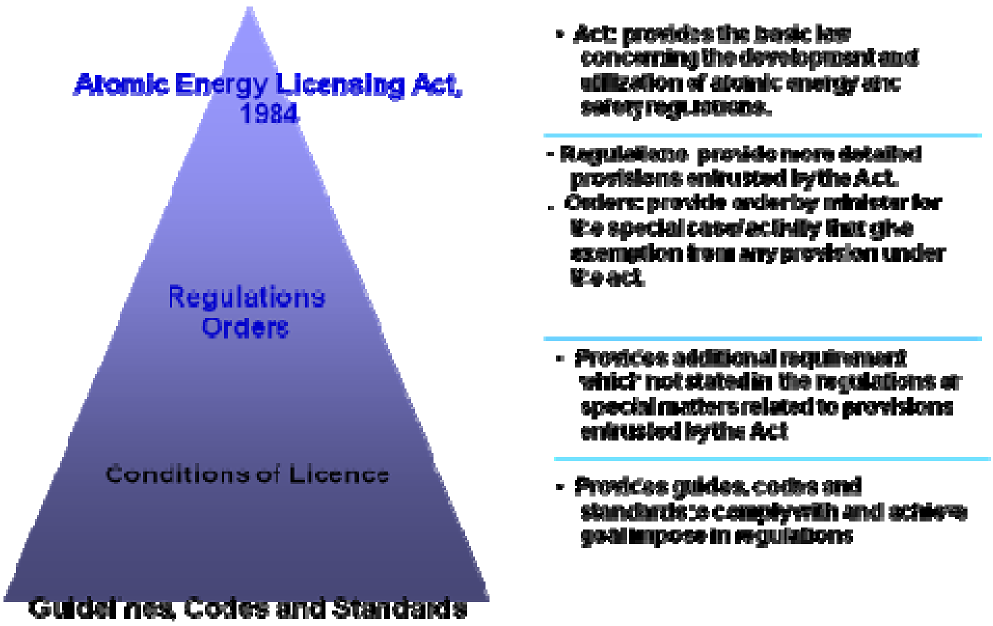
Part 1. Use of Radiation Sources and Radiation

1.1 General

1.1.1 Legislative framework and policy for radiation safety

Control over the use of radioactive substances in Malaysia began in 1968 when the Parliament passed the Radioactive Substances Act 1968. Due to rapid development of atomic energy activities in Malaysia which requires more effective control, inspection and enforcement, the Atomic Energy Licensing Bill was drafted and was passed by Parliament in April 1984 as the Atomic Energy Licensing Act (Act 304).

Fig. 1: Hierarchy of Legal System



There are three main regulations made under the Act 304 namely:
Radiation Protection (Licensing) Regulations 1986;
Radiation Protection (Basic safety Standard) Regulations 1988;
Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010;
Radiation Protection (Transport) Regulations 1989

1.1.2 Structure and System (Regulatory organizations)

In line with Section 3 of the Act 304, the Atomic Energy Licensing Board (AELB) was established under the Prime Minister's Department on 1 February 1985. The AELB acts as an enforcement body for the implementation of the Act. However on 27 October 1990 the Board was place under the Ministry of Science, Technology and Innovation (MOSTI).
The functions of AELB as stated in Act 304 are as follows:

- To advise the Minister and the government of Malaysia on matters relating to the Atomic Energy Licensing Act 1984 and developments pertaining thereto with particular reference

to the implications of such developments for Malaysia;
- To exercise and supervision over the production, application and use of atomic energy and matters incidental thereto ;
- To establish, maintain and develop scientific and technical co-operation with such other bodies, institutions or organizations in relation to nuclear matters or atomic energy as the Board thinks fit for the purposes of the Atomic Energy Licensing Act 1984 ;
- Where so directed by the government of Malaysia, to perform or provide for the performance of the obligations arising from agreements, conventions or treaties relating to nuclear matters or atomic energy to which Malaysia is a party where such agreements, conventions or treaties relate to the purposes of the Atomic Energy Licensing Act 1984 ;and
- To do such other things arising out of or consequential to the functions of the Board under the Atomic Energy Licensing Act 1984 which are not inconsistent with the purposes of this Act, whether or not directed by the Minister.

Since the enforcement of the Act 304, a major part of the responsibility was under the jurisdiction of the Atomic energy licensing Board. However, the control of application in medical purposes is under jurisdiction Director General of Health, Ministry of Health.

1.2 Outline of Radiation Facilities and Radiation sources

1.2.1 Number of specialists and Workers in related organizations

In Malaysia, the number specialists and workers involved with radiation related industry are maintained by the AELB and MOH. However, the exact total number of workers involved with radiation is very difficult to define.

1.3 Education and Training

1.3.1 Radiation Industry usage

Under the Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010, all licensees are required to have a Radiation Protection Officer (RPO). RPO is defined as a technically competent person approved and recognized by the regulatory body. The RPO shall go through special radiation protection course at recognized institutions and shall pass an examination before can be approved as RPO by the regulatory body.

The Licensee is also required to employ and engage well trained radiation workers. The workers are also shall be provided an appropriate retraining for updating their skill and knowledge. Industry related occupations include industrial radiographers, borehole loggers, industrial gauges user, seller and trader, radiation source testers and persons servicing, installing, commissioning, maintaining, repairing or manufacturing radiation sources and equipment, lecturers and technician at higher leaning institutions, researchers at research institutes etc.

Health related occupations include medical practitioners, dental practitioners, veterinary surgeons, diagnostic radiographers, radiation therapists, nuclear medicine technologists, health and medical physicists.

1.3.2 Radiological protection

Numerous companies, institutes and universities provide education and training in radiation safety, radiological protection and related courses. There are approximately seven providers and around 100 radiation safety training courses covering subjects including general radiation awareness, radiation protection, use of radionuclides, use of gauges, transport, and use of radiation in medical procedures.

1.4 Standardization on radiation and radioactivity

1.4.1 External radiation and its personnel dosimetry

External radiation quantity can be measured in terms of exposure, air kerma, absorbed dose, dose equivalent, ambient dose equivalent and directional dose equivalent by using radiation measuring instruments. Various kinds of radiation measuring instruments such as survey meters, area monitors, personal dosimeters, contamination monitoring instruments are used in the radiation facilities for radiation protection purposes. For implementation of the proper monitoring, radiation monitoring survey meters e.g. ionization chambers, Geiger-Muller (GM) counters and scintillation counters should be calibrated in terms of dose equivalent quantities. Area dosimeters or dose ratemeters should be calibrated in terms of the ambient dose equivalent, H*(10), or the directional dose equivalent, H'(0.07). In radiotherapy centres, the radiation dosimeters are normally used for determinations of the output of Cobalt-60 teletherapy units and medical linear accelerators (linacs) should be calibrated in terms of exposure, air kerma or absorbed dose to water. Radiation measuring instruments need to be calibrated to ensure that they give accurate and correct reading with a certain uncertainties and to comply with the regulations imposed by the relevant authority. They should be calibrated annually or after major repair. In Malaysia, calibration of radiation measuring instruments is a legal requirement under the Radiation Protection (Basic Safety Standard) Regulation, 1988[8]. The SSDL-Nuklear Malaysia was established in 1980 and a member of the IAEA/WHO Network of SSDLs. The laboratory had acquired the status of national standard laboratory with the basic aim of improving accuracy in radiation dosimetry in the country. It is also the national focal point for the calibration of radiation measuring instruments used in radiation protection and radiotherapy. More than 1500 radiation instruments are normally calibrated every year. The laboratory has also the responsibility to ensure that the calibration services provided by the laboratory follow internationally accepted metrological standards. This is achieved by calibrating the protection and therapy levels dosimeters belongs to SSDL-Nuklear Malaysia against the Primary Standard Dosimetry Laboratories (PSDLs) or the International Atomic Energy Agency (IAEA) or by participating the international comparison on dosimetry measurements.

1.4.2 Calibration Facilities

1.4.2.1 Irradiation facilities.

The calibration of radiation instruments used for radiation protection and radiotherapy purposes requires appropriate irradiation facilities capable of providing air kerma rates up to approximately 1Gy/min. The SSDL-Nuklear Malaysia has four irradiation rooms or bunkers to accommodate radiation sources and to perform calibration of radiation protection survey instruments and therapy level dosimeters. The dimensions of the irradiation rooms were approximately 9m x 4.8m x 3.2m high. The floor, walls and ceiling are concrete. The design of the irradiation rooms are in accordance with the relevant national and international safety regulations. The shielding of the rooms is sufficient to ensure that the radiation doses to the staff and the public are kept as low as reasonably achievable and that the given dose limits are not exceeded. The irradiation rooms are equipped with the radioactive and x-ray sources that are operated remotely in the control room. This room also contains monitors coupled to video cameras in the irradiation rooms. The rooms are provided with the calibration benches running on a pair of rails to carry out the measurements of radiation at various distances from the sources and calibrate the radiation measuring instruments. The ionization chambers or radiation survey instruments are positioned on the calibration benches where they can be moved into a required distance from the source. Their position is fixed at the calibration distance using a telescope or laser. Laser alignments are also installed at each irradiation room to ensure that the radiation survey meters and dosimeters are placed in the centre of the radiation beam during the measurements. The irradiation rooms are also provided with appropriate safety equipment and accessories such as warning light for each irradiation unit, door interlocks and continuously operating radiation monitors.

1.4.2.2 Radiation sources.

(i) X-radiation.

Calibration at photon energies below 300 keV is usually carried out using an x-ray system. SSDL-Nuklear Malaysia has created a series of x-ray beam qualities which were selected to match the beam qualities offered by the International Bureau of Weight and Measures (BIPM) and based on ISO Narrow Spectrum Series. The Yxlon constant potential x-ray systems type MG 325 with a 320 kV tube is used to generate ISO narrow spectrum series x-ray reference radiation for the calibration of radiation protection instruments. Their beam characteristics are shown in table 1, where the values of the mean energies have been adopted from the ISO document. X-rays generated between 100 kV and 250 kV in accordance with the BIPM therapy qualities are used for calibration of therapy level dosimeters.

Table 1: ISO Narrow Spectrum Series X-ray Beams at the SSDL-Nuclear Malaysia

Radiation quality	Mean energy	Tube potential	Additional filtration [mm]				HVL [mm]
	[keV]	[kV]	Al	Cu	Sn	Pb	Cu
N-40	33	40	4.0	0.2	-	-	0.09
N-60	47	60	4.0	0.6	-	-	0.25
N-80	65	80	4.0	2.0	-	-	0.59
N-100	83	100	4.0	5.0	-	-	1.15
N-120	100	120	4.0	5.0	1.0	-	1.78
N-150	117	150	4.0	-	2.5	-	2.58
N-200	164	200	4.0	2.0	3.0	1.0	4.13
N-250	207	250	4.0	-	2.0	3.0	5.34
N-300	248	300	4.0	-	3.0	5.0	6.33

Table 2: Therapy Qualities X-ray Beams at the SSDL-MINT

Tube potential [kV]	Additional filtration [mm]		HVL [mm]	
	Al	Cu	Al	Cu
100	3.5	-	4.05	-
135	1.0	0.3	-	0.50
180	1.0	0.6	-	1.01
250	1.0	1.6	-	2.51

(ii) Gamma radiation.

Radionuclide sources are used to perform calibration at photon energies above 300 keV. There are several gamma sources i.e. Caesium-137, Cobalt-60 and Americium-241 with different activities are available to provide radiation standards for protection and therapy level dose rates. Two irradiation rooms are equipped with two collimated gamma irradiators model OB 85 which consists of ^{137}Cs (740 GBq) and ^{60}Co (37 GBq) and two panoramic gamma irradiators model OB 34. The panoramic gamma irradiator contains a total of seven ^{137}Cs and ^{60}Co gamma sources with activities ranging from 3.7 MBq to 7.4 GBq that produce uncollimated radiation fields. Table 3 shows the specification of protection level gamma sources used to calibrate radiation survey instruments. The reference gamma radiation fields are determined in terms of air kerma rate. A teletherapy ^{60}Co unit model Eldorado 8 is used to provide national standards for air kerma and absorbed dose to water at therapy level and calibration service for therapy level dosimeters.

Table 3: Protection level gamma sources

Gamma irradiator	Nuclide	Activity range	No. of source	Covered air kerma rate range	Source distance [m]
OB 34	Cs-137	7.4MBq-7.4GBq	4	0.49 µGy/h - 1.59 mGy/h	0.5 – 2.5
	Co-60	3.7MBq-370MBq	3	0.29 – 38.94 µGy/h	0.5 – 2.5
OB 85	Cs-137	740 GBq	1	16.53 µGy/h- 150.48 mGy/h	0.5 – 5.0
	Co-60	37 GBq	1	5.76 µGy/h – 5.54 mGy/h	0.5 – 5.0
OB 6	Cs-137	74 GBq	1	0.22 – 14.56 mGy/h	0.5 – 4.0
-	Am-241	11.1 GBq	1	5.08 – 119.92 µGy/h	0.4 – 2.0

(iii) Beta radiation

The beta radiation sources of the Pm-147, Kr-85 and Sr-90/Y-90 nuclides of the PTB Beta Secondary Standard (BSS 2) developed by the Physikalisch-Technische Bundesanstalt (PTB), Germany are used to calibrate radiation survey instruments. The radiation qualities are in compliance with the series of standards ISO 6980. The sources are calibrated by PTB at the specified distances in terms of absorbed dose rate to tissue surface, directional dose equivalent rate and personal dose equivalent rate. The dose rate at the calibration distance is between 7 µGy/s and 38 µGy/s. The irradiation procedure is controlled by a personal computer which stores the calibration data for the source used. The specifications of beta sources have been summarized in table 4.

Table 4: Beta Secondary Standard Sources.

Source	1	2	3
Radionuclide	Pm-147	Kr-85	Sr-90/Y-90
Nominal activity	3.7 GBq	3.7 GBq	460 MBq
Beam flattening filter	Yes	Yes	No
Mean beta energy (MeV)	0.06	0.24	0.8
Calibration distance (cm)	20	30	11, 20, 30 & 50
Reference date	07.02.2003	27.02.2003	28.03.2003
Half-life (years)	2.62	10.72	28.8 years

(iv) Neutron

The collimated neutron calibrator model OB 26 manufactured by Buchler GmbH, Germany which consists of 185 GBq Americium-241/Beryllium neutron source is available to carry out calibration of neutron survey instruments and personal dosimeters. The neutron emission rate quoted by manufacturer was 1.1 x 10^7 n/s on July 20, 1984.

1.4.2.3 Dosimetric equipments

The SSDL-Nuklear Malaysia is equipped with secondary standard dosimeters and working standard dosimeters to provide exposure and air kerma standards used for calibrating radiation survey instruments while the air kerma and absorbed dose to water standards for calibrating therapy level dosimeters. The secondary standards for radiation protection are based on 1,000 cm^3 and 10,000 cm^3 spherical ionization chambers, LS-01 and LS-10 designed and manufactured by PTW, Germany and the Austrian Research Centre, Austria respectively. The chambers are calibrated in terms of air kerma at ^{137}Cs, ^{60}Co and a number of x-ray beam qualities at the IAEA Dosimetry Laboratory and the Austrian Research Centre Seibersdorf. A 0.6 cm^3 ionization chamber NE 2571 has been selected as reference chamber for the calibration of therapy level dosimeters. The chamber had been calibrated in terms of absorbed dose to water at ^{60}Co and air kerma at ^{60}Co and x-ray beam qualities at the IAEA Dosimetry Laboratory. The ionization current from the ionization chambers is measured with a PTW-Unidos Universal Dosimeter and Digital Currentintegrator DCI 8500 with calibration is traceable to the National Metrology Laboratory, SIRIM Berhad. The leakage current for the system ionization chamber plus electrometer is considered negligible. The stability of the chamber plus electrometer system is checked at regular intervals using a ^{90}Sr and ^{241}Am check source. Working standard dosimeters used for protection and therapy levels at SSDL are calibrated against secondary standard dosimeters. They are routinely used for the calibration of radiation protection survey instruments and therapy level dosimeters.

