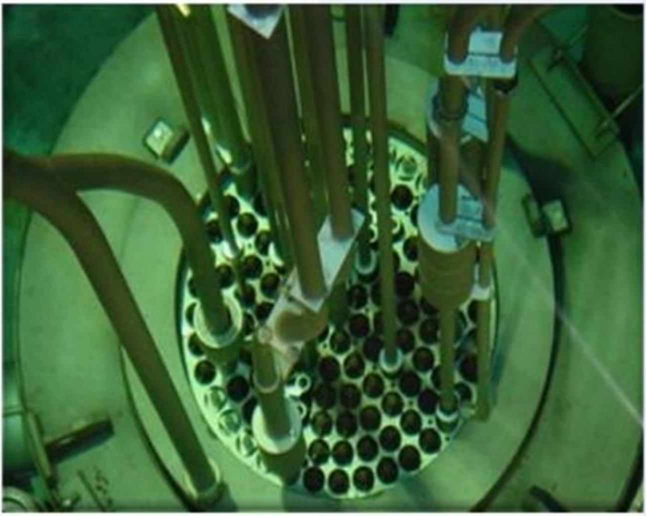
PUSPATI TRIGA REACTOR

USER GUIDEBOOK



CONTENTS

Contents

INTRODUCTION 4

2.1 EXTRACTS FROM ACT 304 5

 Part V – Health and Safety 6

 Part VI – Disposal of Radioactive Waste 7

The appropriate authority may, if it fit to do so, consult the Director General of Environmental Quality appointed under subsection 3 (1) Environmental Quality Act 1974 on any matter. ....

2. 2 EXTRACTS FROM BSRP 2010..

3.1 Radiation ....

3.2 Types of exposure to ionizing radiation ....

3.3 Radiation Quantities and Units ....

3.4 What are the effects of ionizing radiation on the body? 30

3.5 Protection against exposure to radiation ....

3.6 Radiation Protection ....

4.1 Introduction to PUSPATI TRIGA Reactor ....
4.2 Reactor Management ....
4.3 Experimental Facilities ....
4.4 Reactor Utilization....................................
4.5 Category of Experiment....................................
Nuclear Malaysia Waste Zones 74

1 INTRODUCTION

The activities carried out at PUSPATI TRIGA REACTOR present a wide variety of risks. In particular, you may be required to work in conditions involving a risk of exposure to ionizing radiation. The aim of this booklet is to familiarize you with:

a) National and Internal Regulations dealing with radiation protection, which are applicable to anyone working at or visiting RTP, general information on radiation and more detailed explanations of the points outlined in the National and Internal Regulations,

b) information specific to PUSPATI TRIGA Reactor,

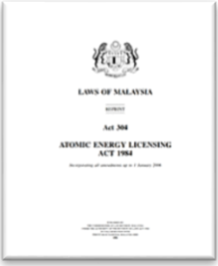
c) Procedures in the event of an incident or accident.

This booklet is a revised and expanded version of the previous user guide, “Panduan Pengguna Reaktor Triga PUSPATI” that has been published in December, 1982. It does not claim to be complete. Please do not hesitate to contact the Pusat Teknologi Reaktor (PTR) should you require further information or advice on a specific problem relating to radiological safety.

2 LAWS AND REGULATIONS

The use of ionizing radiation is controlled by the National Law on the Atomic Licensing Act 1984 (Act 304). The aim of Act 304 is to provide the regulation and control of atomic energy; for the establishment of standards on liability for nuclear damage; and for matters connected therewith or related thereto.

Subsidiary to the Act 304, there are few regulations which discussed in detailed provisions entrusted by the Act included the Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 (BSRP 2010) [P.U. (A) 46], which widely applied in our facility that related to ionizing radiation. BSRP 2010 is a replacement of the previous subsidiary legislation known as Radiation Protection (Basic Safety Standards) Regulations, 1988.



LAWS OF MALAYSIA

REPRINT

Act 304

ATOMIC ENERGY LICENSING ACT 1984

2.1 EXTRACTS FROM ACT 304

The contents of the Act 304 consist of 71 sections which are divided into ten parts. The following extracts from Act 304 are related to health and safety, and disposal of radioactive waste.

- **Part V: Health and Safety**

Section 25

Deal with protection of the health and for the safety of workers and all other persons from ionizing radiation, including directives of matters pertaining to:

a) Conditions of exposure;
b) Dose limitation;
c) Occupational exposure;
d) Medical exposure;
e) Exposure of members of the public and persons other than workers, excluding medical exposure;
f) Accidental exposure;
g) Emergency exposure; and
h) Exposure other than any of those specified in (a) to (g).

- **Part VI: Disposal of Radioactive Waste**

Section 26

No person shall dispose of or cause to be disposed any radioactive waste without prior authorization in writing of the appropriate authority.

Section 27

No person shall accumulate or cause to be accumulated any radioactive waste on any premises without prior authorization in writing of the appropriate authority.

Section 30

No person shall transport any radioactive waste without the prior authorization in writing of the appropriate authority.

Section 31

The appropriate authority may, if it fit to do so, consult the Director General of Environmental Quality appointed under subsection 3 (1) Environmental Quality Act 1974 on any matter.

2. 2 EXTRACTS FROM BSRP 2010

BSRP 2010 was formed under the powers conferred by Section 25 (6) and Section 68 of the Act 304. The regulation shall be applied to all activities involving ionizing radiation. Based on this regulation, the registrant and licensees are required to foster and maintain safety culture. The regulations are categorized into 10 parts which in total includes 80 provisions. The following extracts are related to system of radiological protection, occupational, public and potential exposure, and intervention during emergency.

- **Part II: System of Radiological Protection**

The provision of the regulations included the justification of practice (JOP); Optimization of protection and safety (OPS); Dose constraint (DS); and Dose limit (DL) for workers, members of public, apprentices and students, and special circumstances.

- **Part III: Occupational Exposure**

The provision of the regulations encompassed the responsibilities of licensee and employer; employment of RPO and qualified expert; classification of working areas and administrative procedures; monitoring of work place, personnel monitoring and records; investigation of over exposure and notification and report accidental and emergency exposure; medical surveillance and responsibilities of worker.

- **Part V: Public Exposure**

The provision of the regulations incorporated the protection of exposure to the public; control of visitor; control of radiation source in respect of public; control and monitoring of radioactive discharge; monitoring of public exposure; and release of radioactive material, nuclear material and prescribed substance.

- **Part VI: Potential Exposure and Safety of Radiation Sources**

The provision of the regulations considered safety procedure for potential exposure; requirements for radiation source; prevention of accident; emergency plan; accountability for radiation source; security and protection of radiation source; and notification of theft, loss or sabotage.

- **Part VII: Intervention**

The provision of the regulations explained the requirements for intervention; intervention in emergency situation; discontinuous protection action after accident; assessment and monitoring after accident; and protection for workers undertaking an intervention.

3 RESPONSIBILITIES

In line with the enforcement of the Act 304, the radiation protection program [SHE/R/05] that has been established in Nuclear Malaysia since 1978 went through its first revision to cater the requirement of the regulations as well as requirements of safety according to IAEA safety series No.115, entitled International Basic Safety Standard for protection against ionizing Radiation and for the Safety of Radiation Sources.

The content of the radiation protection program is divided into eight parts including the organization structure; responsibilities; training program for workers; operational limit; maintenance, operation and keeping of records; operational procedures; abnormal operational procedures; and references. The following extracts of the document highlighting the responsibilities of Radiation Protection Officer (RPO), Radiation Protection Supervisor (RPS), Operator (Radiation Worker).

