Radiation Hazard Evaluation and Control, Radiation Emergency Preparedness & Regulatory Requirements

DR.P.K.DASH SHARMA
dashsharma@aerb.gov.in

RADIOLOGICAL SAFETY DIVISION
ATOMIC ENERGY REGULATORY BOARD
NIYAMAK BHAVAN, ANUSHAKTINAGAR
MUMBAI-400094
What is in the presentation

- Radiotherapy facilities in India
- Hazard Evaluation & Control
- Emergency preparedness
- Regulatory System in India
## Radiotherapy Facilities in India

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiotherapy Centres</strong></td>
<td>336</td>
</tr>
<tr>
<td><strong>Teletherapy Facilities</strong></td>
<td>499</td>
</tr>
<tr>
<td>- Telecobalt Units</td>
<td>231</td>
</tr>
<tr>
<td>- Linear Accelerators</td>
<td>253</td>
</tr>
<tr>
<td>- Gamma Knife</td>
<td>8</td>
</tr>
<tr>
<td>- Tomotherapy</td>
<td>3</td>
</tr>
<tr>
<td>- CyberKnife</td>
<td>4</td>
</tr>
<tr>
<td><strong>Brachytherapy Facilities</strong></td>
<td>350</td>
</tr>
<tr>
<td>- Remote Afterloading Units (HDR/MDR/LDR)</td>
<td>221</td>
</tr>
<tr>
<td>- Manual Afterloading kits (Cs-137)</td>
<td>61</td>
</tr>
<tr>
<td>- Manual Afterloading Interstitial Implants (Ir-192)</td>
<td>20</td>
</tr>
<tr>
<td>- Brachy facilities using Sr-90, I-125, Ru-106</td>
<td>48</td>
</tr>
</tbody>
</table>

Dr. P. K. Dash Sharma, RSD, AERB
Medical Electron Accelerators

X-ray: 4 MV-18 MV
Electron: 4 MeV-20 MeV
Total units: 253
Tomotherapy

X-ray: 6 MV

Total units: 3
Cyberknife

X-ray: 6 MV

Total units: 4
Telecobalt unit

Co-60 : 8000 Ci – 15000 Ci

Total units: 231
Gamma-knife Unit

Co-60 : 200 sources

Total activity
~ 6000 Ci

Total units: 8
RAL Brachytherapy Unit

Ir-192 : Single 10 Ci
Co-60 : Single 2 Ci

Total units: 221

Cs-137: Multiple sources
10-40 mCi each
Ir-192 : Multiple sources
5-40 mCi each
MAL (LDR) Brachytherapy sources

Intracavitary application
Cs-137: Multiple sources (10-40 mCi each)
Facilities: 61

Ocular therapy
I-125
Sr-90
Ru-106
Facilities: 48

Interstitial Implants
Ir-192: Multiple sources (8 mCi – 40 mCi)
Facilities: 20
Intra-operative Brachytherapy Unit

X-ray: 50 kV, 40 µA

Total units: 2
Simulator

X-ray: 125 kV

Total units: 150
RADIAION PROTECTION

- To prevent deterministic effects
- To reduce the probability of stochastic risk at an acceptable level
## DOSE LIMITS

<table>
<thead>
<tr>
<th>Part of the body</th>
<th>Occupational Exposure</th>
<th>Public Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body (Effective dose)</td>
<td>20 mSv/year averaged over 5 consecutive years; 30 mSv in any single year</td>
<td>1 mSv/y</td>
</tr>
<tr>
<td>Lens of eyes (Equivalent dose)</td>
<td>150 mSv in a year</td>
<td>15 mSv/y</td>
</tr>
<tr>
<td>Skin (Equivalent dose)</td>
<td>500 mSv in a year</td>
<td>50 mSv/y</td>
</tr>
<tr>
<td>Extremities (Hands and Feet, Equivalent dose)</td>
<td>500 mSv in a year</td>
<td>-</td>
</tr>
</tbody>
</table>
External Radiation Dose

Gamma, beta or neutron radiation emitted by radioactive material outside the body exposing the skin, lens of the eye, extremities & the whole body (i.e. internal organs)
Internal Radiation Dose