1.4.3 Calibration of Radiation Instruments

1.4.3.1 Radiological protection instruments.

Radiation protection survey instruments such as ionization chamber, Geiger-Muller counter, scintillation counter and solid state detector are calibrated in terms of exposure, air kerma, dose equivalent and ambient dose equivalent as well as directional dose equivalent. Reference photon radiation selected from ISO Standard 4037-1[9] are used for calibration of radiation survey instruments and for determination of their energy response. For the x and gamma radiation qualities, the conversion coefficients given in ISO Standard 4037-3 were used for conversion from air kerma to ambient dose equivalent, H*(10) or directional dose equivalent, H' (0.07). Reference conditions are temperature = 20.0 ^{0}C, pressure = 1013.25 mbar and relative humidity (RH) = 50 %. H*(10) and H'(0.07) are new operational quantities for area monitoring for external radiation sources introduced by ICRU Report 39 and intended mainly for the measurements of strongly penetrating and weakly penetrating radiations respectively. Calibrations are performed either by the substitution method (comparing the response of the instrument to be calibrated with that of a reference standard instrument) or simultaneous method (both instrument to be calibrated and reference standard instrument are placed in the radiation beam at the same time and irradiated together). These methods are normally used when the radiation survey meters are calibrated at x-ray beams. Calibration is performed in a known radiation field when the survey meters are calibrated against gamma, beta and neutron beams. Standardization of ^{137}Cs, ^{60}Co, and ^{241}Am gamma sources (protection level) at various distances using reference standard dosimeters are performed once a year with accuracy better than ± 2%. Calibration with beta radiation is performed using beta secondary standard sources which the absorbed dose rates at particular distances of each sources i.e. ^{90}Sr/^{90}Y, ^{85}Kr and ^{147}Pm have been determined by the PTB, the national standard laboratory of Germany or by using PTW extrapolation ionization chamber. Portable survey instruments are calibrated at least at one point on each measuring range i.e. at approximately half of their full scale value or in each decade for an instrument with a logarithmic scale or with digital indication. The calibration factor or coefficient is defined as the ratio of the value of stated true exposure or dose equivalent rate at the position of the centre of the detector in the absence of the instrument to the instrument indication. The stated true exposure or dose equivalent rate was measured using reference standard dosimeters.

1.4.3.2 Therapy level dosimeters

Radiotherapy centres must possess an ionization chamber with a calibration factor or coefficient traceable to a secondary standard dosimetry laboratory. SSDL has provided air kerma calibration coefficient, N_K or exposure calibration coefficient, N_X and absorbed dose to water calibration coefficient, $N_{D,W}$ at a single high energy photon beam which is normally refer to ^{60}Co gamma rays.

The ionization chamber is calibrated in air with build-up cap. The reference point of the chamber is positioned on the central axis of the beam so that the chamber axis was perpendicular to the central axis of the beam. Source to the chamber distance(SCD) is 100 cm and the field size (FS) at SCD was 10 x 10 cm^2 in the ^{60}Co gamma beam or focus to the chamber distance (FCD) is 100 cm and the field size is diameter (ϕ) 10 cm in x-ray beam. The air kerma calibration factor N_k [mGy/nC] of the chamber was determined as the ratio of the air kerma standard, K_{air} obtained by the SSDL standard and the electrical charge Q (nC) produced in the chamber under calibration. The charge is measured by the electrometer belongs to the users. The results of the calibration normalized to the standard atmospheric conditions (i.e. T = 20 ^{O}C, P = 1013.25 mbar and R.H. = 50%). The calibration is performed by the substitution method using the SSDL reference standard chamber.

1.4.4 Accreditation of Laboratory

The laboratory is well known as the national focal point for the calibration of radiation measuring instruments used in radiation protection and radiotherapy. To maintain the radiation dosimetry standard in accordance with an international standard, a comprehensive quality assurance programme based on the ISO/IEC 17025 was adopted and implemented. In July 23rd 2004, the SSDL-Nuklear Malaysia has been accredited as a calibration laboratory for radiation survey meters and therapy dosimeters by the Department Standard of Malaysia (The Malaysian accreditation body) under the Laboratory Accreditation Scheme of Malaysia (SAMM). The scheme would provide solid foundation for the SSDL-Nuklear Malaysia to earn strong status in strengthening and maintaining public and customers confidence in the measurements of ionizing radiation.

Part 2. Status of Radiation Safety Management

2.1 Radiation Safety Measurement in Various Radioisotope Usages

2.1.1 Radiation Safety Management System

The management of radiation safety within various radiation industries is governed by the regulator according to the regulations, order, licence conditions, code of practice, guideline, established under the Act 304 and from time to time regulatory directive published by the AELB. These include all radiation management considerations for research, industrial and medical related facilities as follows:

- Radiation Protection (Transport) Regulations 1989;
- Radiation Protection (Basic safety Standard) Regulations 1988;
- Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010;
- Guidelines on Radiological Monitoring for Oil and Gas Facilities Operators Associated with Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM).
- Code of Practice on Radiation Protection of Industrial Radiography.
- Guidelines for Testing X-Ray Apparatus.
- Code of Practice on Radiation Protection of Non Medical Gamma & Electron Irradiation Facilities
- Code of Practice on Radiation Protection Relating to Technically Enhanced Naturally Occurring Radioactive Material (TENORM) in Oil and Gas Facilities
- Guidelines on Radiological Monitoring for Oil and Gas Facilities Operators Associated with Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM)' LEM/TEK/30);
- Guidance on Scheme towards the Recognition of a Radioactive Laboratory by Atomic Energy Licensing Board.
- Guidelines for Decommissioning of Facilities Contaminated with Radioactive Materials.
- Guideline on Preparation of Radiation Protection Programme for Industrial Radiography (LEM/TEK/45 Part D)
- Guideline on Preparation of Radiation Protection Programme for Industrial Seller/Trader (LEM/TEK/45 Part A)
- Guideline on Preparation of Radiation Protection Programme for Nuclear Gauges (LEM/TEK/45 Part B)
- Guideline on Preparation of Radiation Protection Programme for Research Institute (LEM/TEK/45 Part C)

2.1.2 Radiological Protection for Radiation Workers

It has been recognised that exposure to at certain level can cause clinical damage to human tissues. It is therefore essential that activities involving radiation exposure shall be subjected to certain standards of safety in order to protect individual worker exposed to radiation. As such, all radiation industries and facilities are required to implement ALARA concept limits possible detrimental effects arising from occupational radiation exposure. This concept can be achieved through:

- No practice within a practice should be authorised unless the practice produce sufficient benefit to the exposed individuals or society
- avoidance of exposure, where practicable;
- use shielding to isolate of sources of radiation, where practicable,
- keep the distance by remote handling techniques;
- Use appropriate personal protective equipment whether deal with sealed or unsealed sources.
- Use fume hood if deal with volatile material or liquid.

Under the Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 radiation dose limitation for worker and public are as stated in Table 5.

Table 5: Radiation Dose Limits

	Annual Dose limit		
Application	**Occupational**	**Public**	**Apprentices and students**
Effective dose	20mSv	1mSv	**6mSv**
Lens of the eye	150mSv	15mSv	**50mSv**
Skin	500mSv	50mSv	**150mSv**
Hands and feet	**500mSv**	**-**	**150mSv**

2.1.3 Radiological Protection for Radiation Area

Radiation area programme should be established by the operator in the supervised area and controlled area. Monitoring of workplace areas is required to be performed by the operator under supervision of radiation protection officer. The monitoring programme shall include—

- measurements of external radiation levels and contamination levels (where appropriate) at specified places, times and frequencies at all appropriate locations so as to evaluate the radiological conditions in all work places;
- exposure assessments in controlled areas and supervised areas;
- assessment of the levels of radiation risks associated with an accident or emergency situation;

2.1.4 Radiological Protection for the Public

The licensee whose radiation sources are under his responsibility shall ensure that exposure attribute to the general public is optimised and shall not exceed the dose limits as stated in Table 1. Therefore the licensee shall ensure that the public exposures be controlled in accordance with the requirement of the regulations and guideline.

The licensee is also shall be responsible for ensuring that the optimization process for measure to control discharge of radioactive substances to the environment is comply with the requirement of the regulatory body taking into account exposure pathways, changes in the habitats or distribution of the population, modification of critical group or changes in environmental dispersion conditions.

For visitors to enter controlled area, they must be accompanied by a person knowledgeable about the protection and safety measures for that area. They also must be provided adequate information and instruction before they enter a controlled area so as to ensure appropriate protection to them

2.1.5 Radiation Emergency Preparedness

The licensee shall make suitable arrangements to prevent as far as possible, any accident that could reasonably be foreseen for any radiation source which is in his possession or under his control, and to limit the consequences of any accident that occurs. It is obligatory requirement for the operators to establish radiological emergency plan if it happen inside their premises.

The National Security Council (NSC) which is under the Prime Minister's Department, is responsible for managing the whole operation of nuclear and radiological emergency, whether it is a national, state or district level, if the emergency is considered a disaster. The AELB is a lead technical agency whereas Nuclear Malaysia will be called if there is a need for technical assistance in handling the emergency. In the event of a radiological emergency the following plans are in place:

- Radiological Emergency Response Plan (RAD Plan)
- Directive No 20 of National Security Council – The Policy and Mechanism on National Disaster and Relief Management
- Convention on Assistance in the Case of Nuclear Accident and Radiological Accident
- Convention on early Notification of a Nuclear Accident.

2.2 Radiation Safety Management in Research Reactor

2.2.1 Introduction

Malaysian Nuclear Agency or Nuclear Malaysia, which was established in early 1970's, is an institution that develops, promotes and enhances the peaceful uses of nuclear technology in agriculture, medical, manufacturing, industry, health and the environment. In order to enhance research and development activities, a TRIGA MARK II research reactor, called Reaktor TRIGA PUSPATI (RTP), was built. It came into operation in 1982 and reached its first criticality on 28 June 1982.

The reactor was designed to effectively implement the various fields of basic nuclear science and education. It incorporates facilities for advanced neutron and gamma radiation studies as well as for application, including Neutron Activation Analysis (NAA), Delayed Neutron Activation Analysis (DNA), radioisotope production for medical, industrial and agricultural purposes, neutron radiography and Small Angel Neutron Scattering (SANS).

2.2.2 RTP Technical Specifications

RTP was supplied by General Atomic of the USA and installation programme was started on 9 November 1981. RTP is a pool type reactor where the reactor core sits at the bottom of 7 metre high aluminium tank which is surrounded by a biological shielding made of high density concrete (see Figure 2). The reactor uses solid fuel elements in which a zirconium-hydride moderator is homogeneously combined with enriched uranium. Demineralised water acts both as coolant and neutron moderator, while graphite acts as reflector. The following are brief descriptions of RTP:

Fig. 2: Nuclear Malaysia's Reactor TRIGA PUSPATI (RTP)

- Type: TRIGA Mk II, pool type
- Fuel: Uranium Zirconium Hydride Alloy
- Coolant: Light Water
- Moderator: Light Water
- Reflector: Graphite
- Control Rods: Boron Carbide
- Status: Operating
- Operational Mode: Steady State (1MW)
- Operation: 6hrs/day weekdays

2.2.3 Safety Objective

Since established, the promoting safety of RTP operation is a prime concern of the management and the staff of Nuclear Malaysia. These include during operation, repair and maintenance, radiation doses to workers, radioactive waste management and environmental management. The fundamental safety objective is to protect people, both individually and collectively (workers and public at large) and the environment from harmful effects of ionizing radiation. However, this should been achieved without unduly limiting the operation of facilities or the conduct of activities that give rise to radiations risks. In order to achieve the fundamental safety objective, Nuclear Malaysia has implemented the ten safety principles formulated by International Atomic Energy Agency (IAEA) on the basis of which safety requirements are developed and safety measures are to be implemented.

2.2.4 Organisation and Management of Safety

2.2.4.1 Nuclear Malaysia's Occupational Safety, Health and Environment Policy Statement

Nuclear Malaysia, an agency who responsible for the promotion, development and application of nuclear technology and nuclear related technology for the national development, is committed to continually improve and prevent pollution, incidents, accidents and occupational illness in its operation. This is the commitment of the management in ensuring safety at Nuclear Malaysia complex. Toward this end, Nuclear Malaysia will:

- Comply with all applicable environmental, occupational safety and health, legal and other requirements.
- Minimize release of pollutants to air, water, land and promote waste minimization through reduction, recycling and reusing activities.
- Optimize the use of materials and natural resources.
- Ensure that all radiation exposures are kept as low as reasonably achievable.
- Ensure that all other occupational hazards and risks are prevented, where practicable, and controlled and managed through the adoption of proper management measures.

- Stress on environmental, occupational health and safety aspects in our facilities operation, equipment, field work, building construction and modification through appropriate assessments at the planning stage.
- Promote environmental, occupational health and safety awareness among employees, contractors, vendors and visitors.
- Ensure that all employees, contractor, vendors and visitors on site comply with Nuclear Malaysia's environmental, occupational health and safety requirements at all times.

This safety policy statement is displayed at all notices boards within the Nuclear Malaysia premises to inculcate safety culture to all staff and contract workers, and to show that management is serious in managing safety.

2.2.4.2 Safety Management System

In ensuring the above safety policy implemented in daily work, Safety, Health and Environmental Management System (SHE-MS) Committee was established in year 2005 to review all aspects of safety, including occupational, nuclear and radiological safety. This committee is responsible to report all safety activities in Nuclear Malaysia to the highest management committee headed by the Director General. Safety Audit Team performs auditing functions and reports its finding to the SHE-MS committee on a regular basis. For RTP, the set-up of organization safety management is shown in Figure 3.

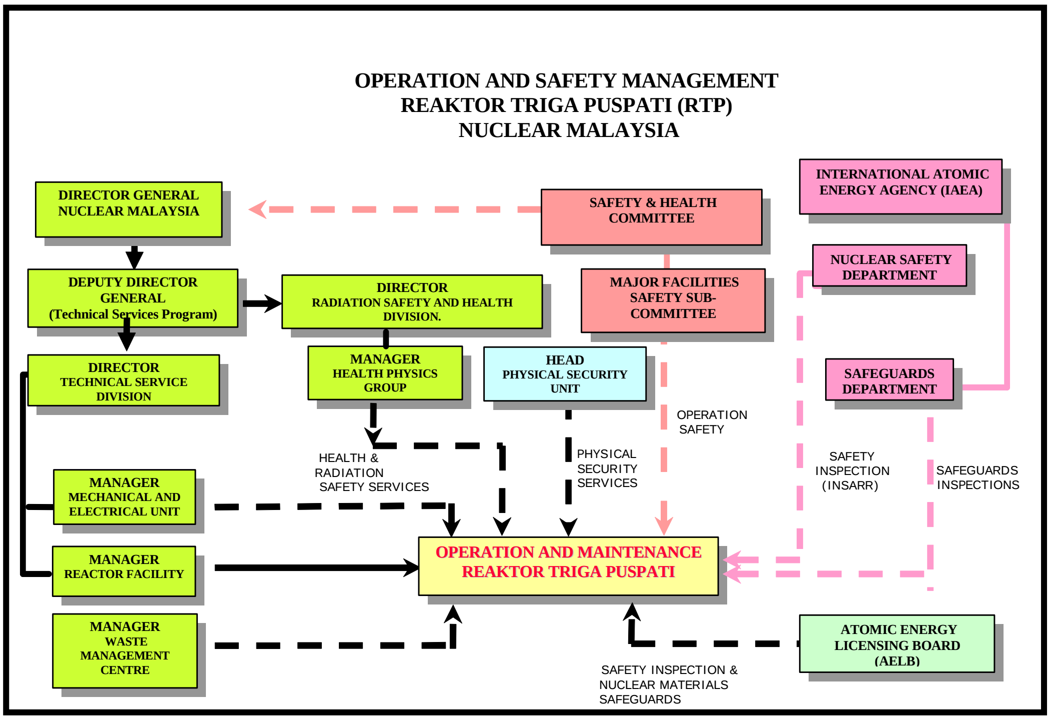


Fig. 3: RTP Safety Management System

The RTP is headed by a Reactor Manager whose is directly report to the Director of Nuclear Power. To maintain high level of safety, the operation and maintenance of RTP are supported by the other groups such as Radiation Safety and Health Division, Waste Technology Development Centre, Mechanical and Electrical Unit and Physical Security Unit.