In order to control and regulate all practices involving nuclear and radiation activities compliances with Nuklear Malaysia internal procedure under the radiation protection program, a Safety, Health and Environmental (SHE) committee was established as the highest authority. Reactor Facility subcommittee (JKKR) has been formed with specific term of reference for supervising and improving safety of the RTP operation.

To ensure the safety, security and quality of the PUSPATI TRIGA Reactor operation, utilization and modification activities, an Integrated Management System (IMS) program has been established. The program is set in accordance to the general requirements of the IAEA Safety of Research Reactor [Safety Series No.NS-R-4 (2005)]. The following responsibilities and authorities are extracted from these internal programs.

3.1 Responsibilities of Radiation Protection Officer (RPO)

RPO is qualified personnel that have attended the Radiation Protection course which include topics on nuclear research reactors such as RTP and passed the Radiation Protection examination conducted by the Atomic Energy Licensing Board (AELB). The responsibilities of RPO are:

a) to prepare and update radiation protection programme whenever required or instructed by AELB.

b) to provide training and information on radiation protection for radiation workers.
c) to identify and analyse radiological hazards in workplace and their surrounding
d) to ensure the maintenance record, import/export and disposal of radioactive materials are kept and updated
e) to ensure the arrangement for medical surveillance of radiation workers.
f) to classify and label working areas in accordance with BSRP 2010.
g) to ensure that radiation protection devices are in good condition and are always being used by workers.
h) to ensure that engagement, termination and retirement of radiation workers follow procedures set by AELB.

3.2 Responsibilities of Radiation Protection Supervisor (RPS)

RPS enquired the same qualification as the RPO which is to sit the Radiation Protection course and passed the examination conducted by AELB. The responsibilities of RPS are:

a) to take over the tasks and responsibilities of the RPO in his absence and report all matters to him as soon as he returns.

b) to assist the RPO in implementing radiation protection activities in compliance with the Act 304 and subsidiary legislation made there under based on LEM/TEK/45 Sem. 1.

3.3 Responsibilities of Radiation Worker / Operator

The radiation workers are required to register themselves to AELB database and show up at the medical surveillance appointment arranged by the Health Physics Group. A reactor operator should be registered as a radiation worker with the minimum academic requirement is diploma in engineering discipline. In addition, all the reactor operators should undergo an intensive training in reactor operation, attending formal lectures including the plant walk around session and pass the written and practical examination conducted by AELB to be a licensed reactor operator.

The responsibilities of the radiation workers and reactor operators are:

a) Follow all instructions, rules and procedures and refrain from careless practices that could result in unnecessary exposure.
b) Use, as instructed, all facilities, devices and PPE.
c) Use approved personnel monitoring devices.
d) Not interfere with, remove or alter any safety equipment.
e) Take all reasonable precautions to prevent damage to such equipment and immediate report any damage or malfunction of any equipment to his supervisor or RPO.
f) Immediately report all accidental exposures or any suspected exposures to his supervisor or RPO
g) Report pregnancy or suspected pregnancy to approved medical practitioner in the case of female worker

3.4 Responsibilities of Facility Users

The facility users are required to attend a comprehensive and dedicated safety briefing provided by the Health Physics Group prior to using the experimental facilities. The records of attendance should be informed to the RPS. The users are responsible for utilising the reactor in a safe manner to ensure safety to other users, environment and to the reactor itself.

4 INFORMATION ON RADIATION

The emission of energy as electromagnetic waves or as moving subatomic particles through space or through a material medium is known as radiation. Radiation is often categorized as either ionizing or non-ionizing depending on the energy of the radiated particles. Figure 3.1 illustrated the common sources of ionizing and non-ionizing radiations with respect to their wavelengths and frequencies.

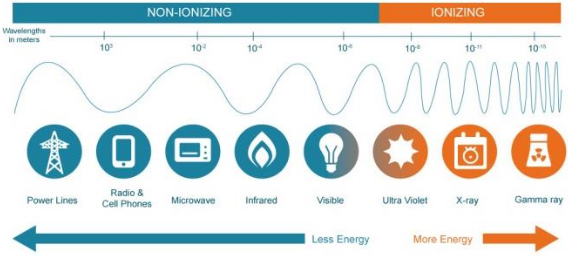


Figure 4.1 Electromagnetic Spectrum
(Source: https://www.mirion.com/)

Compare to non-ionizing radiation, the ionizing radiation could be harmful and potentially lethal to living beings but have health benefits at the same time, such as in radiation therapy for the treatment of cancer. The nuclear research reactor practically emits a lot of ionizing radiations. Therefore, the non-ionizing radiation will not be emphasized in this guidebook.

4.1 Atomic Structure

Neutral atoms of each element contain an equal number of proton and electrons. The number of protons determines the atomic number of the element which differentiates one element from another.

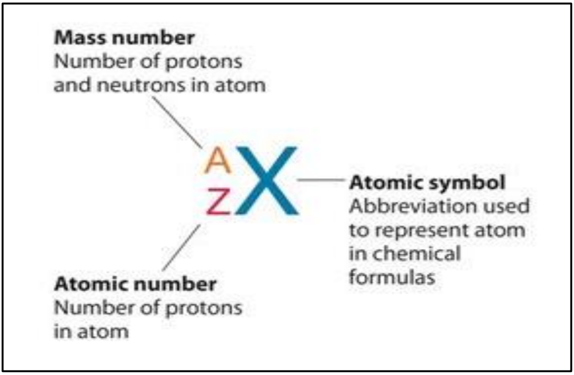


Figure 4.2 Atomic structure

The number of neutrons is variable that distinguish the isotopes of the same atom. The total number of protons and neutrons determine the mass number of the atom. The atomic mass of an element with isotopes is calculated by taking the mean of the mass numbers for its isotopes. On the basis of different proportions of neutrons and protons in the nuclei, atoms can be classified into different categories such as in Table 3.1.

Table 4.1: Classification of atoms based on the proportion of neutrons and protons in the nuclei.

	isotopes	isotones	isobars	isomers
Same	Z	N	A	A, Z, N
Different	A, N	A, Z	Z, N	energy states
Example	${}^{59}_{27}Co$, ${}^{60}_{27}Co$	${}^{14}_{7}N$, ${}^{15}_{8}O$	${}^{32}_{15}P$, ${}^{32}_{16}S$	${}^{131}_{54}Xe$, ${}^{131m}_{54}Xe$

4.2 Radioactivity

Radioactivity is a phenomenon whereby an unstable nucleus emits ionising radiation to achieve stability through a process known as decay. The emitted ionising radiation is including alpha, beta, gamma and neutron.

- **Alpha (α) particles**

Alpha radiation consists of helium nuclei expelled from unstable proton-rich nuclei, with the nuclei losing four mass units and decreasing in atomic number by two. There is no change in mass and atomic number.

$$ {}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha $$

Alpha particles are characterized by very high energy (typically 4-5 MeV) and low penetrating power (microns). These properties can result in intense short-range materials damage including thousands of atomic ionizations and lattice dislocations, and high toxicity when ingested into an organism.

The particles are commonly emitted by heavy radioactive nuclei occurring in the nature (uranium, thorium or radium), as well as the transuranic elements (neptunium, plutonium or americium). In nuclear reactors, the alpha decay of heavy nuclei is produced in the fuel. An example of alpha decay is the spontaneous decay of plutonium-239 to uranium-235:

^{94}Pu 239 → ^{92}U 235 + He 2 + (4.9 MeV)

- **Beta (*β*) particles**

In beta decay, an electron is expelled from a neutron-rich nucleus, with an increase in atomic number by one but negligible change in mass.

$$ {}_{Z+1}^{A}X \rightarrow {}_{Z}^{A}Y + e^{-} + \overline{\nu}_e \text{ } (\beta^{-} \text{ decay}) $$
$$ {}_{Z-1}^{A}X \rightarrow {}_{Z}^{A}Y + e^{+} + \nu_e \text{ } (\beta^{+} \text{ decay}) $$

Beta particles have much lower energy (typically 100-200 KeV) than alpha but greater penetrating power (millimeters). An example is the spontaneous decay of plutonium-241 to americium-241.