Alpha, beta or gamma radiation emitted by radioactive material inside the body exposing internal organs such as:

- Thyroid
- Bone
- Lung
- GI System
Adult Occupational Dose Limits

Whole Body (everything except extremities)
30 mSv maximum per year
20 mSv averaged over 5 years

Skin of the Whole Body
500 mSv per year

Extremities
500 mSv per year

Lens
150 mSv
Public Dose Limits

Whole Body (everything except extremities)
1 mSv per year

Skin of the Whole Body
50 mSv per year

Extremities
50 mSv per year

Lens
15 mSv
Exposure to Radiation Dose

If a life threatening dose (50% probability) is illustrated by the height of the Eiffel tower (over 300 meters), the dose limit for occupational (radiation) workers corresponds to the height of a man (2 meters) and the limit for the public to the thickness of a brick (0.1 meters).

Life threatening dose – more than 3000 mSv

Radiation illness – Passing Symptoms

No symptoms, temporary changes in blood picture (A Skyscraper)

No detectable effects (A House)

Limit for the Occupational Worker (A Man)

Limit for the public (A Brick)

Dr. P. K. Dash Sharma, RSD, AERB
# Comparison of Risk

<table>
<thead>
<tr>
<th>Accident type</th>
<th>Individual risk/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicle</td>
<td>1 in 4 000</td>
</tr>
<tr>
<td>Fires</td>
<td>1 in 25 000</td>
</tr>
<tr>
<td>Air travel</td>
<td>1 in 100 000</td>
</tr>
<tr>
<td>Electrocution</td>
<td>1 in 160 000</td>
</tr>
<tr>
<td>Lightning</td>
<td>1 in 2 000 000</td>
</tr>
<tr>
<td>Radiation Industry</td>
<td>1 in 5 000 000 000</td>
</tr>
</tbody>
</table>
## Average annual exposures

<table>
<thead>
<tr>
<th>Practice</th>
<th>Average annual dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial radiography</td>
<td>0.9</td>
</tr>
<tr>
<td>Nucleonic gauges</td>
<td>0.13</td>
</tr>
<tr>
<td>Gamma irradiators</td>
<td>not significant</td>
</tr>
<tr>
<td>Teletherapy</td>
<td>0.55</td>
</tr>
<tr>
<td>Brachytherapy</td>
<td>0.49</td>
</tr>
<tr>
<td>Nuclear medicine</td>
<td>0.54</td>
</tr>
<tr>
<td>Diagnostic radiology</td>
<td>0.49</td>
</tr>
</tbody>
</table>
Basic Safety Objective

- Protection of occupational workers, patient, public and environment
- ALARA during normal operations
- Radiation exposure during normal operations with in relevant dose limits
- Potential exposures and the magnitude of such exposures are kept ALARA
Basic Radiation Protection Techniques

- For External Hazards:
  I. Time
  II. Distance
  III. Shielding

- For Internal Hazards:
  I. Contamination control
Reduce Time

Time Relationship

Exposure rate = 1 mR/hr \times Time = Total Exposure

1 hour = 1 mR
2 hours = 2 mR
Less time = Less radiation exposure

Use Radioactive Material only when necessary

Dry runs (without radioactive material)
   Identify portions of the experiment that can be altered in order to decrease exposure times

Shorten time when near Radioactive Material

Obtaining higher doses in order to get an experiment done quicker is NOT “reasonable”!
Increase Distance

Distance Effect

Inverse Square Law

12,000 mR/hr
at 1 cm from source

4.8 mR/hr

d = 50 cm
Effect of Distance on Dose Rate

25 mrem/hr @ 6 ft  100 mrem/hr @ 3 ft
Distance

- Effective & Easy
- Inverse Square Law
  - Doubling distance from source, decreases dose by factor of four
  - Tripling it decreases dose nine-fold
- More Distance = Less Radiation Exposure
- Tongs, Tweezers, Pipettes, Pliers
Use Shielding

Shielding
Shielding

- Materials “absorb” radiation
- Proper shielding = Less Radiation Exposure
Shielding