2.2.5 Safety Analysis Report

Safety analysis report (SAR) is an essential document when talking about safety in nuclear installations. Nuclear Malaysia's first SAR document for RTP was prepared in 1982. Since then, the document had not been revised until 2007 when the new SAR document was prepared in accordance with the IAEA safety standards and recommendations [3]. The SAR document has been submitted to the regulatory body for an approval. In preparing this document, Nuclear Malaysia had engaged experts from abroad to help preparing the document because of lacking of capability and expertise to do analysis especially on risk analysis.

2.2.6 Quality Assurance Programme

Quality Assurance Programme (QAP) is very important in running nuclear reactor and it is not exceptional with RTP. QAP for RTP has been reviewed and approved by SHE-MS Committee last year and will be submitted to the regulatory body this year for their comment. Some of the content of the QAP are Operational Control, Emergency Response and Preparedness, Safety and Health, Physical Security, Infrastructure Maintenance, Reactor Maintenance, Experiment and Modification, Measurement and Monitoring Device Control, Human Resource Management, Waste Management, Special Nuclear Material Counting Control and refuelling.

2.2.7 Radiation Protection Programme

Radiation exposure is set-out in the safety manual approved by the SHE-MS Committee. It is based on the Radiation Protection (Basic Safety Standards) Regulations [2] and IAEA safety documents. In the manual, radiation exposure is managed using radiation protection principles such as policy on As Low As Reasonable and Achievable (ALARA), annual dose limit, annual limit of intake (ALI), Derived Air Concentrations (DAC), classification of area, personal dosimetry etc.

All radiation workers are provided with TLD badges for personal monitoring which are assessed on monthly basis. Staff working with unsealed sources or using hand on more of their work wear wrist and finger TLDs as well. On the other hand, area monitoring using TLDs is performed at all control areas. Medical surveillance of radiation workers are also carried out at least once in two years.

Environmental samples such as water, sediments, soils, vegetables from areas surrounding Nuclear Malaysia complex are collected and analysed. Whilst external radiations from the nuclear installation are monitored using TLDs which are changed on monthly basis.

2.2.8 Emergency Preparedness and Response

Emergency preparedness means being ready to reacts or response to a broad range of emergency situations that can occur at anytime and anywhere. Widespread use of nuclear technologies in application as diverse as industry, medicine, agriculture etc. in Malaysia, means that more possibility of accident can happen. In recent year, most countries including Malaysia are very concern about emergencies arising from malicious use of radioactive material or 'dirty bomb'.

In Nuclear Malaysia, emergency preparedness and response are given very top priority by the top management. On-site Emergency Response Plan (ERP) is in place and recently has been revised. On the other hand the off-site emergency plan is under the jurisdiction of the regulatory body which is the lead technical agency to handle any radiological emergency at national level under the Directive No. 20, National Security Council. Emergency drill is performed at least twice a year. In year 2007, two exercises have been done where the first exercise was done at RTP building and the second was done at the Waste Treatment Centre.

2.2.9 Operation and Maintenance

Without a doubt, a good design, manufacture and construction of reactor are pre-requisites for high levels of safety. However, the ultimate responsibility for safe operation lies with the operating organization (Safety Principles 1). Therefore, Nuclear Malaysia is really emphasized on this issue. RTP reactor building, equipment and facilities are well maintained, generally clean and tidy and in good condition [4]. The annual and semi-annual maintenance are carried out in June and December respectively. Any change in operation and maintenance plan must be approved by Reactor Supervisor. However any unplanned maintenance works must be approved by the Reactor Manager upon recommendation of the Reactor Supervisor.

2.2.10 Reactor operation supervisors, radiation protection supervisors and trainees

As safety is a prime concern of Nuclear Malaysia, therefore education and training on nuclear and radiological safety to staff are very important. For a new staff, they are required to attend an induction course while the other staff are encouraged to attend a radiation safety awareness training course conducted by Nuclear Malaysia. Nuclear Malaysia is also sent their staff to, either local institutions or a broad for updating their skills and knowledge.

For a reactor operator, there is a training programme which is based on the guidelines issued by the AELB where Nuclear Malaysia is responsible for conducting the course while the examination and issuance of operator licence are managed by the AELB. The reactor operator licence can only be renewed after the licensed operators have successfully undergone a refresher course.

2.2.11 Regulations and Licensing

Principle 2 of the safety objectives is clearly stated that there shall be an independent regulatory body in each country to control and supervise all atomic energy activities. Therefore, to maintain independency, Nuclear Malaysia is licensed by the Atomic Energy Licensing Board (AELB), which is independent body established under the Atomic Energy Licensing Board 1984 (Act 304). This is to ensure that the safety is kept in high standard and consistent with the IAEA's nuclear safety standards. The AELB regularly inspects RTP to ensure that all requirements under the law and regulations are complied.

Alongside inspections, yearly dialogue and direct meeting between the Nuclear Malaysia and AELB are made to exchange information and resolution of issues raised. This meeting is alternately chaired by the Director General of AELB and Director General of Nuclear Malaysia. A part of that, the AELB is reviewing their regulations and guidelines related with nuclear safety in accordance to the latest IAEA's safety standards and guidelines.

2.2.12 Peer Review

Peer review is necessary to achieve and maintain a high level of nuclear safety and safety culture. For this purpose, international peer review group on safety culture and nuclear safety are welcome. In 2005, the implementation of nuclear safety culture at RTP has been reviewed by Forum for Nuclear Cooperation in Asia (FNCA) review team. Recommendations from this team have been implemented.

2.3 Radiation Safety Management in Radioactive Waste Management

2.3.1 Introduction

Nuclear Malaysia is committed to minimize release of pollutants to air, water, land and promote waste minimization through reduction, recycling and natural resources. All precautions are taken into account to minimise the generation of unnecessary activation radionuclides to minimise waste generation. This is evaluated when request for irradiation is received.

There also has a specific procedure for collection, control and treatment of radioactive waste activities as specified in the Nuclear Malaysia's safety, health and environment manual. The Waste Treatment Centre, an organization within Nuclear Malaysia, is gave responsibility to manage radioactive waste and chemical waste. In this centre, radioactive wastes are categorized and separated based on their types, solid or/and liquid and according to the standard classification of radioactive waste established by the IAEA. With respect of spent fuel, until now, Nuclear Malaysia has no spent fuel at all. However, the RTP was designed in such a way that it can be used as a storage facility for spent fuels before these spent fuels are sent back to the supplier.

2.3.2 Radiation Safety Management in Transport of Radioactive Material

The regulation of the transport of radioactive material in Malaysia has, for many years, been based on international requirements published by the International Atomic Energy Agency (IAEA). The regulatory frameworks of the Malaysia currently apply the Radiation protection (Transport) Regulations 1989, which adopts the IAEA's *Regulations for the Safe Transport of Radioactive Material*. The transport regulations apply to any activities involving transportation of radioactive materials in Malaysia whether they transport by air, water-ways or inland (road and railways). The regulation is also applied on any activities at economic exclusive zone. The Atomic Energy Licensing Board (AELB) is the regulatory body who has the jurisdiction to enforce the transport regulation.

In 1996, 2003 and 2005, the IAEA published revisions of their *Regulations for the Safe Transport of Radioactive Material* and recommended that 'adoption of these revised Regulations occur within a period of five years from their publication to achieve worldwide harmonization of their application. However, in Malaysia, since gazetted in 1989, the transport regulations never been amended even though the IAEA's regulation for the safe transport of radioactive material has been amended. Nevertheless, the AELB has made initiative to amend the regulations and the new amended regulation is waiting to be read before the parliament.

7. The Philippines

7. The Philippines

Part 1. Radiation Safety in Radioisotope Facilities

1.1 General

1.1.1 Legislative framework and policy for radiation safety

The Philippine legislative framework on radiation safety includes a hierarchy of laws, executive orders and regulations under the National Constitution. The Science Act of 1958 (RA 2067) created the Philippine Atomic Energy Commission (PAEC), the predecessor of the now Philippine Nuclear Research Institute (PNRI), was mandated to promote the peaceful uses of atomic energy and promulgate rules and regulations to ensure the safe use and application of radioactive materials in the different fields of application. Ten years later, RA 5207 was enacted to provide for the licensing and regulation of atomic energy facilities and materials.

In parallel, PD 480 (1974), as amended by PD 1372, EO 119 and EO 102 established the Department of Health (DOH) as the Regulatory Authority for the regulation of X-ray units and other electronically generated radiation devices, including non-ionizing radiation.

1.1.2 Structure and System (Regulatory organizations)

The regulatory framework considers nuclear facilities and radioactive materials separately from radiation emitting devices, with separate jurisdictions for each. The Philippine Nuclear Research Institute (PNRI) through its Nuclear Regulations, Licensing and Safeguards Division (NRLSD) regulates the former, while the Department of Health (DOH) through its Bureau of Food and Drugs' Center for Device Regulation, Radiation Health and Research regulates the latter.

The PNRI has the roles of promoting nuclear technology, providing services, and regulating. PNRI's own nuclear and radiation activities, however are exempt from licensing as stated under the current laws. To address this specific issue, PNRI has established an internal regulatory control program which essentially delegated to the NRLSD of PNRI the authority and responsibility of regulatory control over PNRI radiation facilities and research laboratories. An Office Order signed by the PNRI Director in 2004 clearly stated, among other things, that all PNRI radiation facilities and laboratories must be authorized by the NRLSD at the end of 2006. A system of authorization is now in place for all of these facilities.

The DOH is responsible for the administration and funding of 72 DOH hospitals. The Center for Device Regulation, Radiation Health and Research provides radiation protection services in addition to regulating ionizing and non-ionizing radiation.

1.2 Outline of Radiation Facilities and Radiation sources

1.2.1 Number of specialists and Workers in related organizations

The number of specialists working in the two regulatory organizations accounts to less than 500. The Philippines has 2 Secondary Standard Dosimetry Laboratories (SSDLs) under a National SSDL Organization, a member of the IAEA-WHO SSDL Network, which are being operated by the PNRI and the DOH, respectively. PNRI operates and maintains a SSDL for national standard radiation dosimetry. It continues to provide a national monitoring service for external exposure to radiation to about 10,000 workers occupationally exposed to radiation using films and TLD. Internal monitoring is not routinely conducted but in cases of probable exposure, monitoring can be done by whole body counting or bioassay technique.

1.2.2 Number of radiation sources including generators

Table 1 gives the typical uses of radioisotopes in the Philippines while figure 1 displays the category of PNRI licensees based on types of use or application. Authorized practices and uses of ionizing radiation in the Philippines include the following.

Medical uses include: a gamma knife facility; a medical cyclotron/PET facility; a PET/CT facility, 13 LINACs, 13 cobalt-60 teletherapy units, 7 HDR brachytherapy facilities, 3 blood irradiators and 21 nuclear medicine facilities with SPECT capabilities; and 4,163 registered diagnostic X-ray units.

Industrial uses include: a high energy electron beam machine and a Co-60 irradiator which was upgraded with support from the IAEA TC project and from the US Department of Agriculture; 113 industrial and anti-crime x-ray facilities; 38 industrial radiography licensees; and about 650 sources used in industrial gauging applications.

Table 1: Typical uses of radioisotopes in the Philippines

USES	RADIOISOTOPES
Hospitals	I-131, I-125,Co-60, Ba-133, Sr-90, Cs-137, I-131, Tl-201, Ga-67, Tc-99m, I-129, Ra-226, C-14
Industrial Radiography	Ir-192, Se-75, Co-60
Research and Education	Co-60, Cs-137, Sr-90, Ra-226, Th-232, Co-60, Cs-137, Cs-137/Ba-133m
Industry (Fixed and portable gauges)	Sr-90, Kr-85, Po-210, Am-241, Cs-137, Am-241, Co-60, Cf-252, Am-241:Be, Cd-109

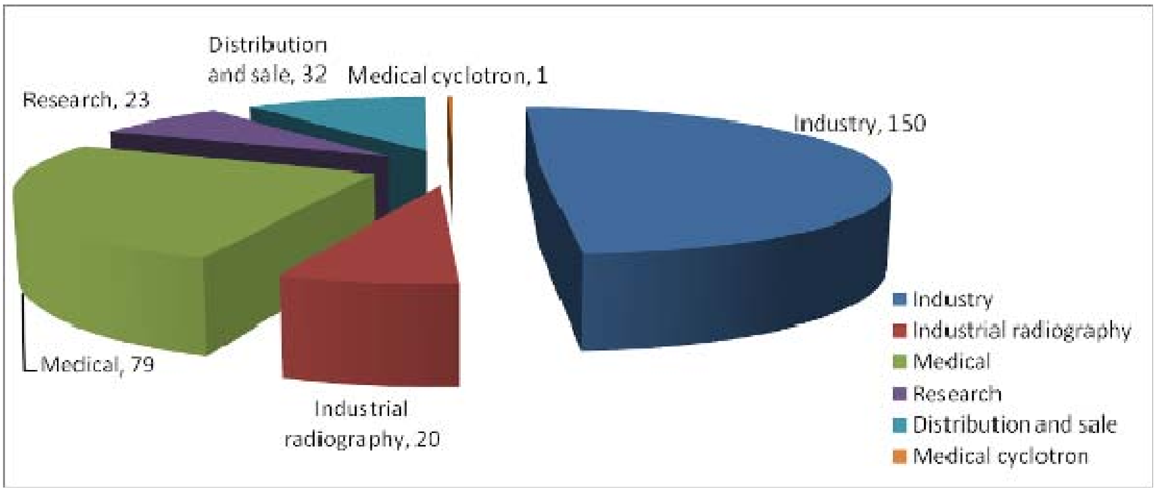


Figure 1: Category of PNRI licensees based on types of use or application

The PNRI owns the country's only research reactor, the PRR-1, which became critical in 1963. The PRR-1 became the principal facility for many research and manpower activities in the field of radioisotope production, neutron spectrometry, neutron activation analysis, and reactor physics. By the early 1970's routine production of some 30 radioisotopes and labeled compounds was undertaken. The PRR-1 was converted into a TRIGA Facility designed for 3 MW operation in 1984 and was expected to be operational in 1989. However, the PRR-1 has been shut down since 1988 immediately after a successful critical testing when the reactor pool lining developed a leak. Philippine authorities have decided to decommission PRR-1 and have accepted to host the IAEA Research Reactor Decommissioning Demonstration Project (R2D2P).

1.2.3 Future plans and issues to be solved

Radiation Control and Safety is continuously being updated and introduced by PNRI through, among others, its training program for all prospective users of radioactive materials in the country. The modules usually include topics on radiation protection standards, dosimetry, personnel monitoring, radiation control practices, emergency planning, radioactive waste management, among others. Theoretical work is usually followed by experiments and case studies.

Standards and regulations are also continuously being updated to consider not only safety but also security of radioactive sources. Current initiatives include the implementation of a Nuclear Safety Caravan project to promote the open exchange of safety and security information among the various stakeholders involved in the peaceful application of the atom. Effective communication and exchange of information are important tools to achieve a sustainable high level of safety and security awareness for radiation facilities and related nuclear infrastructure in the country. The PNRI strives for the public's proper understanding of nuclear technology and the establishment of safety culture by providing opportunities for information exchange and addressing the public's concerns and by using the collected efforts of all those involved to resolve any public health issue.

1.3 Education and Training

1.3.1 Radioisotope usage

The Philippine Nuclear Research Institute (PNRI) provides different technical services to other government agencies, private companies, medical institutions, the academe, and the general public. One of these services is the provision of training courses in nuclear science and technology, and nondestructive testing techniques (in cooperation with the Philippine Society for Nondestructive Testing).