^{94}Pu 241 → ^{95}Am 241 + e- (21 KeV)

Common feature of the fission products in the nuclear reactor is an excess of neutrons. An unstable fission fragment with the excess of neutrons undergoes *β*− decay, where the neutron is converted into a proton, an electron, and an electron antineutrino.

- **Gamma (γ) Particles**

Gamma radiation is highly ionizing electromagnetic radiation with high penetration power, leaving trails of ionization as they pass through matter. Highly lethal gamma radiation levels and wide ranges of photon energies (KeV to MeV) result during nuclear fission as unstable nuclei relax to lower energy. Gamma rays are not charged particles like α and β.

$$^{A}_{Z}X \longrightarrow {}^{A}_{Z}X + {}^{0}_{0}\gamma$$

- **Neutron (n) particles**

Neutrons are high-speed nuclear particles that have an exceptional ability to penetrate other materials. Free neutrons can be classified according to their kinetic energy. This energy is usually given in electron volts (eV). The term temperature can also describe this energy representing thermal equilibrium between a neutron and a medium with a certain temperature.

a) Thermal
   - Neutrons in thermal equilibrium with their surroundings

- Most probable energy at 20 degrees (C) - 0.025 eV; Maxwellian distribution of 20 degrees(C) extends to about 0.2 eV.

b) Epithermal

- Neutrons of energy greater than thermal
- Smaller nuclear cross sections than thermal neutrons.
- Energies between 1 eV and 10 keV

c) Slow

- Neutrons of energy slightly greater than thermal
- Less than 1 to 10 eV (sometimes up to 1 keV)

d) Intermediate

- Neutrons that are between slow and fast
- Few hundred eV to 0.5 MeV

e) Fast

- Greater than 0.5 MeV

f) Fission

- Neutrons formed during fission
- 100 keV to 15 MeV (Most probable: 0.8 MeV; Average: 2.0 MeV)

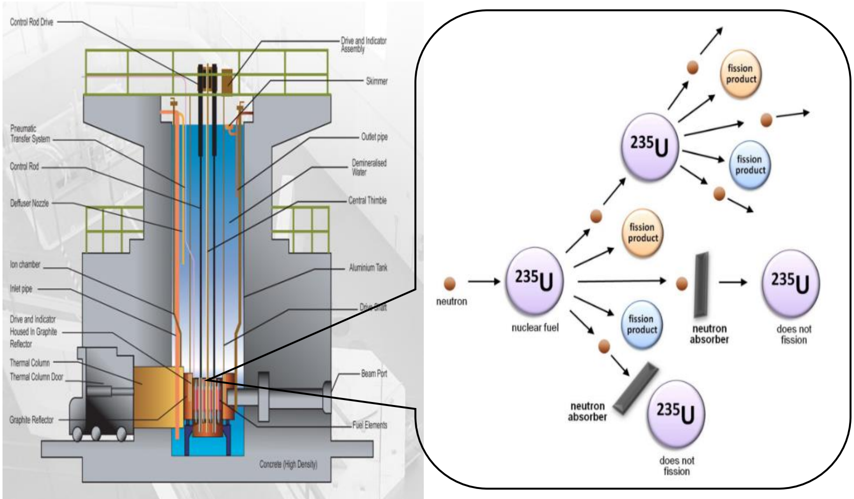


Figure 4.3: Neutron chain reaction in research reactor (Source: https://mnr.mcmaster.ca/)

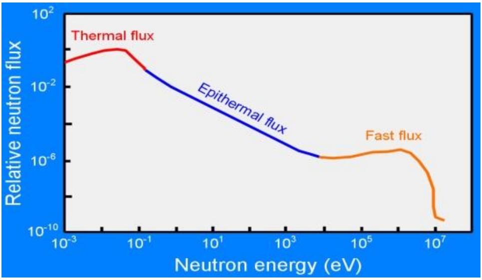


Figure 4.4 Distribution of kinetic energies of neutrons in the thermal reactor. (Source: serc.carleton.edu)

The fission neutrons (fast flux) are immediately slowed down to the thermal energies through a process called neutron moderation.

4.3 Exposure to Ionizing Radiation

There are two potential primary exposure types connected with work involving ionizing radiation which are external and internal exposure to radiation. Each must be carefully evaluated prior to working with radioactive materials, and precautions must be taken to prevent these exposures.

- **External exposure**

External hazards arise when radiation from a source external to the body penetrates the body and causes a dose of ionizing radiation. These exposures can be from gamma or x-rays, neutrons, alpha particles or beta particles; they are dependent upon both the type and energy of the radiation.

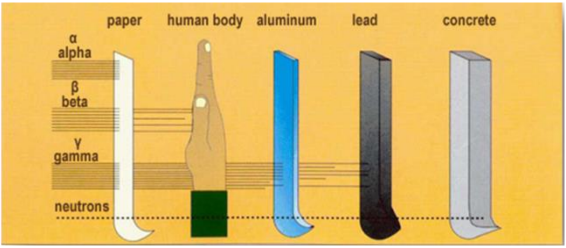
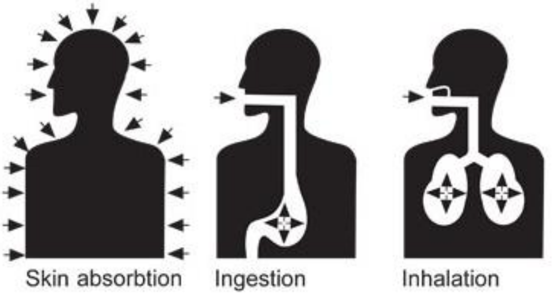


Figure 4.5: Penetrating power of Ionizing radiation

- **Internal exposure**

Radioactive materials may be internally deposited in the body when an uptake occurs through one of the three routes of entry: inhalation, ingestion and skin contact. These exposures can occur when radioactive material is airborne; is inhaled and absorbed by the lungs and deposited in the body; is present in contaminated food, drink or other consumable items and is ingested; or is spilled or aerosolizes onto the skin and absorbed or enters through cuts or scratches. Internal deposition may also result from contaminated hands, with subsequent eating or rubbing of eyes.



4.4 Radiation Quantities and Units

Ionizing radiation is not detectable by one's senses and cannot be seen, heard, smelled, tasted, or felt. That is the reason many types of instruments to detect and identify radioactive materials and ionizing radiation have been developed to measure different physical quantities that can be used to express the amount of radiation delivered to a human body and environment.