- **Alpha Emitters** ($^{238}\text{U}, \, ^{230}\text{Th}, \, ^{241}\text{Am}, \, ^{222}\text{Rn}$)
  - Paper

- **Low Energy Beta Emitters** ($^{3}\text{H}, \, ^{14}\text{C}, \, ^{35}\text{S}, \, ^{33}\text{P}$)
  - Paper

- **Medium / High Energy Beta Emitters** ($^{32}\text{P}$)
  - Plastic

- **X-ray & γ-ray Emitters** ($^{60}\text{Co}, \, ^{137}\text{Cs}, \, ^{192}\text{I}, \, ^{125}\text{I}$)
  - Lead, concrete, steel, etc.

- **Neutron Sources (Accelerators, Reactors, Am/Be)**
  - Water, plastic, paraffin, etc.
Emergency Preparedness

- Availability of Devices and Survey Meter for handling emergency and display of procedure to be followed
  - In control room of telecobalt/RAL Brachytherapy unit
  - In source handling area of manual brachytherapy
- Emergency situations include
  - failure of source movement mechanism of telegamma and remote after-loading brachytherapy equipment
  - loss of source in manual brachytherapy
Preparation of Emergency Action Plan

- Foreseeable emergencies, include
  - Radioactive source failing to return to the safe shielding position
  - Dislodge/loss/theft of radioactive source during use, storage, transport, loss of shielding
  - Natural calamities such as fire, flood, or earthquake
  - Death of patient, with sources *in situ*
  - Selection of wrong treatment mode
  - Selection of wrong beam modifiers and wrong dose delivery.
Emergency Handling and Reporting

- Display of Emergency Procedures
- Ensure that all workers are familiar with the emergency action plan
- Release of dead body containing sources, after removal and monitoring by RSO
- Report to licensee/employer immediately and to the competent authority within 24 hours
- Lodge written complaint with police in case of loss or theft of radioactive sources, if not traced within 24 hours.
Reporting of emergency/unusual occurrences/accidental medical exposures

- Investigation report on emergency to be submitted to AERB which includes
  (i) any equipment failure, accident, mishap, miscalculation or other unusual occurrence with the potential for causing a patient dose significantly different from that intended, and
  (ii) any therapeutic treatment delivered to either the wrong patient, or the wrong tissue, or using wrong source, or with a dose or dose fractionation differing substantially from the value prescribed by the radiation oncologist, or that may lead to undue acute secondary effects.
WHAT IS REGULATION?

- **Regulation** refers to “controlling human or societal behavior by rules or restrictions”
- **Costs** for some and **benefits** for others
- Efficient where the total benefits to some people exceed the total costs to others
- Regulatory agencies deal in regulation or rulemaking and enforcing rules and regulations for the **benefit of the public at large**
System of Regulatory Control

Issued by Central Government

- Act
  (Atomic Energy Act, 1962)

- Rules

- Notifications
  (Radiation Surveillance Procedures for Medical Applications of Radiation, 1989)

Published by AERB

- Safety Codes

- Safety Standards

- Safety Guides

- Safety Manuals

Dr. P. K. Dash Sharma, RSD, AERB
Radiation Safety

Total Radiation Safety is achieved by

Built-in Safety

combined with

Operational Safety
Built-in Radiation Safety

- **Sealed Source – Classification**
  (safety of worker and public)

- **Equipment – Type-approval**
  Electrical, Mechanical, Radiological
  (safety of rad. worker and patient)
Built-in Radiation Safety

- **Installation – Plan Approval**
  Thick concrete walls, maze
  (safety of rad. worker, public and patients’ relatives)

- **Transport Package – Package approval**
  (safety of worker, public)
Operational Safety

Components of operational safety

- Qualified and certified persons
- Work place monitoring
- Personnel monitoring
- Safe and secure storage place
- Preventive maintenance of equipment
- Interaction with regulatory body
- Emergency planning and preparedness
Operational Safety

- Qualified and certified persons
  (Radiation Oncologist, Medical Physicist, Radiation Therapy Technologist)

- Personnel monitoring
Operational Safety

- **Work place monitoring**
  - (Gamma Zone Monitor)
  - (Switches, Interlocks, Indicators)