The training program of the PNRI on nuclear science and technology aims to familiarize participants with the fundamentals of nuclear science and technology, the basic principles of radiation protection, and the peaceful applications of nuclear technologies in agriculture, in medicine, in industry, in esearch and the environment.

The nuclear training courses are offered every year to different groups such as medical practitioners, science educators, researchers, engineers, and technicians.

The courses consist of lectures, experiments, film showings, demonstrations, workshops and case studies. Examinations are given to assess the participants' understanding of the subject matter being taught. Certificates of satisfactory completion are issued to participants who have demonstrated satisfactory knowledge of the subject matter presented and the ability to apply it.

Some of these courses have been accredited by the Commission on Higher Education (CHED) with masteral units.

Laboratories and facilities of the different research units in PNRI are made available to the trainees. For certain training courses, PNRI makes arrangements with other private companies, government agencies, universities, and hospitals for PNRI training participants to use their facilities.

The PNRI also provides its trainees with manuals containing lectures and laboratory experiments written by Filipino scientists.

Participants in any course must be endorsed by the head of office if they belong to a government agency or a private company. Those participating on their own have to submit a written request to join the course.

Nomination forms/application forms should be submitted together with the following:

- Transcript of academic records
- Medical certification by nominee's Medical Officer as to his/her physical fitness to undergo training.

❑ **Workshops/Seminars**

Specialized subjects such as the safe transport of radioactive materials and emergency planning and preparedness.

❑ **Thesis Advisorship Program**

This is open to any deserving and qualified graduate or undergraduate university/college student who may wish to undertake the laboratory research portion of his/her thesis at the PNRI, making use of PNRI facilities, equipment and instruments.

❑ **Apprenticeship/On-the-Job Training**

For students and technologists who would like to use nuclear techniques.

1.3.2 Radiological protection

Education and training in radiation safety and radiological protection is provided mainly by the PNRI and the DOH's Center for Device Regulation, Radiation Health and Research regulates the latter. The training program of the PNRI on nuclear science and technology aims to familiarize participants with the fundamentals of nuclear science and technology, the basic principles of radiation protection, and the peaceful applications of nuclear technologies in agriculture, in medicine, in industry, in research and the environment.

Part 2. Radiation Safety in Research Reactors, NPPs and Other Various RI Usage

2.1 Radiation Safety in various RI usage

Table 2 presents the various regulations currently issued by the Institute. The PNRI continue to develop practice-specific Code of PNRI Regulations (CPRs) which are reviewed and revised periodically through a system of consultations involving a number of stakeholders. The CPRs are referenced and updated against the recommendations of the International Atomic Energy Agency (IAEA), the International Commission on Radiation Protection (ICRP) and the various codes of the USNRC, especially those referring to the licensing of the nuclear power plant.

Table 2: Code of PNRI Regulations

CPR PART 2	**Licensing of Radioactive Materials**
CPR PART 3	**Standards for Protection Against Radiation**
CPR PART 4	**Rules and Regulations on the Safe Transport of Radioactive Materials in the Philippines**
CPR PART 5	**Reactor Site Criteria**
CPR PART 6	**Rule of Procedure for the Licensing of Atomic Energy Facilities**
CPR PART 7	**Licensing of Atomic Energy Facilities (under its original title- "Regulations for the Licensing of Atomic Energy Facilities")**
CPR PART 8	**Atomic Energy Facility Operator's Licenses**
CPR PART 9	**Physical Protection of Nuclear Power Plants and Materials**
CPR PART 10	**Financial Security and Government Indemnity**
CPR PART 11	**Licenses for Industrial Radiography and Radiation Safety Requirements for Radiographic Operations**
CPR PART 12	**Licenses for Medical Use of Sealed Radioactive Sources in Teletherapy**
CPR PART 13	**Licenses for Medical Use of Radiopharmaceuticals**
CPR PART 14	**Licenses for Medical Use of Sealed Radioactive Sources in Brachytherapy**
CPR PART 15	**Licenses for Large Irradiators**
CPR PART 16	**Licenses for the Use of Sealed Sources Contained in Industrial Devices**
CPR PART 17	**Licenses for Commercial Sale and Distribution of Radioactive Materials**
CPR PART 18	**Licenses for Use of Radioactive Materials in Research and Education**
CPR PART 19	**Licenses for Use of Radioactive Materials In-Vitro Clinical and Laboratory**
CPR PART 20	**Licenses to Manufacture and Dispense Radiopharmaceuticals**
CPR PART 21	**Licensing and Safety Requirements of Particle Accelerator Facilities for the Production of Radioisotopes**
CPR PART 20	**Licenses to Manufacture and Dispense Radiopharmaceuticals**
CPR PART 21	**Licensing and Safety Requirements of Particle Accelerator Facilities for the Production of Radioisotopes**
CPR PART 23	**Licensing Requirements for Land Disposal of Radioactive Waste**
CPR PART 26	**Security of Radioactive Sources**

Currently, a number of these CPRs are being reviewed to ensure consistency with CPR PART 3 which is largely based on IAEA SS 115, International Basic Safety Standards and the Code of Conduct for the Safety and Security of Radioactive Sources including the additional guidance for the export and import of radioactive sources. Appropriate security requirements in addition to safety requirements are included for purposes of granting authorization for the use of radioactive sources in the various fields of application. Priority is given to practices using Category 1, 2 and 3 sources. Categorization of sources are practically based on the IAEA Categorization of Radiation Sources which was published in 2000 and revised in 2003. In the interim period, these security requirements are imposed as additional specific conditions of licenses subject to inspection and audit for compliance monitoring.

Regulatory guidance documents, information packages and regulatory bulletins are issued to promote a common understanding of the regulations and to facilitate regulatory inspections and audits for compliance monitoring purposes.

2.2 Radiation Safety in Research Reactors

Philippine authorities have decided to decommission PRR-1 and have accepted to host the IAEA Research Reactor Decommissioning Demonstration Project (R2D2P). In 1999, all the 50 spent fuel elements were shipped back to the USA under a US program to recover all spent enriched uranium fuel of US origin. The only irradiated fuel elements that remained were those from the TRIGA core.

At present, the Philippines has only the 115 slightly irradiated TRIGA fuel rods, plus 15 fresh TRIGA and 2 MTR type fuel rods. The slightly irradiated fuel rods are stored in a wet stainless steel storage tank having a diameter of 12 ft. and a height of 16 ft. The fresh fuels are stored in the dry gamma room. These fuels are all currently stored inside the shutdown research reactor. After the proposed decommissioning of the PRR-1, a storage facility that meets the radiological, safety and security requirements for special nuclear material is planned to be built near the PNRI interim storage facilities for conditioned wastes. The fuel rods will be kept in storage until more definite plans are made for its use.

2.2.1 Radiation Safety Management System

The Philippines has only one research reactor (PRR-1) and is currently undergoing decommissioning. The regulatory process for the decommissioning of PRR-1 and related activities is defined by the PNRI Internal Regulatory Control Program, which is the internal authorization process set up in 2004 through PNRI Office Order 002 series of 2004. The Regulatory Safety and Security Board was instituted to coordinate the request for authorization on the operator side and be the link between the NRLSD and the radiation facility operators. Nuclear safety and radiological protection are a primordial pursuit, much as adherence to international standards and criteria in the area of decommissioning and compliance with local regulatory requirements, such as those embodied by the relevant Code of PNRI Regulations (CPRs).

With respect to local regulations, the decommissioning effort is committed to comply with the following: CPR Part 2, on Licensing of Radioactive Material; CPR Part 3, on Standards for Protection Against Radiation; CPR Part 4, on Regulations for the Safe Transport of Radioactive Materials in the Philippines; and CPR Part 26, on Security of Radioactive Sources. The administrative limits applied to PRR-1, which are at levels lower than the regulatory limit on radiation exposure of workers, will also be adhered to.

The decommissioning of the PRR-1 will also comply with the IAEA safety standards. The project receives technical assistance from the IAEA, and the IAEA requires such compliance as a condition for assistance. This requirement has been published in IAEA Information Circular 127, *The Revised Guiding Principles and General Operating Rules to Govern the Provision of Technical Assistance by the Agency*, March 1979.

The IAEA Safety Requirements that will notably be applied (among others) to PRR-1 Decommissioning are:

a. Safety Series No. 115, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. February 1996. STI/PUB/996.
b. Safety Standards Series No. WS-R-2, Predisposal Management of Radioactive Waste, Including Decommissioning. July 2000. STI/PUB/1089.
c. Safety Standards Series No. WS-R-5, Decommissioning of Facilities Using Radioactive Material. October 2006. STI/PUB/1274.

The following IAEA Safety Guides, Safety Reports, and Technical Reports are notably being used (among many others) to guide compliance with the IAEA Safety Requirements:

a. Safety Standards Series No. RS-G-1.7, Application of the Concepts of Exclusion, Exemption and Clearance. August 2004. STI/PUB/1202.
b. Safety Standards Series No. WS-G-2.1, Decommissioning of Nuclear Power Plants and Research Reactors. October 1999. STI/PUB/1079.
c. Safety Standards Series No. WS-G-5.1, Release of Sites from Regulatory Control on Termination of Practices. November 2006. STI/PUB/1244.
d. Safety Standards Series No. WS-G-6.1, Storage of Radioactive Waste. November 2006. STI/PUB/1254.
e. Safety Reports Series No. 45, Standard Format and Content for Safety Related Decommissioning Documents. July 2005. STI/PUB/1214.
f. Safety Reports Series No. 50, Decommissioning Strategies for Facilities Using Radioactive Material. March 2007. STI/PUB/1281.
g. Technical Reports Series No. 389, Radiological Characterization of Shut Down Nuclear Reactors for Decommissioning Purposes. October 1998. STI/DOC/010/389.

2.3 Radiation Safety in Radioactive Waste Management

Radioactive wastes in the Philippines are generated from the applications of radioactive materials in medicine, industries and research. The Philippine Nuclear Research Institute (PNRI) currently manages these wastes through its centralized treatment and storage facilities located on site. Radioactive wastes that are received at the Institute are of different types ranging from contaminated solid and liquid materials to spent sealed sources, including radium. The Philippines does not have an operating nuclear power plant hence the amount of radioactive waste is small compared to countries with nuclear power program. The amount of presently stored waste plus expected institutional waste is estimated at about 3000 m^3. In addition, the contaminated wastes from the Philippine Research Reactor which is expected to be decommissioned soon will generate a considerable volume of waste that need to be considered. The volume of the decommissioning waste will depend on the decommissioning technology that will be employed and the application of the clearance levels for bulk solid materials. The institutional waste also includes a considerable amount of spent sealed sources used in medicine and industry. More than 2400 sources representing a total activity of approximately 3.6×10^{14} Bq are listed in the waste inventory. Historical waste with an unknown radionuclide spectrum and activity is also present. The inventory of spent sealed sources currently in store at the PNRI Radwaste Management Facility. On-going work is being done to undertake complete documentation of solid and liquid waste.

The Philippines issued in 2000 a regulatory policy on the use of radium sources for human use following its participation in the IAEA Radium Conditioning Project. A Philippine team under advisement of an IAEA Expert collected and successfully conditioned all the previously authorized radium sources in March 2001.

Decommissioning of all disused Co-60 teletherapy sources in the country and the subsequent management of these sources have been successfully undertaken and completed in 2004 with the assistance of the IAEA.

These conditioned sources are now safely stored at the PNRI interim storage facilities awaiting final disposal. The PNRI continue to pursue the upgrading of its centralized facility for low to intermediate level radioactive waste treatment facility with assistance from the IAEA through the INT project on sustainable development. Moreover, the PNRI in collaboration with other government agencies is currently evaluating the possible implementation of the IAEA recommended Borehole Disposal Concept for disused sources.

The government is currently pursuing a project on the final disposal of all radioactive waste including disused sources. Site selection studies and preliminary assessment are on going. All activities take into consideration not only the requirements of CPR Part 23 mentioned above but also international best practices practicable in the selection, design and operation of a waste repository, as appropriate.

2.3.1 Radiation Safety Management System

The Philippines has only one (1) operating centralized facility for radioactive waste treatment, conditioning and interim storage of all radioactive waste generated in the country. The facility has a total land area of about 0.4 hectare and a floor area of about 600 m^2 located inside the PNRI compound in Quezon City. The facility includes the following: wet laboratory for R&D activities, shielded cell and decontamination rooms, compressive strength testing area for concrete specimens, decay storage room, chemical precipitation area, cementation area for conditioning process and compaction area for compactible wastes. The interim storage for conditioned wastes has a total capacity of about 535 m^3. It is a concrete-lined trench with concrete slabs roofing and an opening on one end with access from the Radioactive Waste Management Facility (RWMF) Building. In addition, a decay storage room having a capacity of about 100m^3 is also present. The facility has a truck entrance leading to the basement level of the building. This serves as the only entrance for large and heavy waste packages for management and also serve as the emergency exit for personnel in case of any untoward incident.

This facility is subject to authorization in accordance with PNRI Policy Instruction No. 02 Series of 2001, “Radiological Health and Safety Policy” and PNRI Office Order No. 002 Series of 2004 “Regulatory Control Program for PNRI Nuclear and Radiation Facilities and Laboratories.” Regular inspections are also carried out to verify compliance to the authorization issued by the PNRI regulatory division.

Two important regulations govern the safe management practices of radioactive waste in the Philippines. These are :

1) The Code of PNRI Regulations (CPR) PART 3 entitled *Standards for Protection Against Radiation is largely based on IAEA SS 115 International Basic Safety Standards* provides for the general requirements involving waste management and disposal of licensed

radioactive material include (a) storage under controlled conditions, (b) control and monitoring of environmental discharges, (c) regulatory limit for airborne and waterborne discharges adopting the IAEA Clearance Levels for waste resulting from medical, industrial and research application of radioactive materials and the IAEA Safety Guide No. RS-G-1.7 entitled "Application of the Concepts of Exclusion, Exemption and Clearance for solid waste materials. In the case of disused sources, the licensee has the following options in the management of disused sealed sources: (a) transfer of source to another licensee for application or use at the current activity level, (b) decay storage of short half life disused sources, (c) return to the original manufacturer or supplier. These options should be thoroughly considered prior to disposal at the PNRI Centralized Radwaste Treatment and Storage Facility.

2) The CPR Part 23 *entitled Licensing Requirements for Land Disposal of Radioactive Waste* contains technical and procedural provisions applicable to all phases of the lifecycle of a LLW Facility. This includes specific technical requirements involving siting, design, operations and closure, monitoring, waste classification, and institutional requirements. The requirements were basically based on international best practices and accepted guidelines such as those recommended by the IAEA.

The PNRI adopts two basic waste treatment and conditioning options for radioactive waste. These are (a) waste collection and packaging for decay storage for final disposal as ordinary refuse; (b) waste collection, segregation, treatment, conditioning and packaging, followed by interim storage awaiting final disposal in a repository. The last option includes compaction, as appropriate and chemical precipitation, ion exchange of aqueous wastes. Depending on chemical composition and physical properties, wastes are appropriately treated and immobilized in cement prior to interim storage. Conditioned wastes are then coded in accordance with a system established for the purpose.

Two above ground roofed trenches with a maximum capacity of 315 m^3 and 220 m^3, respectively serve as the interim storage for conditioned radioactive waste prior to final disposal. The facility also includes a 100 m^3 storage room for decay.

Criteria to define Waste Category

The Comprehensive Hazardous and Nuclear Waste Management Act that is currently undergoing the legislative mill defines the criteria for radioactive wastes as follows:

1. Exempt Wastes (EW) are radioactive wastes with activity level at or below clearance levels set by the PNRI which are based on an annual dose of 0.01 mSv to members of the public
2. Low and intermediate wastes (LILW) are radioactive waste with activity or concentration level above the clearance levels set by the PNRI. LILW may be a short lived waste or a long lived waste. A short lived waste (LILW-SL) is a waste containing radionuclide with half lives below or equal to the limits set by the PNRI. Long lived wastes (LILW-LL) are wastes containing radionuclides with long half-lives and with activity exceeding the short lived waste limits set by the PNRI; and
3. High level waste (HLW) is radioactive waste with activity or concentration level exceeding the limits for low and intermediate waste set by the PNRI.