- **Activity (A)**

Activity represents the number of atomic nuclei that disintegrate per unit of time. The unit of activity is Becquerel [S.I unit] and Curie:

1 Becquerel (Bq) = 1 dps (disintegration per second)

1 Curie (Ci) = 3.7 x 10^{10} Bq

- **Exposure (X)**

Exposure describes the amount of radiation traveling through the air. One exposure unit (X unit) is the quantity of x-rays or gamma radiation that ionizes 1 Coulomb of total charge in a kilogram of air. The more commonly used exposure unit is the roentgen (R), defined to ionize one state coulomb of total charge in a cubic centimeter of standard air. Many radiation monitors measure exposure. The units for exposure are the roentgen (R) and Coulomb/kilogram (C/kg) [S.I unit]:

1 R = 2.58x10^{-4} C/kg;

87.8 ergs/g (air);

96 ergs/g (tissue)

- **Absorbed dose (D)**

Absorbed dose describes the amount of radiation absorbed by an object, person or environment or the amount of energy per unit mass of that radioactive sources deposit in materials through which they pass. The units for absorbed dose are the radiation absorbed dose (rad) and gray (Gy) [S.I unit]:

1 Gy = 1 J/kg (Should specify the medium).

1 Gy = 100 rad; 1 rad = 100 ergs/g

- **Equivalent dose (H)**

Equivalent dose combines the amount of radiation absorbed and the medical effects of that type of radiation. For beta and gamma radiation, the equivalent dose is the same as the absorbed dose. By contrast, the equivalent dose is larger than the absorbed dose for alpha and neutron radiation, because these types of radiation are more damaging to the human body. Thus, equivalent dose normalizes each types of radiation to its propensity to cause biological damage or its relative biological effectiveness (RBE). Equivalent dose (H) = Absorbed dose (D) x Radiation weighting factor (W_R)

Units for dose equivalent are the roentgen equivalent man (rem) and Sievert (Sv) [S.I unit], and biological dose equivalents are commonly measured in 1/1000th of a rem (known as a millirem or mrem)

Sievert (Sv), 1 Sv = 1 J/kg

1 Sv = 100 rem

Table 4.2 Radiation weighting factor (W_R)

Type and Energy of Radiation		W_R
Photons (all energies)		1
Electrons (all energies)		1
Neutron	< 10 keV	5
	10 keV to 100 keV	10
	> 100 keV to 2 MeV	20
	> 2 MeV to 20 MeV	10
	> 20 MeV	5
Apha particles, heavy nucleus		20

- **Effective dose (H_E)**

Effective dose accounts for the non-uniform sensitivity of different parts of the body by including a tissue or risk weighting factor according to Table 4.2.

Effective dose (H_E) = Summation of Equivalent dose (H) x Tissue weighting factor (W_T) = $\Sigma H\ W_T$

The total effective dose is the weighted sum of local doses. When the entire body uniformly receives the same dose, the total effective dose reduces to the dose to each area of the body. Units for effective dose are same with units for equivalent dose.

4.5 Effects of ionizing radiation on the body

Radiation effects on the body depend on:

a) Total dosage and exposure rate
   - More dosage, more severe
   - Acute / Chronic exposure rate

b) Extent and part of body exposed
   - Different organ response differently

c) Age of the individual exposed
   - Children suffer more severe effect compare to adult if given same dose of radiation

Possible effects of radiation on cells:

a) Cells are undamaged by the dose (no impact) -> no impact
b) Cells are damaged, repair the damage and operate normally -> ok
c) Cells are damaged, repair the image and operate abnormally -> cancer/genetic effect
d) Cells die as a result of damage – depend on how sensitive the cells to radiation -> die

Body respond to radiation:

a) The effects of radiation on the human body can be classify as either chronic or acute
b) Chronic effects occur some years after exposure such as cancer and genetic defects
c) Acute effects occur within hours after exposure due to the radiation's direct physical damage to tissue

The health effects of radiation are divided into two categories:

a) Threshold or Deterministic effects
   - Threshold dose exists (500mSv), severity is proportional to dose after exceeding threshold especially in short term (acute) exposure

b) Stochastic effect
   - Probability, no threshold, long term (chronic/delayed effects such as cancer, cataract, leukemia, carcinogenesis

4.6 Protection against exposure to radiation

Installations in which radioactive material or radiation generating devices are used and designed to:

a) Prevent the dispersion of radioactive material in the surrounding environment (by means of containment devices and ventilation and filtrations systems)
b) Exclude, or reduce to very low levels, any external exposure (using lead, concrete or water shielding)

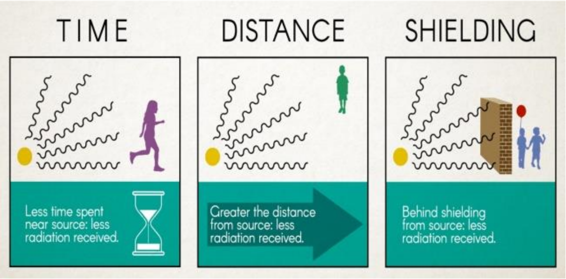
Protection against external exposure

a) Keep the activity of sources such as the quantity of radioactive material handled, to a minimum

b) Reduce the exposure time by planning the handling sequences carefully

c) Work at a sufficient distance from the source by using equipment such as remote handling tongs

d) Use the appropriate shielding for the level of activity of the source and the type and energy of the radiation involved



Protection against internal exposure

a) Reduce the amount of radioactive material to be handled, to an absolute minimum
b) Isolate radioactive material from the surrounding area by:
   - Handling operations in suitable enclosures (ventilation hood, glove box, housing for use with remote manipulator arms
   - Ensuring the ventilation systems are working properly
   - Storing unsealed sources in tightly closed containers as soon as they are no longer required
   - Ensuring that the work place is kept clean
c) Isolate the operator's body, if necessary by:
   - Using filter such as type mask or a separate fresh air supply to protect the respiratory tract in the event of atmospheric contamination
   - Wearing the appropriate protective clothing (overalls, gloves, etc)
   - Never eat, drink, smoke in areas where there is risk of contamination

4.7 Radiation Protection

The objectives of radiation protection are to:

a) Ensure the effective control of external and internal doses to the workers and public, and of releases to the environment;
b) Ensure conformance with all regulatory requirements;
c) Enable further optimization of operational practices.

The basis of the operational radiation protection implementation at the PUSPATI TRIGA Reactor (RTP) aimed to meet the requirement of reactor licensing by Atomic Energy Licensing Board (AELB) 1984 - Safety Radiation Protection 2010 (BSRP 2010) (Act 304).

- **Principles of Radiation Protection**

a) Protection of man and his environment from unnecessary radiation exposure without eliminating the beneficial application of radiation and radioactive materials
b) Prevent deterministic effects and limit the probability of stochastic effect to acceptable level

- **Categories of exposure**

There are three (3) categories as spelled out in BSRP 2010:

a) Occupational exposure
   - Exposure of workers incurred in the course of their work.

b) Medical exposure
   - Exposure incurred by patients as part of their medical diagnostic or treatment procedures.
   - Persons providing support and comfort of patients.
   - Volunteers in a medical research programme.

c) Public exposure
   - Exposure incurred by members of the public from radiation sources excluding occupational exposure, medical exposure and natural background.

- **Dose Limit**

a) Used to apply controls on each individual's accumulation of dose

b) Not a line of demarcation between "safe" and "dangerous"

  - Account dose from occupational exposure only, excluding dose received from natural radiation and medical exposure
  - Similar for men and women except pregnant women

c) Annual Dose Limit (ADL). There are different categories of dose limit for:

  - Radiation workers:

    Effective Dose:

      20 mSv/yr for whole-body exposure

    Equivalent Dose:

      150 mSv/yr to the lens of the eye

      500 mSv/yr to skin, hands, feet and other organ or tissue

    Operating Dose:

      10mSv/yr for whole-body exposure

*Operating dose limit is stipulated under BSRP Regulations 2010, Act 304.

- Pregnant women

  Fetal dose should be limited to less than 1mSv

- Members of the public

Application	ADL (mSv)
Dose limit for the whole bode exposure	1
Equivalent dose for lens of the eyes	15
Equivalent dose for the skin	50
Effective dose constraint for supporting personnel (during diagnostic examination or treatment of the patient)	< 5
Effective dose constraint for visitor (< 16 years old) (of patient undergoing treatment or diagnostic examination)	< 1

- Apprentices & Students

  Apprentices and students in radiation work (in a supervised or controlled area) **must not be less than 16 years old.**

Application	ADL (mSv)
Dose limit for the whole body exposure	6
Equivalent dose for lens of the eyes	50
Equivalent dose for the skin	150

- Special planned exposures (with written approval from the authority)

  Extended period

  Dose equivalent averaged over 10 consecutive years < 20 mSv/yr

  < 50 mSv in one calendar

  Review, when accumulated dose of 100 mSv

  Change of ADL

  Not more than 50 mSv per year for five consecutive years

  Voluntarily and temporary in nature

  Should be review annually

  No renewal

  Specific working area and radiation worker

  Not for pregnant women or student
- Derived and Authorized Limits (Special modeling and special limit approved by AELB)

4.8 Monitoring Equipment

Radiation protection surveillance carried out on workers/users/visitor to ensure that the received dose does not exceed the dose limit.

- **Personnel Monitoring**

a) Thermoluminescene Dosimeter (TLD) badge
b) Film Badge
c) TLD Ring
d) Optically Stimulated Dosimeter (OSLD)
e) Pocket Dosimeter
f) Hand and foot monitor

TLD Badge

TLD Ring
(The label should be facing the radiation source)

Pen Pocket Dosimeter

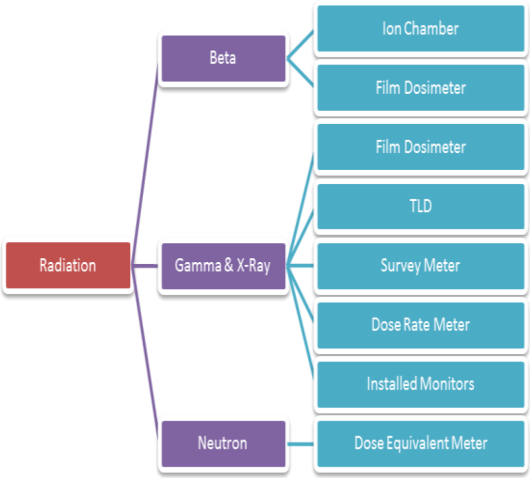
Digital Pocket Dosimeter

Hand and foot monitor

- **Area monitoring**

Radiation protection surveillance carried out in a supervised area or controlled area. RTP monitoring equipment is important to ensure the environment of RTP is safe and secured.

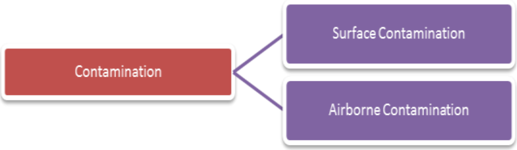
a) Equipment for external radiation:



Survey Meter

Film Dosimeter

b) Equipment for contamination:



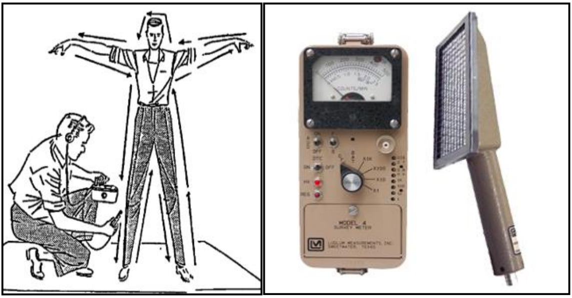
The detector used depends on type of radiation involved in the contamination.

- Alpha contamination

  Scintillation type (ZnS), proportional counter and solid-state detector

- Beta-gamma contamination

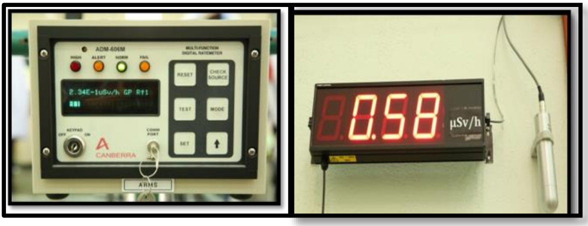
  G-M detector and scintillation detector



Scintillation counter for surface contamination and body part that prone to contamination

c) Area Radiation Monitoring System (ARMS)

- 8 area radiation monitors available to monitor the radiation level inside the reactor hall:
  - 4 ARM are positioned at strategic location on the wall, facing each beam port of the reactor. Each of the ARM is set with the pre-alarm and alarm setting at 5 µSv/hr and 10 µSv/hr, respectively.
  - on the reactor top
  - reactor basement
  - pneumatic room (1)



ARMS at RTP

d) Continuous Air Monitoring

e) Stack Monitor

- A stack monitor is installed to monitor the activity level of the discharge air at the stack on the roof of the reactor building and sounds an alarm when the set point is exceeded.
- The system consists of four detectors that provide the reading for background, particulate, iodine, and noble gas.
- Stack discharge is sampled by pumps at a rate 3.0 m^3/hr for particulate, 1.8 m^3/hr for iodine and 0.1 m^3/hr for noble gas.
- Alarm setting for stack monitor
  - Background: 55 cps
  - Particulate: 5000 Bq/m^3
  - Iodine: 5000 Bq/m^3
  - Noble gas: 650000 Bq/m^3

f) Radiation Portal Monitor (RPM)

- For physical security purpose
- Minimum setting limit : 0.01mSV/h
- The functions of RPM are:
    - To detect and monitor the movement of radioactive or nuclear materials generating gamma rays and neutrons
    - To monitor, filter and detect any possibility of radioactive contamination on people and goods or equipments entering or leaving the reactor building.
    - To support physical security systems at the reactor by monitoring and tracking the movement of radioactive or nuclear materials by unauthorized person

4.9 Restricted Access and Designated Work Areas

The radiation signage is posted where radioactive materials are handled, or where radiation-producing equipment is used. This sign is used as a warning to protect people from being exposed to radioactivity. The radiation area is any area with dose rates greater than 100 millirems (1 millisievert) in one hour 30 centimeters from the source or from any surface through which the ionizing radiation penetrates. Areas at licensee facilities must be posted as "high radiation areas" and access into these areas is maintained under strict control.

Table 4.4: Safe exposure limit received by the worker for work areas at RTP

Working area classification	Average over 2000h/year	Potential radiation exposure level received (mSv/year)
Controlled area	>3 μSv/h	>6
Supervised area	0.5-3 μSv/h	1-6
Clean area	<0.5 μSv/h	<1

- **Controlled area**

Area where the specific radiation and safety regulation are required to control the normal exposure or to avoid the spread contamination during normal working condition and to avoid or limit the potential exposure.

- **Supervised area**

Area where the dose received by the worker is revised from time to time even though the specific radiation protection and safety procedure is sometimes unnecessary.