2.4 Radiological Protection for Radiation Workers

PNRI regulations clearly define exposure limits involving sources of ionizing radiation to both radiation workers and members of the public. These limits strictly adhere to the International Basic Safety Standards (IBSS) recommendations. The regulations also prescribe the appropriate corrective measures to be implemented to control the release of radioactive materials into the environment and mitigate its effects.

Licensed facilities are also required to submit radiation protection and safety program which includes functions, responsibilities, and qualification and training of individuals.

The PNRI ensures that the following dose limits will not be exceeded by the radiation workers.

a) An effective dose of 20 mSv per year averaged over five consecutive years
b) An effective dose of 50 mSv in any single year
c) An equivalent dose to the extremities (hands and feet) or the skin of 500 mSv in a year

A national monitoring service for external exposure to radiation to about 10,000 workers occupationally exposed to radiation using films and TLD is being provided by the PNRI.

The PNRI provides dosimetry laboratory services for the calibration and standardization of radiation measurements in the country through its Secondary Standards Dosimetry Laboratory (SSDL). The SSDL was established in 1974 and is a member of the International Atomic Energy Agency-World Health Organization (IAEA-WHO) network of SSDLs. Metrological controls and certification of measuring equipment for ionizing radiation are conducted at the PNRI's SSDL to ensure compliance of radiation protection and dosimetry practices with international measurement standards. Beneficiaries of the SSDL services are the different radiation facilities of PNRI and PNRI-licensees in private and government institutions using radiation and radioactive materials in medicine, industry, agriculture, research, and training.

The Radiation Protection Services Section of PNRI maintains the SSDL with its equipment and source standards for the provision of services for the calibration of radiation monitoring instruments and dosimeters (i.e. survey meters, pendosimeter, rate meter, personal monitors; output calibration of brachytherapy, teletherapy and activity meters in hospitals; and radiation monitoring and hazards evaluation of radiation facilities.

Efforts to strengthen the capability for providing dosimetry and calibration services are being exerted to have a wider range and more practice-specific technical service thus ensure the accuracy and control of occupational and medical radiation exposures in the country. Some of the areas that are to be pursued and improved include: beam quality measurements and characterization of the x-ray generator; establishment of protection level radiation dosimetry standards using x-ray, Co-60 and Cs-137 radiation qualities; calibration for dose and energy response of personnel and area monitoring instruments for gamma ray and x-ray standards in the low, medium and high energy range; standardization and calibration of quality assurance measurement tools for medical, x-ray, radiotherapy and nuclear medicine applications; and development of neutron and beta dosimetry protocols.

2.5 Radiological Protection for Radiation Area

As part of the regulatory requirements of PNRI, all licensed stakeholders are required to perform monitoring of their workplace from radioactive contamination. The PNRI conducts regulatory inspections annually and verifies that the work areas are free from contamination.

The licensees can also request technical services from the PNRI to ensure safety in their facilities. Among the services provided by the institute are the following.

i. Leak testing of sealed radiation sources
ii. Radiation hazards evaluation of radiation facilties
iii. Collection and management of disused radioactive sources, solid and liquid radioactive wastes.

These services are provided b y the Radiation Protection Section of the PNRI for a specific fee. The schedule of fees for the different services of PNRI has been published for ease of reference of the stakeholders.

2.6 Radiological Protection for the Public

Public and environmental safety is implicitly stated as a matter of government policy for all projects or undertakings. This is emphasized in the specific provisions in the Codes of PNRI Regulations which the Institute follows in its licensing process. Dose limits to the public follows the recommendations stated in the International Basic Safety Standards. Each licensee shall ensure that the estimated average dose to any member of the public does not exceed the following dose limits:

(a) An effective dose of 1 mSv in a year;
(b) In special circumstances, an effective dose of up to 5 mSv in a single year provided that the average dose over five consecutive years does not exceed 1 mSv per year;
(c) An equivalent dose to the lens of the eye of 15 mSv in a year; and
(d) Equivalent dose to the skin of 50 mSv in a year

The PNRI's Health Physics Section has been actively involved in the management of an international monitoring system to verify compliance to the Comprehensive Nuclear Test Ban Treaty which was ratified by the Philippine Senate in 2001. The radionuclide monitoring station (RN52) which is co-located at our National Weather Bureau station is now part of the 321 global network of the International Monitoring System (IMS) that collect data on evidence of nuclear tests.

Several nuclear research projects that seek to protect environmental and public safety are also being implemented by PNRI. These projects include the following.

1. Access to Clean Drinking Water
2. Control of Harmful Algal Bloom
3. Air Pollution Characterization
4. Radiological Impact of TENORM
5. Environmental Radioactivity Surveillance

In addition, the PNRI also provides services, upon requests, on the certification of radioactivity content of foodstuffs for export and monitoring and clearance of scrap metals for export.

2.7 Radiation Emergency Preparedness

Emergency Planning and Preparedness is part of the licensing process. All licensees including PNRI authorized facilities are required to prepare and submit a facility emergency response plan for approval of the regulatory body. The level of preparedness is commensurate to the level of hazards expected in the facility.

The PNRI in collaboration with 16 government agencies developed and maintains the National Radiological Emergency Response Plan (RADPLAN) which covers any peacetime radiological emergency that has or is expected to have a significant radiological effect within the Philippines, and its territorial waters and which requires a response by several government organizations. There are five major types of radiological emergencies that are covered by this RADPLAN. These are:

a) Emergencies from fixed nuclear or radiation facilities.

An emergency of this type is one that occurs at a facility with licensed or regulated radioactive sources in their installations. Included in this category are the following:

- Nuclear Facilities owned and operated by the PNRI
- Nuclear Reactors
- Industrial or Medical Facilities licensed to use, possess, or import radioactive materials or equipment containing radioactive materials
- All other facilities or establishments using or possessing radioactive materials.

b) Emergencies Occurring in the Transport of radioactive materials.

An emergency of this type is one that involves radioactive materials or wastes being transported by land, sea, or air inside Philippine territories. This includes the hazards from lost, missing or stolen radiation sources

c) Emergencies from foreign sources having environmental impact on Philippine territories.

This type of emergency is one in which radiation from a foreign source poses an actual, potential, or perceived threat to any area within the territorial limits of the Philippines. The source may be an accident from a foreign nuclear power reactor (for example, Chernobyl), radioactive waste repositories, fuel reprocessing plants, or from the testing of nuclear weapons. This includes the possible entry of contaminated food, plants and other commodities from affected areas outside the country

d) Emergencies from Satellites with Nuclear Materials as component

This is a special type of emergency in which a spacecraft with nuclear materials would land within the territory of the Philippines.

e) Emergencies from Nuclear Ships.

This type of emergency is one that involves radioactive material or wastes from nuclear powered seacraft including nuclear submarines.

The level of the government response to a specific emergency will depend on the type and the amount of radioactive material involved, the location of the emergency, the potential for impact on the public and the size of the affected area.

The RADPLAN is currently being reviewed to integrate security of radioactive sources.

8. Thailand

8. Thailand

Part 1. Radiation Safety in Radioisotope Facilities

1.1 General

Thailand set up the first nuclear institution "Office of Atomic Energy for Peace" (OAEP) in 1961, following the enactment of the Atomic Energy for Peace Act (B.E.2504). Then, the Thai research reactor went to criticality in October 1962. Thus the first step was taken in research and development and towards as a better standard of living.

Recently, the Office of Atomic Energy for Peace (OAEP) was renamed to be Office of Atoms for Peace (OAP), plays as the regulatory body arm to control the use of radiation and nuclear applications in Thailand by the authorization from Thai Atomic Energy Commission (Thai AEC).

At present, there are about 20,000 licenses including X-ray and radiation source possessions and utilizations in the country. These licensees are a heterogeneous mixture of individual and governmental institutions which possess the radionuclides of activity ranging from a few kilo becquerel up to some gega becquerel. The type of nuclear facility, radiation facilities and radionuclide utilizing facilities is vary on the development of the atomic energy techniques and application. At present, Thailand has no nuclear power plant, but the feasibility study on Nuclear Power Plant preparation was conducted by the Ministry of Energy and Electricity Generation Authority of Thailand (EGAT).

1.1.1 Legislation and regulations

The main laws and regulations regarding control of radiation sources and Atomic Energy are as follows:

- Atomic Energy for Peace Act B.E.2504 (1961) and B.E.2508 (1965)
- MOST Ministerial Regulations B.E. 2550 (2007) on the Condition and Procedure of Licensing Process on Radioactive Materials, Nuclear Materials, and Atomic Energy.

  MOST Ministerial Regulations (2007) is as the requirements for the licensing process of the possession and utilization of radioactive materials, nuclear materials, and atomic energy from radiation generators and from nuclear reactor. This regulation covers in board areas. The main issues are the basic requirements for those licensee to prepare their documents as well as their general radiation safety procedure for their workers and also for the public; such as the radiation protection training to radiation workers, radioactive waste management, dose limits, decommissioning, and etc.
- MOST Ministerial Regulation B.E. 2546 (2003) on Rules and Procedures of Radioactive Waste Management. This regulation is as guidance for the radioactive material users to manage their radioactive wastes. The main issues are for preparation of radioactive waste before transport to the centralized RWM in the country (it was the OAP). However, since Dec 2006, the centralized RWM has been conducted by Radioactive Waste Management Center (RWMC), Thailand Institute of Nuclear Technology (TINT). This regulation included the recommendation to manage disused sealed radioactive sources, which written that DSRS should be returned back to their original manufacturers. The regulation also covers several important issues, such as waste classification, clearance

level of solid, liquid, gaseous waste. However, this regulation need to be revised for the up-date conditions in the present time as well as the development of international standard in several issues. The relative legislative framework for radiation safety is also provided through

- Hazardous Substance Act (1992)
- Enhancement and Conservation of National Environment Quality Act (1992)

Note: The both Acts (1992) do not make specific provisions for radiation safety except listing a radioactive material as one of a list of hazardous substances.

1.1.2 Structure and System (Regulatory organizations)

Regarding to the Atomic Energy for Peace Act (1961), the Thai Atomic Energy Commission (AEC) plays as a National Regulatory Body. The OAP Secretary General is as the secretariat of the Thai AEC. The Office of Atoms for Peace(OAP), Ministry of Science Technology plays as a regulatory functional arm of Thai AEC. There are several sub-committees appointed from external experts and OAP staff to review all matters related to the regulatory function. The OAP has authorized from the Thai AEC to regulate, control as well as pre-review the license of the production, possession, and utilization of radioactive materials, research reactor, including radiation generators, such as X-ray machines, then submit to the sub-committee and the Thai AEC for further permits.

Since 1961, the OAP has had the roles of promoting nuclear technology, providing services, and regulating. Up to now, the OAP owns a nuclear research reactor and several radiation facilities, however, all are exempt from licensing as stated under the current regulations. To address this specific issue, the new Atomic Energy Act should be established. The regulatory control program need to be improved. Therefore, R&D tasks on nuclear applications and related nuclear service activities has been separated, and to be carried on by the Thailand Institute of Nuclear Technology (TINT), as an implementer of nuclear research activities.

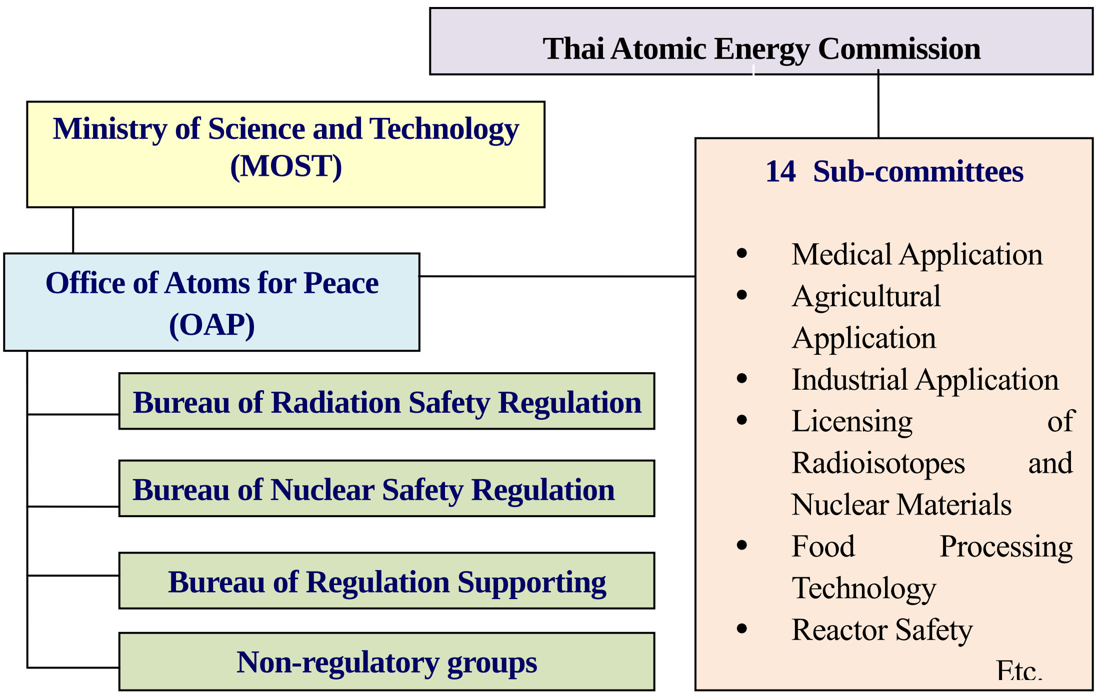


Fig. 1: Nuclear Regulatory Organizations in Thailand

1.2 Outline of Radiation Facilities and Radiation sources

Table 1: Type of Radiation Facilities in Thailand

Facilities	Number of Facilities/unit
Research Reactor	1
Isotopes Production	2
Synchrotron	1
Research Gamma Irradiator	5
Industrial Gamma Irradiator	5
Gamma Tele-therapy	25 facilities, 44 units
X-ray devices- Diagnosis and Therapy in medicine	About 8500
X-ray devices - Industry	About 1500
Linear accelerator (LINAC)	45
Medical Remote after-loader and Brachytherapy	56 units, 25 facilities
Level/density thickness or conveyor gauge	350
Industrial Radiography	23
Education and R&D Laboratories using radionuclides	~250
PET cyclotron	3
Electron beam (education)	1
Electron beam (Jams-Irradiator)	1
Neutron Generator	1
Radioactive Waste Processing and Storage	1 center

Utilization in each category

❑ **Radio-isotopes**

Radio-isotopes of activity ranging from a few kilo becquerel up to some gega Becquerel are possessed in many areas of applications. There are several radionuclides produced in the country by Radio-Isotope Production Center, Thailand Institute of Nuclear Technology (TINT), such as I-131, P-32 and Tc-99 m.

Several radionuclides are used in R&D, medicine, and industry, such as Am-241, C-14, H-3, I-125, I-131, Cs-134, Cs-137, Co-60, Sr-90, Kr-85, and etc.

❑ **Accelerators**

There are several accelerators in uses for educational organizations and research

Institutes, such as synchrotron, neutron generator, and electron beam.

For the hospitals and clinic, linear accelerators (LINAC) and PET cyclotron are used for therapy.

❑ Distribution of radioisotopes

Table2: Distribution of radionuclide use by its applications.