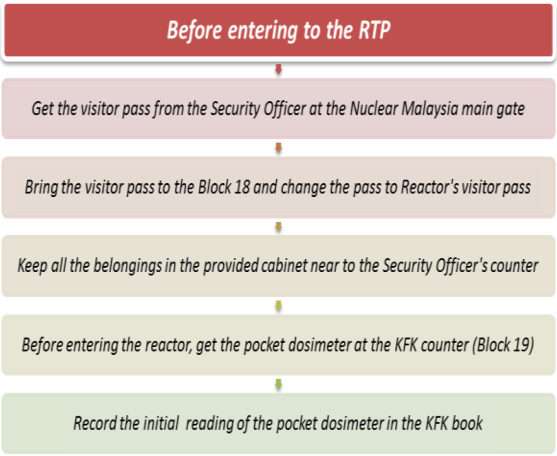
- **Clean area**

Area where the annual dose received by worker is not more than the dose received by the member of the public

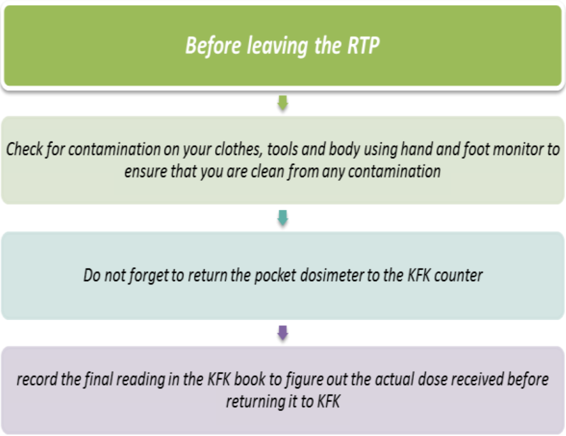
- **Radiation Signage**

4.10 Procedures

In order to ensure the safety, security and quality of the PUSPATI TRIGA Reactor operation, utilization and modification activities, an Integrated Management System (IMS) program has been established. The program is set in accordance to the general requirements of the IAEA Safety of Research Reactor [Safety Series No.NS-R-4 (2005)]. Following is the procedure for entering and leaving the RTP extracted from the IMS Procedure.



Procedures before entering to RTP



Procedures before leaving the RTP

5 RTP INFORMATION

The PUSPATI TRIGA Reactor (RTP), located at the Malaysian Nuclear Agency in Bangi, Malaysia, is a 1 MW TRIGA Mark II research reactor. It was first commissioned on 28 June 1982 and is utilized as a neutron irradiation facility and for beam line applications.

The various facilities of the RTP such as the in-core pneumatic and dry irradiation facilities, out-core irradiation facility, beamport facilities and thermal column. These reactor facilities are also made available as a service to the community e.g. for industrial benefit and in particular to academic organizations as an institutional benefit. RTP characteristics are shown in Table 5.1.

Table 5.1 Summary descriptions of RTP characteristics.

Items	Data
Type	Pool type reactor
Maximum Thermal Power	1 MW (Steady-State & Square Wave Mode)
Maximum Thermal Flux	1 x 10^{13} n/cm^2/s
Shape of Reactor Core	Cylindrical
Coolant & Moderator	Demineralized Light Water
Core Cooling	Natural Convection
Control Rod	Boron Carbide (B_4C)
Reflector	Graphite
Shape of Fuel	Rod Type
Fuel	Uranium Zirconium Hydride (U-$ZrH_{1.6}$)
Fuel Clad	Stainless Steel
Enrichment of U-235	19.99%
Fuel Element Weight Percent	8.5wt%, 12wt% & 20wt%

5.1 Reactor Management

The RTP is placed under the responsibility of the Reactor Technology Centre (PTR). Within PTR, there are four sections: Reactor Operation & Maintenance (O&M), Reactor Physics (RXP), Reactor Technology, Eng. & Safety (TES), Reactor Instrumentation & Control (RIC), and Reactor Quality Management (RQM). However, the operation and maintenance of RTP is mainly under control of O&M Section. The main tasks of the Reactor O&M Section are to conduct and ensure safe operation, maintenance of the 1-MW RTP and all its related systems, to provide irradiation services as well as to assist and coordinate the use of the reactor experimental facilities.

5.2 Experimental Facilities

Experimental facilities available for the users to utilize are located either in core, out of core or beamports.

- **In core facilities**
  RTP has a hexagonal and two triangular in core facilities for high flux irradiations. The sample dimension that can be irradiated in the hexagonal facility reaches 11 cm in diameter and 68 cm height. Each triangular irradiation

facilities can accommodates a sample of 6 cm in diameter and 68 cm height. The use of both in core irradiations facilities requires the transfer of RTP fuel element. Replacement of the fuel element with samples would affect major changes in the reactivity of the reactor. Therefore, details assessment on the operations and safety of the reactor needs to be done before the experiment can be conducted.

Figure 5.1 shows RTP core layout for all in core facilities: The hexagonal (A1, B1 to B6) and triangular (D5, E6, E7 and D14, E18, E19), Dry Tube and Delayed Neutron Activation (DNA) in core facilities.

A **Central Thimble** (CT) is a hollow aluminium tube diameter of 3.38cm, shows in Figure 5.2. It is vertical from the central part of the reactor core to the reactor pool top. A CT that enters the centre of the core lattice makes possible the extraction of a highly collimated beam of radiation or insertion of small samples into the region of maximum flux.

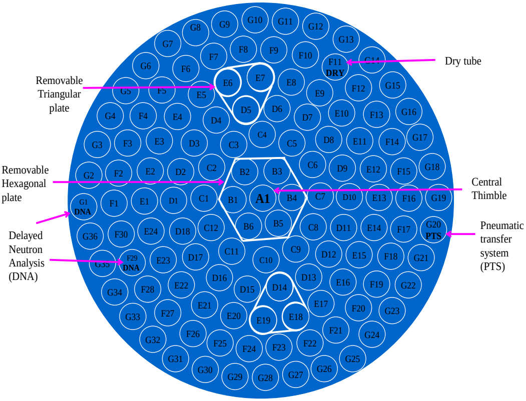


Figure 5.1 RTP core layouts for all in core facilities

Figure 5.2 Central Thimble

Pneumatic Transfer System (PTS) is a pneumatically operated "rabbit" transfer system, which enters the reactor core lattice in position G-20, provides for production of very short-lived radioisotopes for neutron activation analysis. It is controlled by the difference in air pressure generated by air suction. The pressure in the system is always at a lower level than the surrounding air pressure.

In the event of a leak, it will not cause radioactive materials released into the surroundings. Figure 5.32 shows the PTS control station near the fume cupboard.

Figure 5.3 PTS station.

The sample sender and receiver were placed in a fume cupboard at the pneumatic room. Samples should first to be placed into plastic vials. This container is sealed and put into an irradiation tube (polyethylene container) special for pneumatic systems. Figure 5.4 shows the TRIGA tube and vial for PTS.

Figure 5.4 TRIGA tube and vial for PTS

- **Out of core facilities**

The **Rotary Rack** (RR) facility is used for activation analysis and isotope production. The RR assembly consists of a ring-shape, seal-welded aluminum housing containing an aluminum rack mounted on special bearings. The rack supports 40 evenly spaced tubular aluminum containers that serve as receptacles for the specimen tube. The tube is shown in Figure 5.5.

Figure 5.5 TRIGA Tube and vial for RR

Each receptacle has an inside diameter of 3.17 cm and height of 27.4 cm and can hold two irradiation containers, with the exception of position number 1 which can only hold one irradiation container. The rack can be rotated manually or by the motorized drive that permits continuous rotation at about one revolution per minute.

A standard fishing rod, specifically modified for this purpose is used for transferring irradiation containers into and out of the rotary specimen rack. The irradiation container consists of a cylindrical body and screw cap moulded from polyethylene. The cap is formed to fit the pickup tool which is used for unloading the containers from the RR as shown in Figure 5.6.

Figure 5.6 Unloading irradiation containers from the RR.

- **Beam port facilities**

  The beam ports provide tubular penetrations through the high density concrete shield and the reactor tank water, making beams of neutrons and gamma radiation available for a variety of experiments. It also provides an irradiation facility for large (up to 15.2 cm diameter) specimens in a region close to the core. There are three radial beam ports and one tangential beam port at RTP. Figure 5.7 shows the layout of the RTP beam ports.