Category by application	Radionuclide	Percent (%)	Remarks
Medical	Ga-67,Cr-51,Tc-99m, Co-60,I-125, I-131,Tl-201, H-3,C-14,P-32, S-35,Ra-226, Sr-90	13	SRS and RI
Education and Research	P-32,S-35,Cr-51,Ca-45, Tc-99m,I-131,Co-60, Sr-90,Cs-137, Am-241, Be	30	SRS and RI
Industrial	Fe-55,Kr-85,Sr-90, Cd-109,Cs-137,Co-60, Ir-192,Am-241, Am-241/Be, H-3	40	SRS
Others/consumer products	Am-241 Ra-226(lightning preventer)	17	SRS

Table 3.Number of Radioactive Source Users and Radiation Users (OAP, Nov2010)

Radioactive Sources User (Licensee)	
Medicine	**129**
Industry	**377**
Research & Education	**280**
Others (smoke detector, lightning preventer)	**160**
Radiation User Licensee	
Medical X-ray devices	**8500**
Industrial and Security X-ray devices	**1500**
Medical Electron accelerators (LINAC)	**35**
Custom Electron accelerators	**10**
PET cyclotron(medical)	**3**
Synchrotron (R&D)	**1**
Neutron Generator (education)	**1**
Electron beam (education)	**1**
Electron beam (industrial irradiator)	**1**
Nuclear research reactor	**1**

1.3 Education and Training

The OAP and the TINT have experiences to arrange the national training courses related to the radiation protection for radiation users, and another safety aspects, such as safe managing of radioactive waste, emergency preparedness and etc, as follows:

- Training Course on Radiation Protection for General Radiation Workers.
- Training Course on Radiation Protection for Radiation Supervisors.
- Training Course on Radiation Protection for Radiation Workers in Medicine.
- Training Course on Radiation Protection for Radiation Workers in Industry
- Training Course on Emergency Preparedness
- Training Course on Radioactive Waste Management for Medical and R&D workers.
- Training Course on Radioactive Waste Management for Industrial workers.
- Refreshment Course on Radiation Protection for TINT staff (every 2 years)

TINT- In House Radiation Protection Training

The radiation protection training is conducted by the Technology Transfer Section which cooperated with Nuclear and Radiation Safety Section. It is structured at different levels in order to meet the needs of different categories of facility staff and researchers using radioactive materials and the operators of research reactor. All personnel and visitors entering the TRR-1/M1 facility receive training in radiation protection sufficient for the work/visit, or shall be escorted by an individual who has received such training. The levels of training are as follows:

❑ Initial Training – All personnel permitted unescorted access in the TRR-1/M1 facility shall receive training in radiation protection as required by the Ministerial Regulation. Initial training shall cover the following areas in sufficient depth for the work being done:

a) Storage, transfer, and use of radiation and/or radioactive material in portions of the restricted area, including radioactive waste management and disposal.

b) Health protection problems and health risks (including prenatal risks) associated with exposure to radiation and/or radioactive materials.

c) Precautions and procedures to minimize radiation exposure (ALARA).

d) Purposes and functions of protective devices.

e) Applicable regulations and license requirements for the protection of personnel from exposure to radiation and/or radioactive materials.

f) Responsibility exposure to radiation or radioactive materials.

g) Appropriate response to warnings in the event of an unusual occurrence or malfunction that involves radiation or radioactive materials.

h) Radiation exposure reports which workers will receive or may request.

❑ Specialized Training – Certain personnel (e.g., reactor operators) require more in-depth training than that described above. Such individuals shall successfully complete training over the following outlined topics in sufficient depth for the work being done and pass a written examination with a minimum grade of 70%.

a) Principles of atomic Structure
b) Radiation Characteristics
c) Sources of Radiation
d) Interaction of Radiation with Matter
e) Radiation Measurements
f) Biological Effects of Radiation
g) Radiation Detection
h) Radiation Detection Practices
i) ALARA
j) Radioactive Waste Management and Disposal

- ❑ Annual Refresher Training – All personnel permitted unescorted access in the TRR-1/M1 facility shall receive annual radiation safety refresher training. The annual training shall cover the following areas in sufficient depth for the work being done:

a) Review of proper radiation safety practices, including radioactive waste management and disposal
b) Occurrences at TRR-1/M1 facility over the past year
c) ALARA summary
d) Notable changes in procedures, equipment, facility, etc.
e)

Part 2. Status of Radiation Safety Management

2.1 Radiation Safety in various RI usage

Radiation Safety Management in various RI usage, is regulated in accordance with the Atomic Energy for Peace Act B.E.2504 and Ministerial Regulation B.E. 2550. The main issues are comprised of the licensing system and requirements of radiation safety and security.

- The Act B.E.2504 (1961) is the main law governing radiation safety in Thailand. It is stated in section 12 that all radiation sources have been subjected to licensing:
- OAP Orders B.E.2552 (2009) on the Forms for licensing of radioactive materials, nuclear materials, and the use of atomic energy from radiation generators and the use of atomic energy from nuclear reactor.

There are 4 types of License

- License for production, possession or utilization of radioactive materials
- License for utilize Atomic energy from radiation generator and from nuclear rector
- License for modification of source materials from the natural chemical form
- License for export and import of special nuclear material, by-product materials or source materials

2.1.1 Inspection Program

The OAP has established a planned program for inspections of radioactive sources. How frequency and extent of inspection depend on:

- potential magnitude and nature of the hazard presented as determined by Thai radioactive source categorization system
- the categorization system is used to set the duration of the licence which corresponds with the categorization number

Table 4. Radioactive Source Categorization System.

Category	Source and practice	Duration of License/Inspection
1	Radioisotope thermoelectric generators Irradiators Teletheraphy Fixed multi-beam teletherapy (gamma knife) Industrial gamma radiography Nuclear Medicine (except Radioimmuno Assay)	1year/annually
2	High/medium dose rate brachytherapy Fixed industrial gauges(level gauges, density gauges, Well logging gauges Portable gauges (moisture/density gauges)	2years/ every 2 years
3	Low dose rate brachytherapy Thickness/fill-level gauges Sealed source for research , activity > 400 MBq Unsealed source for research, activity > 40 MBq	3years/ every 3 years
4	Low dose rate brachytherapy eye plaques and permanent sources Analytical Device Static eliminators Bone densitometers Sealed source ,40 MBq< activity <400 MBq Unsealed source, activity < 40 MBq	3years/ every 3 years
5	Lightening preventer, smoke detector Standard sealed source, activity < 40 MBq	3years/ every 3 years

Radiation licensee are required to submit radiation protection and safety program which includes functions, responsibilities, and qualification and training of individuals.

2.1.2 Dose Limit of Radiation Workers

a) An effective dose of 20 mSv per year averaged over five consecutive years
b) An effective dose of 50 mSv in any single year
c) An equivalent dose to the extremities (hands and feet) or the skin of 500 mSv in a year

In addition, the safety culture was introduced to radiation users. They are enforced to follow the radiation safety requirements and code of conducts which are mainly based on IAEA SS 115, International Basic Safety Standards and the Code of Conduct for the Safety and Security of Radioactive Sources.

2.1.3 Radiological Protection for the RI User

2.1.3.1 Dose Monitoring

The occupational radiation monitoring service for external exposure to about 25,000 workers using films, TLD and OSL has provided by Department of Medical Science, Ministry of Health which has the accreditation following ISO-17025.

The Department of Medical Science has provided dosimetry laboratory services for radiation workers in the country through its Secondary Standards Dosimetry Laboratory (SSDL) since 1971. The Department of Medical Science's dosimetry laboratory is a member of the International Atomic Energy Agency and World Health Organization Cooperation network in South-East Asia.

The OAP-dosimetry laboratory has carried on Metrological controls and certification of measuring equipment for ionizing radiation. The Bureau of Regulation Supporting maintains the SSDL with its equipment and source standards for the provision of services for the calibration of radiation monitoring instruments and dosimeters (i.e. survey meters, rate meter, personal monitors, etc.)

2.1.3.2 Radiation Safety Service

The users can also request technical services from the TINT to ensure safety in their facilities. Among the services provided by the institute are the followings:

(i) Leak testing of sealed radiation sources/ Contamination checking
(ii) Certify of the Packaging of Sealed Radioactive Source.
(iii) Survey Meter
(iv) Collection and management of disused radioactive sources, solid and liquid radioactive wastes
(v) Transportation of radioactive wastes and disused radioactive sources.

These services are provided by the TINT for service charges. The schedule of service-charge for the different services of TINT has been published for ease of reference of the stakeholders.

2.1.4 Radiological Protection for the Public

Dose limits to the public follows the recommendations stated in the OAP- regulation based on International Basic Safety Standards. Each licensee shall ensure that the estimated average dose to any member of the public does not exceed the following dose limits:

(i) An effective dose of 1 mSv in a year;
(ii) In special circumstances, an effective dose of up to 5 mSv in a single year provided that the average dose over five consecutive years does not exceed 1 mSv per year;
(iii) An equivalent dose to the lens of the eye of 15 mSv in a year; and
(iv) Equivalent dose to the skin of 50 mSv in a year

Note : In addition, the TINT provides services, upon requests, on the certification of radioactivity content of foodstuffs for export.

2.1.5 Radiation Emergency Preparedness

Emergency Planning and Preparedness is part of the licensing process. All licensees including OAP authorized facilities are required to prepare and submit a facility emergency response plan for approval of the regulatory body. The level of preparedness is commensurate to the level of hazards expected in the facility.

2.2 Radiation Safety Management in Thai Research Reactor-1 / Modification1 (TRR-1/M1)

TRR-1/M1 Safety Management System, regulated in accordance with the Atomic Energy for Peace Act B.E.2504 and Ministerial Regulation B.E. 2550, is comprised of the Radiation Protection program, the Radiation Monitoring program, the ALARA program and Access control. The system was established by the Reactor Operation Section and the Safety Unit, which are supervised by the TINT Executive Director. The Safety Unit is an administrative organization for radiation protection management, which is performed by health physicists.

The goal of the Radiation Protection program of TRR-1/M1 is to allow the maximum beneficial use of radiation sources with minimum radiation exposure to personnel. Requirements and procedures set forth in this program are designed to meet the fundamental principles of radiation protection, which are *Justification, Optimization* and *Limitation*. The legal dose limit for both occupationally exposed personnel and the general public are 20 mSv and 1 mSv, respectively.

The Radiation Monitoring program was established to ensure that all radiation sources are detected and assessed in a timely manner. To achieve this, the monitoring program is organized so that two major types of radiation surveys are carried out; referring as routine radiation level and contamination level surveys of specific areas and activities within the facility, and special radiation surveys necessary to support non-routine facility operations such as shutdown periods.

The Gas tight area of the reactor is classified as a Controlled area and is equipped with a permanent monitoring system for both Gamma and Neutron (so-called RAM-Radiation Area Monitoring). Effluent and airborne radiation monitors are located in the Gas tight area and the Ventilation system. The monitoring systems are continuously measuring radioactive dust/particle and volatile gas during reactor operation. The data is recorded with electronic devices and is transferred to the monitor and data storage system in the control room. The air pressure in Gas tight area is negative pressure to ensure the radioactive materials are kept inside the Gas tight area during reactor operation.

The water in the primary coolant system is sampled once a week and measured for fission products by HP-Ge detector gamma spectrometer. Radioactive particle/gas and dust are also sampled with an activated charcoal air filter. Hand and Shoe monitoring, including a portable contamination survey meter are located in the Reactor hall entry and near the emergency door exit. A decontamination facility shower- room is also located at the Reactor hall entry.

Radiation surveys inside and outside the controlled area are routinely performed by health physicists as per health physics procedures. Sample irradiation procedures and forms require checks of radiation level each time a sample is removed from an irradiation facility by a health physicist. Experiment reviews and approvals require radiation surveys for new experiments and modifications of ongoing experiments.

Radiation workers are required to wear protective clothing when they enter the Gas tight area. Protective clothing, shoes and shoe covers are provided for all individuals who enter the gas tight area, including visitors, to avoid contamination. Everyone is checked for contamination upon exiting. Radiation workers must also wear at least one type of personal dosimeters. TLD's are issued to each radiation worker every 3 months. Digital dosimeters-direct reading personal dosimeters are provided for both radiation workers and visitors. Visitors must be escorted by an Operator. The number of visitors at one time must not be greater than 20 persons.

The ALARA program is based on the guidelines found in Basic Safety Standards for Radiation

Protection. It incorporates a review of all TRR-1/M1 operations with an emphasis on operational procedures and practices that might reduce TRR-1/M1 staff and operators exposure to radiation and lower potential radioactive effluent releases to unrestricted areas. Personnel radiation doses at the TRR-1/M1 are minimized by considering use of the following ALARA actions when performing work with radiation or radioactive materials.

- Reviewing records of similar work previously performed
- Eliminating unnecessary work
- Preparing written procedures
- Using special tools
- Installing temporary shielding
- Performing as much work as possible outside of radiation areas
- Performing mockup training
- Conducting pre-work briefings and post-work critiques
- Keeping unnecessary personnel out of areas where radiation exposure may occur

In addition to the above actions, the TRR-1/M1 ALARA program also contains the following elements which are designed to enhance the effectiveness of the overall program:

- Exposure investigations are conducted when an individual receives greater than 1 mSv in one month or 3 mSv in one quarter. The investigation is focused on determining the cause of the exposure so that appropriate ALARA actions, if any, can be applied.
- ALARA dose trend analysis charts are prepared quarterly and posted for review by all TRR-1/M1 personnel.
- An annual inspection of the TRR-1/M1 ALARA program is conducted by an individual who has no operational responsibilities at the TRR-1/M1. This individual is appointed by the RSC and inspection findings are presented to the RSC within 30 days after completion of the inspection.
- A health physicist is required to be involved during planning, design approval, and construction of new TRR-1/M1 instruments and facilities; during planning and implementation of TRR-1/M1 reactor use; during maintenance activities; and during management and disposal of radioactive waste. In addition, written procedures are required to be reviewed by Health Physics Supervisor.

The procedures for radiation protection are written by Safety Unit in accordance with the relevant Quality Assurance program of the Institute, which is ISO9001 certified. All the procedures are approved by the TINT Executive Director and reviewed by the Radiation Safety Committee. The procedures include the policy, methods and frequencies for conducting radiation surveys and air sampling; effluent monitoring; administrative measures for controlling access to radiation area; control of contamination of personnel and equipment; control of radioactive materials transportation within facility; methods of handling and storage of sources, radioisotopes and other radioactive material.

Radiation protection training is conducted by the TINT Technology Transfer Section which cooperated with the Safety Unit. It is structured at different levels in order to meet the needs of different categories of facility staff and researchers using the reactor. All personnel and visitors entering the TRR-1/M1 receive training in radiation protection appropriate for their work/visit, or shall be escorted by an individual who has received such training. All personnel permitted unescorted access in the TRR-1/M1 facility shall receive annual radiation safety refresher training.

Access controls are installed at various locations including the reactor gate, the reactor building entrance, the reactor registration area, the water treatment area, the reactor gas tight area and the refresh fuel storage room. All staff must be authorized at the level relevant to their work by the reactor manager and the head of the Safety Unit.

Emergency plans and procedures are implemented in two different levels, which are emergency for operator in-house developed by reactor operation section and emergency preparedness plan for institute (TINT) developed by the Safety Unit activated in the case of a critical situation which Reactor Operators cannot handling. The training on emergency preparedness is conducted once a year and is compliant with Ministerial Regulations

2.3 Radiation Safety in Radioactive Waste Management

Radioactive waste in Thailand is generated by R&D laboratories, the operation of a 2 MW research reactor, nuclear medical applications, radio-pharmaceutical production, industries and others. At present, Thailand has no nuclear power plants.

The Radioactive Waste Management Center (RWMC), Thailand Institute of Nuclear Technology (TINT) has been separated from the Office of Atoms for Peace (OAP) to act as the centralized radioactive waste management service in the country.

The main waste management facility is located in Chatuchak, a part of Bangkok. It is composed of solid waste treatment facilities (such as incineration and compaction), liquid waste treatment facilities (such as chemical precipitation and filtering systems) and storage facilities (see Table 5.) Currently, there is no disposal facility in Thailand.

The nuclear regulatory function is conducted by the OAP. The RWM regulation and guidance was first implemented in 2003, under the Atomic Energy for Peace Act B.E.2504 (1961) and the Ministerial Regulation on Rules and Procedures of Radioactive Waste Management B.E.2546 (2003). Up to now, there are no specific regulations on licenses for radioactive waste operation facilities.