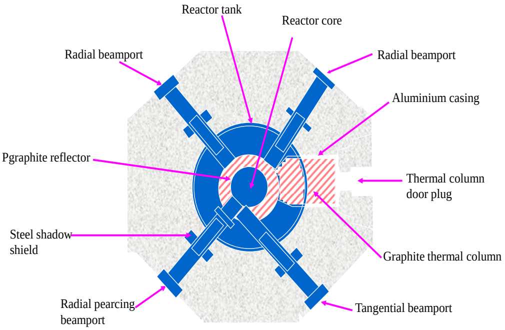


Figure 5.7 The RTP beamports

BP#1 and BP#2 are still vacant but studies for certain applications are being carried out. BP#3 houses the **neutron radiography and imaging facility** (NuR II) where film-based and digital neutron radiography and 2D tomography can be conducted. Both these techniques can be used for imaging internal structure of various materials or components. The neutron radiography system is equipped with an indicator for image quality characterization while tomographic projections are acquired using image acquisition system coupled with linear and rotating stage.

The **Small Angle Neutron Scattering** (SANS) facility, located at BP#4, is designed for studying the properties of materials with equivalent scattering vector of around 1/5.4 Angstrom. The system is equipped with two dimensional Position Sensitive Detector (PSD), Histogramming Memory and in-house software for data recording, viewing scattering pattern and analysis. Beam conditioning is done using High Ordered Pyrolytic Graphite (HOPG).

The **thermal column** is graphite blocks that have been gathered in the exterior of the reactor tank. The graphite block can be removed one by one. Samples may also be disclosed in the neutron column by placing among the set of graphite. The thermal column is closed by a concrete door operated by an electric motor.

5.3 Reactor Utilization

RTP has been utilized for several irradiation and research experiments. Training and education programs are actively conducted to fulfill the increasing demand of the program locally and internationally.

- **Radioisotope production**

  Neutron Radioisotopes can be produced in reactors by exposing suitable target materials to the intense reactor neutron flux for an appropriate time. This is based on neutron capture in a target material, either by activation or generation of radioisotopes from fission of the target material by bombardment with thermal neutrons.

  Target materials to be irradiated are sealed in capsules, loaded in RTP irradiation facilities such as Central Thimble (CT), Pneumatic Transfer System (PTS), Dry Tube (DT), Delayed Neutron Activation-Bare (DNA-Bare), Neutron Activation-Cadmium (DNA-CD), Rotary Rack (RR), Beamport 1, 2, 3 and 4, and Thermal Column for irradiation. After irradiation, the irradiated targets are loaded in appropriate shielding containers and can be collected by user for further analysis or process.

In general, the new radioisotopes produced in Research nuclear reactor can be used for diagnostics and therapy in nuclear medicine, non-destructive testing and radiotracer industrial applications, as well as for radiotracer studies in scientific research. Several radioisotopes that can be produced in RTP are listed in Table 5.1.

Table 5.1 Several Isotopes that can be produced in RTP

Isotope	*Half-life*	*Isotope*	*Half-life*
Sodium – 24	*15 hour*	*Rubidium – 86*	*19.5 hour*
Phosphorus – 32	*14.3 day*	*Yttrium – 90*	*63 hour*
Argon – 41	*1.8 hour*	*Technetium – 99m*	*6 hour*
Potassium – 42	*12.4 hour*	*Indium – 116m*	*54 hour*
Scandium – 46	*85 hour*	*Iodine – 131*	*8.1 day*
Chromium – 51	*27.8 day*	*Lanthanum -140*	*40 hour*
Manganes – 56	*2.58 hour*	*Promethium – 142*	*19.2 hour*
Copper – 64	*12.8 hour*	*Gadolinium – 159*	*18 hour*
Galtium – 72	*14.2 hour*	*Iridium – 192*	*74 day*
Barium – 80	*18 minute*	*Gold – 198*	*2.7 Day*
Barium – 82	*35.9 hour*	*Mercury - 197*	*65 hour*

- **Neutron activation analysis (NAA)**

NAA is a nuclear process used for identification of elements and determining the concentrations of elements in a vast amount of materials. NAA relies on excitation by neutrons so that the treated sample emits gamma-rays. It allows the precise identification and quantification of the elements of major, minor, and trace elements in samples based on the delayed emitted gamma-rays energies.

NAA has applications in various research fields including nutrition and health, medicine, chemistry, geology, archaeology, environmental monitoring and even in the forensic science. The sequence of events occurring during the most common type of nuclear reaction used for NAA, namely the neutron capture or (n, gamma) reaction, is illustrated in Figure 5.8.

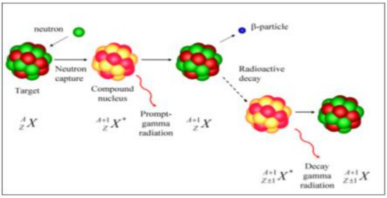


Figure 5.8 Neutron capture by a target nucleus followed by gamma ray emission

Detection of the specific gamma rays indicates presence of a particular element. Suitable semiconductor detector may be used for quantitative measurement. In general, Germanium detectors combine high resolution with low background to an extent not achievable with thallium activated sodium iodide (NaI) detectors whereas the NaI detector has better efficiency. This detector available for use in the room next to Pneumatic room in reactor building under Application of Chemistry Analysis (ACA) group jurisdiction and in nuclear and reactor physics laboratory in block 19 under Reactor and Nuclear Physics (RXP) Group authority.

- **Training and Education**

Besides facilitating research and development in nuclear and related technologies, nuclear research reactors are also designed to be used as a tool for training and education purposes. These include reactor physics and engineering, reactor operation and maintenance, reactor instrumentation and reactor utilization.

The PUSPATI TRIGA reactor has been used to provide hands-on experience for undergraduate and postgraduate students from local and international higher education institutions. Many have successfully completed their projects and thesis. Reactor operator trainees receive their basic training at RTP before advancing to a higher and sophisticated level.

5.4 Category of Experiment

Experiments conducted at RTP are divided into three categories as follows:

a) Type A
   - Creation of minimal radioisotope/radionuclide
   - Creation of minimal reactivity/activity
   - Not require additional shielding

b) Type B
   - Creation of excessive radioisotope/radionuclide
   - Creation of excessive reactivity/activity
   - Require additional shielding

c) Type C
   - Irradiation of fissile materials
   - Irradiation of potential explosive materials
   - Changes in fuel elements

Table 4.3 shows the personnel required to presence during the experiments. Note that user's attendance is compulsory for Type C experiments.

Type	Required Personnel
A	Reactor operator Senior Reactor operator
B	Reactor operator Senior Reactor operator Health Physics representative
C	Reactor operator Senior Reactor operator Health Physics representative User

6 WHAT TO DO IN EMERGENCY?

6.1 What to do in the event of a radiation incident

There are devices for monitoring levels of radioactivity in place throughout the reactor building. The readings from these devices are not only relayed to the reactor control room but are displayed by a system of colored lights on a panel next to each of the devices. The lights indicate the following:

Flashing green light

Normal operations

Flashing yellow light

First threshold exceeded

No immediate danger.

This alarm is relayed to the reactor control room and the Health Physics Duty Officer gives any necessary instruction

Flashing red light + audible alarm

Second threshold exceeded

Danger.

Leave the reactor immediately by the nearest air lock ("Sas")

6.2 What to do in the event of a radiation accident

In the event of an accident, the alarm will be given

BY SIREN

LOUDSPEAKER

by the operator from the control room

The following steps should be taken:

a) The first person who sees any emergency involving radiation exposure that requires evacuation shall immediately trigger the emergency alarm and call Area Supervisor (AS) or Emergency Call Centre (ECC).

b) Use internal landline and call ECC or AS via the extension number below:

ECC's extension number:

1999

03 – 8925 0579

AS extension number:

6144 / 6149

c) Next, extinguish fire if safe to do so (use fire extinguisher or hose reel).

d) The first person who sees any emergency that do not require evacuation shall immediately call AS or ECC.

e) When the emergency siren is activated, immediately stop work and evacuate through the nearest emergency exits in an orderly manner.

Please proceed to the designated assembly point located at the parking lot as showed in the diagram below or the nearest assembly point.

Stay calm and wait for further instructions from the Area Supervisor in charge.

7 WASTE ZONING

The primary objective of waste zone is to ensure that any radioactive waste generated from operation and use of the RTP is disposed of in safe and proper manner so that it will not pose any potential radiation hazard to man and environment. Radioactive wastes are disposed of in accordance with IAEA safety standards.

In order to meet the requirements of these standards, various factors need to be carefully assessed in designing a waste zoning. These factors include the types and characteristics of the waste, suitability and cost of the treatment process and the available options for waste disposal. The signage of radioactive waste is shown in Figure 6.1.

Contact person for inquiry

i. RPO

ii. RPS

Nuclear Malaysia Waste Zones

Block 30 houses the Waste Management Centre while Block 31 sites the treatment plant. Processed wastes are stored in Block 33.

Classification of Radioactive Waste

To allow for easy handling, transportation and enhancement of safety while going through the process of waste management.

Radioactive waste is classified according to:

- *Its physical form (solid, liquid and gaseous);*
- *Its activity (low, medium and high);*
- *Its half-life (short half-life, medium half-life and long half-life); and*
- *Beta-gamma emitters and alpha emitters.*

IAEA classification

- *Exempted Waste-EW*
- *Low Level Waste & Intermediated-Short lived-LILW-SL*
- *Low Level Waste & Intermediated-Long lived-LILW-LL*
- *High Level Waste-HLW*

Solid Waste

cover papers, gloves, empty vials and syringes. Radionuclide generators. Items used by hospitalized patients after radionuclide therapy. Sealed sources used for calibration of instruments. Animal carcasses and other biological waste.

Liquid Waste

Residues of radionuclide, Patient excreta ,Liquid scintillation solutions.

Gaseous Waste

Exhausted gas from patients in nuclear medicine.

Category of solid waste containing beta and gamma emitters based on surface dose rate

Category	Dose Rate, D(mSv/hr)	Note
1	$D<5x10^{-4}$	Exempted waste
2	$5x10^{-4}<D<1.7$	Low level radioactive waste, shielding may required
3	$1.7<D<17.0$	Medium level radioactive waste, shielding required
4	$D>17.0$	High level radioactive waste, shielding and cooling required

Category of solid waste containing beta and gamma emitters based on specific activity

Category	Specific Activity, A(kBq/kg)	Note
1	$A<0.4$	Exempted waste
2	$0.4<A<10$	Very Low level radioactive waste, shielding may required
3	$10<A<1x10^{4}$	Low level radioactive waste, treatment required
4	$A>1x10^{4}$	High level radioactive waste, shielding and cooling required

Category of solid waste containing alpha emitters

Category	Specific Activity, A(kBq/kg)	Note
1	$A<0.4$	Exempted waste
2	$0.4<A<4x10^{3}$	Low level radioactive waste, treatment required
3	$A>1x10^{3}$	Medium and high level radioactive waste, treatment required

Category of solid waste containing alpha emitters

Category	Specific Activity, A(kBq/kg)	Note
1	$A<40$	Exempted waste, treatment not required
2	$40<A<4x10^{4}$	Very Low level radioactive waste, treatment required shielding not required
3	$4x10^{4}<A<4x10^{11}$	Low level radioactive waste, treatment required shielding may required
4	$4x10^{6}<A<4x10^{6}$	Medium level radioactive waste, treatment and shielding required
5	$A<4x10^{11}$	High level radioactive waste, treatment, shielding and cooling required

Category of liquid waste containing alpha emitters

Category	*Specific Activity, A(kBq/kg)*	*Note*
1	*A<1.5*	*Exempted waste, treatment not required*
2	*A>1.5*	*radioactive waste, treatment required*

Category of gaseous radioactive waste

Category	*Specific Activity, A(kBq/kg)*	*Note*
1	*A<3.7*	*Exempted waste, treatment not required*
2	$3.7<A<4x3.7x10^4$	*radioactive waste , treatment required by filtration method*
3	$A>3.7x10^4$	*radioactive waste , treatment required by special method*

6.2 Solid Radioactive Waste

Solid waste generated from operation and use of the RTP is classified as radioactive waste when they contain or are contaminated with radioactive materials in solid form. They include spent ion-exchange resins, air filters, contaminated *clothing, tissues, glassware, etc.*

The dry solid wastes are separated at their origin by the obligation of dropping wastes into suitable separate containers. Separate bins are provided in each controlled rooms of the reactor building for collecting radioactive and ordinary wastes. For short-lived low level radioactive wastes, they are kept in the area for a complete decay, which will then be disposed as ordinary wastes. For other solid radioactive wastes, they are contained in plastic bags and labelled by user/waste producer, then will be verify by KFK and collected by WasTeC for treatment and disposal purposes.

6.3 Liquid Waste

Radioactive liquid wastes may include discarded solution containing radioactive substances or water used for washing of contaminated apparatus, articles and clothing. Based on its chemical nature, liquid waste is classified into organic and aqueous waste. Radioactive waste is also categorized with respect to its activity, namely low and medium/ high-level waste. Transport, treatment and disposal of these wastes are done by WasTeC. They are collected in a pit at the basement of the reactor building and flow down through a pipe by gravity into a collection tank at the Waste Technology Development Centre. The process employed for treatment of liquid waste is chosen based on the above classification as shown in ***Figure 6****.6*

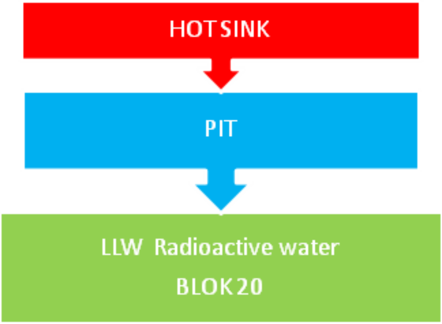


Figure 6.5 Flowchart for Liquid Waste from reactor building

6.4 Gaseous Waste

Airborne waste includes radioactive gases, vapours and particulates. This type of waste originates from volatile radioactive substances, evaporation of radioactive liquids, and production of radioactive gases from reactor operation and from any other activities involving radioactive gases. N-16, Ar-41 and radioiodine are treated before discharging.

6.5 Non radioactive waste

For non-radioactive wastes, they are collected and stored in separate containers by WasTeC for disposal.

Sewerage water system of RTP is divided into two systems and identified based on their roles. First system collects possible radioactive liquid waste, chemical liquid disposals such as acids coming from the reactor building and all hot laboratories. The second system collects the ordinary sewerage coming from toilets and water sinks being free from radioactivity in excess of the natural background.

*The waste treatment building shown in **Figure 6.8** houses the various laboratories and the radioactive waste treatment plant are situated next to it.*

Conclusion

The NUKLEAR MALAYSIA waste zone was established to cater for any nuclear, radiological and conventional waste that might occur in the Bangi Complex of NUKLEAR MALAYSIA and its branch complex in Dengkil (Dengkil Complex). This waste zone is to provide proper waste storage to protect workers, the general public and the environment.

Rujukan

(NM.SP.W.03- Prosedur Pengurusan Sisa Radioaktif).