2.3.1 Related law and regulation on Radiation Safety and Radioactive Waste Management

- The Atomic Energy for Peace Act B.E.2504 (1961)
- Ministerial Regulation on Condition and Procedure Requirements for License of the Possession of Related Nuclear Materials, Radioactive Materials or Atomic Energy B.E.2550 (2007)
- Ministerial Regulation on Rules and Procedures of Radioactive Management B.E. 2546 (2003)
- OAEP-1 Clearance Level of RW (Solid, Liquid and Gas)
- OAEP-2 Measure on Radiation Area
- OAEP-6 Measure on Safety of Radioactive material Nuclear material and X-ray Working Area
- OAEP-7 Measure on Installation of Radiation Generator
- OAEP-10 Measure on Transportation of radioactive materials and wastes
- OAEP-18 Radiation Safety Officer
- OAEP-20 Guides of RW Segregation, Collection, Container and Label
- OAEP-21 Guides of Temporary Storage for RW Generator

Table 5: Radioactive waste management facilities in Thailand

Facilities	***Items***	***Capacity***	***Type of Waste***
Solid waste treatment	Incinerator equipped with off gas cleaning system	15 kg/hr	Burnable waste
	Compactor	40 ton	Compactable waste
Liquid waste treatment	Chemical precipitation plant	5 m^3/batch	Aqueous waste with low salt content
	Stainless steel container	2 x 5 m^3	Organic liquid waste
Conditioning	In drum cement mixer	200 Liter	Ash, sludge
Storage	Storage facility No.1	65 m^2 x 4.5 m 81 m^2 x 4 m	Disused SRS
	Storage facility No.2	80 m^2 x 4.5 m	Treated Waste in drums; ashes, sludge
	Storage facility No.3 (not at the Bangkok site, but in Pathumthani Province)	300 m^2 x 5 m	Treated Waste in drums: glass Conditioned Radium in drums. Newly coming disused SRS

2.3.2 Safety assessment of Thailand Radioactive Waste Management Facility.

The TINT-RWMC (Radioactive Waste Management Center) has participated in several IAEA international/regional projects. TINT- Radioactive Waste Management facility was selected to be a Test Case under the IAEA Safety Assessment Driving to Radioactive Waste Management Solutions. A methodology for preparing the safety case and safety assessment for predisposal waste management facilities or activities is provided in IAEA Safety Guides DS284 . The recommended approach to safety assessment is outlined in Figure 1. It includes the following key components:

(i) Specification of the assessment context (including the purpose, scope, regulatory framework, assessment endpoints, target audience, and philosophy of the assessment);

(ii) Description of the predisposal waste management facility or activity and waste, as well the neighbouring areas;

(iii) Development, selection and justification of scenarios;

(iv) Identification and justification of models and data needs;

(v) Calculation, their verification and evaluation of results;

(vi) Analysis of safety measures and engineering, comparison against assessment criteria;

(vii) Independent verification of safety assessment results (by peer review and/or independent assessment by Regulator), and

(viii) Review and modification of the assessment if necessary (iteration).

The steps outlined in Figure 2 are interdependent and should be performed in an iterative manner. Solid black lines indicate the typical sequence of activities but this sequence is not mandatory. Dotted lines indicate possible changes to this sequence, for example if a hazard is screened out there is no need for further modelling. Similarly the "Assessment Context" may change as a result of subsequent stages in the safety assessment process.

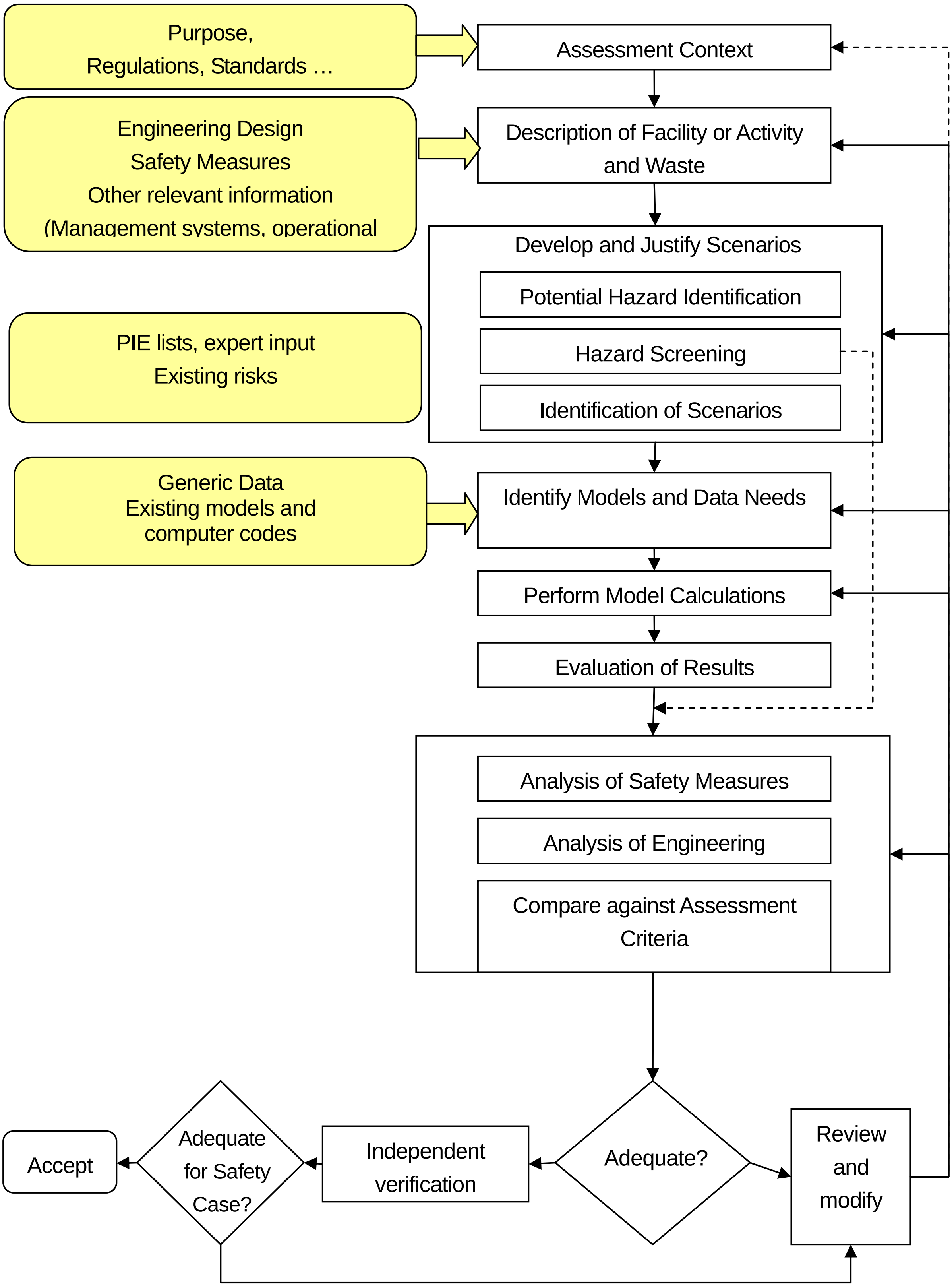


Fig. 2: The Safety Assessment Process for Predisposal Waste Management

2.3.3 Assessment Endpoints

The safety assessment takes the following endpoints into consideration for the normal operation of the facilities:

- The radiation exposure of workers in the waste management facilities is considered as an endpoint to be compared to the worker dose limit.
- Radiation exposure of the general public can arise from atmospheric releases and from aquatic discharges. Respective endpoints for members of the general public are considered and compared to the public dose limit.
- For accident conditions, analogous endpoints are considered. These are not compared to any quantitative criteria, however, but evaluated against the ALARA principle.

In accordance with the scope of the safety assessment, receptors for other endpoints than dose are not considered. Also, no endpoints relating to non-human species are taken into account since this is not required by the current regulations.

2.3.4 Safety Management of Disused Sealed Source

There was a serious radiological accident in Thailand in 2000. The 400 Ci disused Co-60 teletherapy sources was cut open. The Co-60 source was dropped down in a scrap metal shop. The OAP emergency team successfully recovered the source and then the subsequent management, conditioning operation of the source have been successfully undertaken and completed in 2001.

During the year 2000-2002, Thailand team under advisement of an IAEA expert collected the disused Radium-226 in the country and successfully conditioned all radium sources in the year 2004. In addition, the conditioning operation of 4 Ci Ra-226 external source was also successfully conditioned by OAP team (TINT at present) in the year 2005.

These conditioned sources are now safely stored at the TINT interim storage facilities awaiting final disposal. The TINT- RWMC continues to pursue the upgrading of its centralized facility for low to intermediate level radioactive waste treatment and storage facilities. Moreover, the TINT-RWMC in collaboration with other government agencies, such as MEXT/JAEA, FNCA, KAERI, and US-DOE are co-operation for the safety management of radioactive waste development projects.

2.3.5 Radiological Protection for Radiation Workers

The TINT ensures that the following dose limits will not be exceeded by TINT radiation workers; an effective dose of 20 mSv per year averaged over five consecutive years.

9. Vietnam

9. Vietnam

Part 1. Radiation Safety in Radiation Industry Facilities

1.1 General

Now in Vietnam, radiation and radioisotopes have been applied in health care, agriculture, industry, geology, mining, meteorology, hydrology, transport, construction, oil and gas industry, etc.

There is only one nuclear installation in the country is the Dalat nuclear research reactor with capacity of 500 kW.

In order to meet the energy demand in the future, the first nuclear power plant (NPP) will be put in operation in 2020 with capacity of 2000 MW and the second NPP with capacity of 2000 MW will be put in operation in 2021.

Atomic Energy Law had been approved at the twelfth National Assembly Session 3 on 3rd June 2008 and come to enforce on 1st January 2009. The Atomic Energy Law includes 11 Chapters with 93 Articles.

1.1.1 Legislative framework and policy for radiation safety

According to articles 91, 103 of Statute of the Socialist Republic of Vietnam, the order of legislative framework is as following:

- Laws will be enacted by the National Assembly of the Socialist Republic of Vietnam.
- Ordinances will be enacted by the Standing Committee of the National Assembly.
- Decrees will be enacted by the Prime Minister of the Socialist Republic of Vietnam.;
- Circulars, Guidance, Codes of practices will be enacted by the Minister or some Ministers.
- Atomic Energy Law, Article 6, Principles for activities and the assurance of safety and security in the field of atomic energy.
- Any activities in area of atomic energy shall ensure that public health, human life, environment and social security are protected. State management on safety and security shall be independent and scientifically based.

1.1.2 Regulatory Body

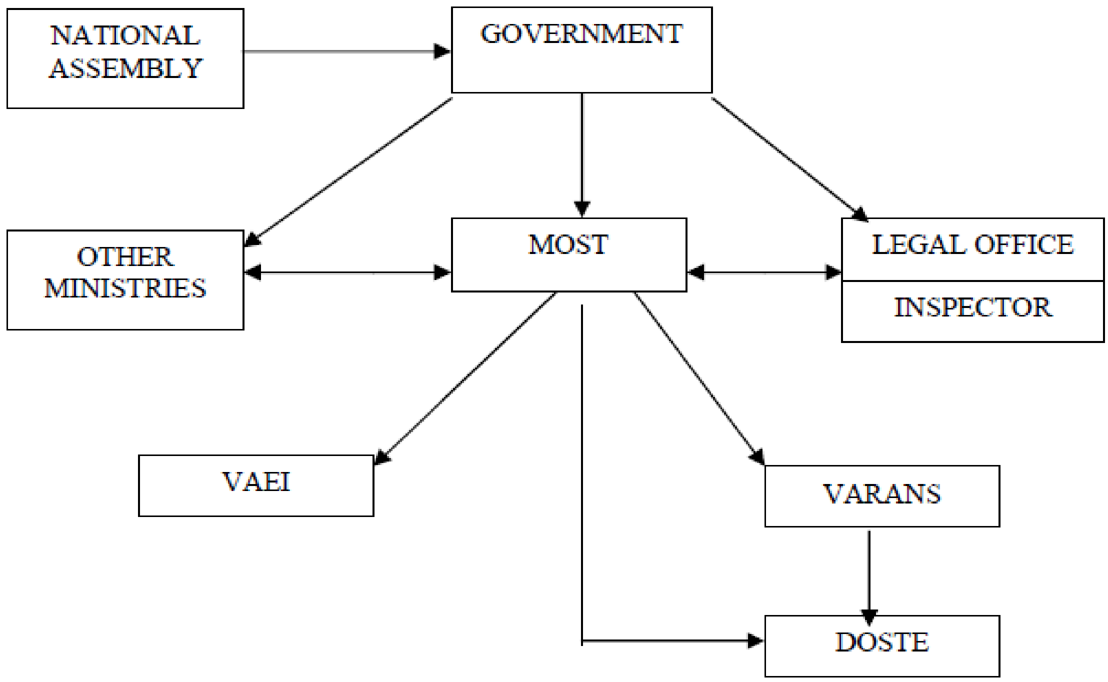


Fig. 1: Structure and resources of regulatory body and supporting organizations

MOST: Under the Article 29 of Ordinance and the Article 34 of Decree 50/CP the MOSTE 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.

VAEI: Under direction of the MOST, the VAEI 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.

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.

DOST: The 63 Provincial Departments of Science & Technology (DOSTs)
are responsible for radiation protection and nuclear safety within the province under supervision by VARANS.

1.2 Outline of Radiation Facilities and Radiation Sources

1.2.1 Number of specialists and Workers in related organizations

The number of people working with radiation related industry in Vietnam is difficult to correctly define however a number is available and is referenced in the VARANS's report. In 2008, there are more than 5,300 radiation workers belong to radiation installation and related organisations. In the South, more than 3,500 radiation workers belong to radiation installation. In the North, more than 1,800 radiation workers belong to radiation installation.

Currently the Service monitors approximately 6,000 workers. The results of personal exposure are reported to VAEI and VARANS, to the supervisors of radiation workers.

1.2.2 Uses of radiation and nuclear in Vietnam

In 2006, MOST fulfill task for nation inventory of uses of radiation in Vietnam. There are 358 radiation facilities and 1,900 X-ray diagnose facilities. There are 2,136 radioactive sources and 2,752 X-ray diagnose equipment.

The largest radiation facilities are:

- There is only one nuclear installation in the country is the Dalat nuclear research reactor with capacity of 500 kW.
- One cyclotron 30 Mev built in 108 Military Hospital and operate in 2009.

There are two RWM facilities in Vietnam:

- The system for RWM at the DNRI (Dalat Nuclear Research Institute) consists of two main parts: The radioactive liquid waste treatment station and the disposal facilities.
- The Interim Storage Facility at the Institute for Technology of Radioactive and Rare Elements (ITRRE) at Phung, Hanoi City;

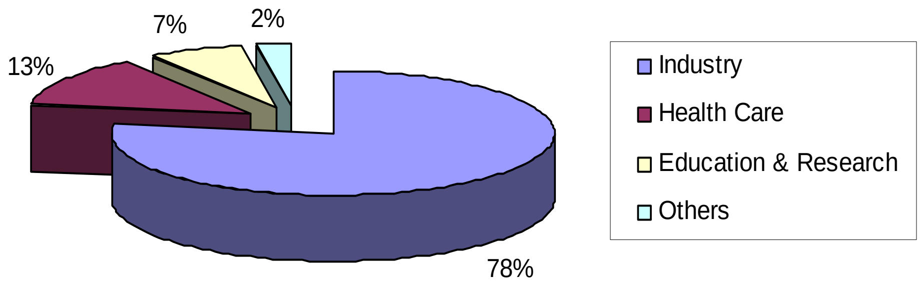


Fig. 2: Percentage of radiation facilities in different areas

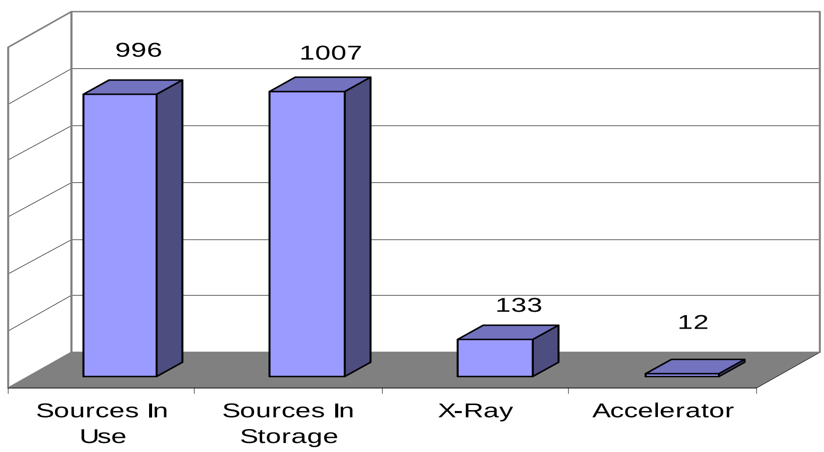


Figure 3: Number of radioactive sources and radiation equipment

Table 1: Number of facilities in health-care

No.	Application	Number of Facilities		Planned
		In operation	Not in operation	
1	Tele-therapy (sealed source)	14	3	2
2	Tele-therapy (accelerator)	6	-	-
3	Brachy-therapy (HDR)	3	2	-
4	Brachy-therapy (Low & Medium dose rate)	0	4	-
5	X-Ray Diagnose	1900	-	-
6	Nuclear Medicine	23	-	1
7	Blood Irradiation	1	1	3
8	Radioisotope Production (cyclotron)	3	-	1

Table 2: Number of sealed sources in health-care

No.	Application	Sealed Source		X-Ray	Unsealed Source	Accelerator
		In Use	In Storage			
1	Tele-theraphy	19	5	0	0	9
2	Brachy-therapy (HDR)	3	~15	2	0	0
3	Brachy-therapy (Low & Medium dose rate)	0	658	0	0	0
4	X-Ray Diagnose	0	0	2752	0	0
5	Nuclear Medicine	0	0	0	0	x
6	Blood Irradiation	1	1	0	0	0
7	Radioisotope Production	0	0	0	X	3 (Cyclotrons)

Table 3: Number of facilities in industry

No.	Application	Number of Facilities		Planned
		In operation	Not in operation	
1	Sterilization Irradiation (sealed source)	4	0	2
2	Sterilization Irradiation (accelerator)	49		
3	NDT (X-ray)	33	0	
4	NDT (radioactive source)	23	0	
5	Gauge (fix)	158		
6	Well loging	12	0	
7	Tracer	1	0	
8	X-ray fluorescent analysis	59	0	
9	Main-board Scanner	1	0	

Table 4: Number of sources in industry

No.	Application	Sealed Source		X-Ray	Unsealed Source	Accelerator
1	Sterilization Irradiator	6	0	0	0	2
2	NDT	67	>180	50	0	0
3	Gauge	422	71	51	0	0
4	Well loging	88	30	0	x	0
5	Tracer	0	0	0	X	0
6	X-ray fluorescent analysis	59	0	18	0	0
7	Main-board Scanner	0	0	7	0	0

Table 5: Number of facilities in education, research& others

No.	Application	Number of Facilities		Planned
		In operation	Not in operation	
Education & Research				
1	Education & Research	27	0	
Others				
1	Agricultural irradiators	0	2	1 gamma field (Da Lat)
2	Geology	1	3	
3	X-Ray scanner (security & customs)	8	0	
4	Radiothermal generators (RTG's)	0	0	

Table 6: Number of sources in education, research& others

No.	Application	Sealed Source		X-Ray	Unsealed Source	Accelerator
		In Use	In Storage			
Education & Research						
1	Education & Research	327	105	11	X	1
Others						
1	Agricultural irradiators	0	2			
2	Geology	4	120	0	x	0
3	X-Ray scanner (security & customs)	0	0	97	0	0
4	Radiothermal generators (RTG's)	0	0	0	0	0

1.3 Education and Training

The radiation workers and the personnel having frequent access to Radiation Facilities shall take appropriate radiation protection training courses in both the theoretical and practical aspects to acquire radiation-handling skills needed for radiation worker, or for access to controlled areas.

- Training trainers
- Establishing training programme for RPO, radiation workers
- Conducting the courses for radiation protection and radiation measurements
- Conducting training courses on Licensing and inspection for 128 staffs from 63 DOST, who are in charge of radiation protection in provinces/cities

Table 7: Type of sevices

No.	Type of Services	Number of Facilities
1	Providing personal Dosimeter	2
2	Calibration of Radiation Survey meter	2
3	Radiation Monitoring (measuring the dose rate)	21
4	Calibration of X-ray Machine in Health Care	17
5	Training in the radiation protection	VAEI + VARANS + DOSTs

*National Education and Training on Nuclear Safety

The Hanoi National University (HNU) which is the largest university in Viet Nam to provide human resources related to nuclear activities has a Department of Nuclear Physics. This department was established in 1956 and currently produces around 50 graduates annually with a basic degree in nuclear physics.

The Hanoi University of Technology (HUT) has a Department of Nuclear Engineering and Environmental Physics. The department was established in 1970 and currently produces about 20 graduates annually with a basic degree in engineering.

Dalat University is the other university which offers courses on nuclear science and it produces about 20 graduate students annually.

1.4 Standardization on Radiation and Radioactivity

Radiation safety and radioactive waste management must be based on the reliable and precise measurement of the quantities associated with ionizing radiation such as dose (Sv) an radioactivity (Bq). For radiation safety, various dose meters are being used such as passive dosimeters for personal dose and survey meters for ambient dose. Dose meters must be calibrated regularly and always must show a right value in order to ensure the safety and security of the people related to ionizing radiations. Measuring instruments such as ionization chambers, scintillation counters and semiconductor detectors are important in radioactive waste management, which need to be calibrated using refernce radioisotope sources.

In the personal dosimetry network, VAEI and VARANS are presented as authority. In this network, there are two recognized personal dosimetry service centers: INST (Hanoi) and NRI (Dalat), which will provide individual monitoring service for the radiation workers in the whole country.

- In the South, more than 3,500 radiation workers belong to radiation installation are examined annually. Read-out frequency: Once in 3 months and in 1 month (for some organization).
- In the North, more than 1,800 radiation workers belong to radiation installation are examined annually. Read-out frequency: Once in 3 months and in 1 month (for some organization).

The results of personal exposure are reported to VAEI and VARANS, to the supervisors of radiation workers.

Secondary Standard Dosimetry Laboratory (SSDL)

INST(Hanoi) operates and maintains a SSDL for national standard radiation dosimetry and calibration of radiation protection instruments such as survey meter, pocket dosimeter but it is limitied in scale.

Intercomparison and international supports in increasing accuracy and personal dosimetry management are essential. The intercomparisons were good way and very useful for finding the problems in our system and help us to gain confidence and improve the accuracy of personal dose equivalent estimation.

Figure 4: The TLD Reader HARSHAW 4500

Figure 5: Calibration Instruments

Part2. Status of Radiation Safety Management

2.1 Radiation Safety Management System

The Ministry of Science and Technology (MOST) is the Regulatory Body responsible for the unified State management of radiation protection and nuclear safety throughout the country; organizing and directing all radiation and nuclear safety activities

The management of radiation safety within various radiation facilities is governed by the specific standards, codes and guides.

These encompass all radiation management consideration for research, industrial and medical related facilities as follows:

Table 8: List of Vietnam standards on radiation safety

1.	TCVN 3727 - 82	Radioactive Wastes, Radioactive Dirt, Decontamination, Radioactive sol – Glossary
2.	TCVN 1638 - 75	Symbol on electrical diagram. Ionizing radiation detector
3.	TCVN 4397 - 87	Ionizing radiation safety standards
4.	TCVN 4498 - 88	Collective protection measures against ionizing radiation
5.	TCVN 4985 - 89	Safe Transport Standards of Radioactive Materials
6.	TCVN 5134 - 90	Radiation safety – Glossary
7.	TCVN 6053 – 95 (ISO 9696:1992)	Water quality – Total amount of beta radiation measurement in unsalted water – Thick-source method
8.	TCVN 6053 – 95 (ISO 9697:1992)	Water quality – Total amount of beta radiation measurement in unsalted water
9.	TCVN 6561:1999	Radiation Protection for Medical Installations
10.	TCVN 6730-1:2000	X-ray shielding materials – Lead rubber
11.	TCVN 6866:2001	Radiation Safety – Occupational Radiation Dose Limits for radiation worker and public
12.	TCVN 6867:2001	Radiation Safety – Safe Transport of Radioactive Materials – Part 1: General Provisions
13.	TCVN 6868:2001	Radiation Safety – Safe Management and Treatments of radioactive Wastes – Classification of Radioactive Wastes
14.	TCVN 6869:2001	Radiation Safety – Medical exposure – General Provisions
15.	TCVN 6870:2001	Radiation Safety – Exemption of declaration, registration and licensing
16.	TCVN 7077:2002 (ISO 1757:1996)	Radiation Safety – Personal photographic dosimeters
17.	TCVN 7078-1:2002 (ISO 7503-1:1988)	Radiation Safety – Evaluation of surface contamination – Part 1: Beta-emitters (maximum beta energy greater than 0.15 MeV) and alpha-emitters
18.	TCVN 7173:2002 (ISO 9271:1992)	Radiation Safety – Decontamination of radioactively contaminated surfaces – Testing of decontamination agents for textiles
19.	TCVN 7174:2002 (ISO 9271:1992)	Nuclear Energy – Radiation protection – Individual thermo luminescence dosimeters for extremities and eyes

2.2 Radiation Safety Management

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.

2.2.1 Radiological Protection for Radiation Workers

An increase in a person's exposure to ionizing radiation, even at low doses, is assumed to increase the risk of harm to that person's health. As such, all radiation industries and facilities are required to implement a system of radiation protection which limits possible detrimental effects arising from occupational radiation exposure. This ALARA approach involves the design of processes in such a way as to minimise exposure and to ensure that occupational dose limits are met. Radiological protection is achieved through the following hierarchy:

- avoidance of exposure, where practicable;
- isolation of sources of radiation, where practicable, through shielding,
- containment and remote handling techniques;
- engineering controls, such as local exhaust ventilation to remove contaminants from the workplace environment;
- adoption of safe work practices, including work methods which make appropriate use of time, distance and shielding to minimise exposure; and
- where other means of controlling exposure are not practicable, the use of approved personal protective equipment.

Radiation Protection of workers has to be monitored to make sure that the total amount of external and internal exposure doesn't exceed yearly lilit of effective dose by personal a dosemeter and regular medical check in accordance with the applied regulations.

Table 9: Radiation dose limits for radiation worker

	Dose limit	
Application	Occupational	Public
Effective dose	20 mSv per year, averaged over a period of 5 consecutive calendar years	1 Sv in a year
Annual equivalent dose in		
the lens of the eye	150 mSv	
the skin	500 mSv	
the hands and feet	500 mSv	

Reference: Occupational Radiation limits for radiation worker was given by TCVN 6866:2001.
About 6,300 of radiation workers in the country are monitored occupational dose. The duties and responsibilities of the radiation service centers and radiation institution were defined by the Atomic Energy Law 1, 2009.

2.2.2 Radiological Protection for Radiation area

Work processes and areas are designed to keep radiation exposure to a minimum. Where the potential for exposure to radiation or contamination still exists, shielding and mechanical ventilation are employ to minimise the dose received. Areas are classified according to the potential radiation and contamination level.

Dose and contamination surveys are carried out by Radiation Safety Officer (RSO) as schduled and also at request.

2.2.3 Radiological Protection for the Public

Monitoring for radionuclieds is carried out continually to determine compliance with the limits imposed by the regulator and to fulfil the duty to protect members of the public. 03 Environmental radiation monitoring stations have been established under the environmental surveillance programme of the Ministry of Resources and Environment.

- 01 station in Dalat Nuclear Research Institute
- 01 station in Ho Chi Minh City (belong to Dalat NRI)
- 01 station in Hanoi (INST)
- Monitoring points in Laocai, Lang Son, Quang Ninh

In future, number of stations will be increased. Environmental Monitoring will cover important areas of Vietnam including area for NPP construction.

2.3 Emergency Plan for Radiation Accident

2.3.1 Plans for radiation incident response

Organizations, individuals conducting radiation activities shall develop their plans for radiation and nuclear incident response.

Provincial People's Committee shall develop provincial plans for radiation and nuclear incidents response; the MOST shall provide guidance on planning and approving the provincial plans for radiation and nuclear incidents response.

The MOST shall collaborate with the Ministry of Industry, Ministry of Health, Ministry of Defense, Ministry of Public Security, Provincial Peoples's Committees in which radiation facilities, nuclear facilities are operating and related organizations and individuals to develop nationals plans for radiation and nuclear incident response to submit to the Prime Minister for approval.

In advent of extremely severe incidents that may cause serious disaster, the emergency announcement and response plan shall be executed in accordance with the law on emergency.

2.3.2 Responsibilities of related organizations individuals in case of incidents

1. Responsibilities of organizations, individuals conducting radiation practices:
   - Mobilising forces and means within the facilities to overcome incidents, mitigate the out spread and consequences, conduct first-aid to injured persons, isolate the dangerous areas, and execute security control measures;
   - Providing information, documents and supports for remedy and investigation of the cause of the incident.
2. Responsibilities of the agencies, organizations, superior to the organizations, individuals conducting radiation activities:
3. Responsibilities of Province People's Committtees:
4. Responsibilities of the Ministry of Science and Technology:
5. Responsibilities of the National Committee for Search and Rescue:
6. Responsibilities of the Ministry of Defense:

7. Responsibilities of the Ministry of Public Security, The Ministry of Foreign Affairs, The Ministry of Public Health, related organizations, individuals.

2.3.3 Training and Practical Exercises

Medical response in the case of Radiological Emergencies:

- Training – about 50 hours every year for pre-hospital radiation emergency response team
- Exercises – Each Team consists about 12-15 responders and has Lectures and Practical exercises every three months
- Drill – often have one radiation emergency drill on-site per year with different scenarios.

National Training Course of Front Line Control with practical exercises for detection and response in the case of illicit trafficking and incident/accident on import/export control.

Drill/Exercises for VAEI and Hanoi local officials: missing sources accident.

Improved DNRR Emergency Plan: include fresh fuel transportation for conversion program.

2.4 Radiation Safety Management in Radioactive Waste Management

2.4.1 Radioactive Waste Management

Radioactive waste in Vietnam is generated by research, industry, medical applications, research reactor operation and radiopharmaceutical production. Naturally occuring radionuclides (NORM) and tecnologically enhanced naturally occuring radioactive materials (TENORM) are produced in Vietnam by the mining, mineral sands processing and other resources sectors. Vietnam has no nuclear power plants.

There are two RWM facilities in Vietnam:

- The system for RWM at the DNRI (Dalat Nuclear Research Institute) consists of two main parts: The radioactive liquid waste treatment station and the disposal facilities.
    + The radioactive liquid waste treatment station: collected and treated liquid radwastes from reactor operation, radioisotope production and other laboratories.
    + The disposal facilities collected, treated and stored dry and wet solid radwastes. In these facilities, eight concrete pits have been constructed for disposal and solidification off radioactive waste.

- The Interim Storage Facility at the Institute for Technology of Radioactive and Rare Elements (ITRRE) at Phung, Hanoi City. In this facilities, all radioactive waste from ITRRE and other Institute in the North of Vietnam are collected, classified, treated and stored in interim storage.

2.4.2 Site selection for Low Level Radwaste Central Facility

On the 3rd of January 2006, the Prime Minister has approved the Strategy for Peaceful Uses of Atomic Energy up to 2020 in Vietnam. According to that, Vietnam will set up the first nuclear power plants in 2020 year. Site selection for low level radioactive waste repository is essential task for activities in the fields of atomic energy and for NPP in future. Office studies on meteorological, geological and hydrogeological conditions of Vietnam show that on the territory of Vietanm, 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 radioactive wastes.

There are 03 most suitable candidate sites: TuThien village, SonHai village, NinhPhuoc district and Thai An village, Ninh Hai district, NinhThuan Province.

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