- **Preventive maintenance**
Radiation Symbol

- Radiation symbol to be posted at:
  - Entrance of treatment room
  - Entrance of the controlled and supervised areas
- A legend in Hindi, English and Local language indicating radiation hazard

For Telegamma/Brachytherapy facility

For Linac/Simulator or facility
Control measures adopted in India

- **Pre-licensing stage**
  - Design Approval of Room layout
  - Approval for procurement of source
  - Commissioning approval
  - Licence for operation
- **During the useful life**
  - Information for any change in working condition
  - Radiation safety report
  - Reporting incidents or accidents
- **Post use**
  - Approval for Decommissioning/Disposal
Clearance of the unit by AERB

- Prior to procurement, verify whether the unit is
  - Type Approved by AERB
  - If no, NOC from AERB
- Demand for the copy of the certificate issued by AERB from supplier
- No unit shall be purchased if the supplier has not obtained ‘Type Approval’ or ‘NOC’
Approval of Room Layout Plan

- Submission to AERB for design approval
- **Not to construct without obtaining approval**
- No modification to be carried out without concurrence of AERB
Appointment of Staff

- Appoint adequate number of qualified staff as stipulated in AERB safety code
  - Radiation Oncologists — min. one per unit
  - Medical Physicists — min. one per unit
  - Radiological Safety Officer — (nominate Medical Physicist, if eligible, to perform additional responsibility)
  - Radiotherapy Technologists — min. two per unit
Appointment of Staff

- Appoint adequate number of qualified staff as stipulated in AERB safety code
  - Radiation Oncologists – min. one per unit
  - Medical Physicists – min. one per unit
  - Radiological Safety Officer – (nominate Medical Physicist, if eligible, to perform additional responsibility)
  - Radiotherapy Technologists – min. two per unit
Procurement of Equipments

- Personnel Monitoring Badges from the agency recognised by AERB for all the radiation workers

- Pocket dosimeters for the radiation workers may also be procured
Procurement of Equipments (contd...)

- Appropriate Monitoring equipment (survey meter, contamination monitor, gamma zone monitor [auto/manual] etc.)

- Appropriate Measuring equipment (RFA, SSD with thimble /parallel plate/well type chamber etc.)
Procurement of other associated equipments

- **TPS**
- **Simulator**
- **CT-Simulator**
- **Beam modifiers**
- **Moulds**
- **QA test tools**
Obtain authorisation from RSD, AERB for **procurement of sources**

Issued based on availability of
- adequate no. of qualified manpower
- personnel monitoring badges for staff
- approved and constructed room for source
- radiation monitoring equipments
- dosimetric equipments
- minimum required QA tools

Dr. P. K. Dash Sharma, RSD, AERB
Receipt of Sources and Installation

- Intimate regarding the receipt of the source
- Install the unit
- Source transfer, in case of telecobalt unit, to be supervised by authorised Medical Physicist
Acceptance test & Commissioning

- Acceptance tests to be carried out including survey
- Permission to be obtained from AERB for using the unit for the patient treatment
- The unit shall not be used for the patient treatment without obtaining the permission
Licences for operation

Radiotherapy is the only practice, in which all category of licences to be issued as per RPR-2004

- **Licence** – Operation of Telegamma & Accelerators
- **Authorisation** – Operation of Brachytherapy
- **Registration** – Operation of Therapy Simulator

- **Consent** – Approval for
  - siting, design, construction
  - commissioning
  - decommissioning
  - sealed sources, radiation generating equipment
  - Equipment containing radioactive sources
  - package design for transport
  - shipment approval for radioactive consignments
Periodic Performance/ Status Report

- Performance tests of the unit, integrity check of the sources, Survey of the installations to be carried out periodically
- Maintenance of records, to be produced during inspection
- Submission of annual safety status report by the end of each calendar year
- Reporting incidents or accidents within 24 hrs.
Decommissioning/Disposal of sources

- Decommissioning of the unit and disposal of sources with due approval
  - Disposal of radioactive materials
  - Segregation and disposal of Depleted Uranium and Contamination part
  - Verification to ensure no radioactivity in the equipment
  - Deform the equipment before handing over to scrap dealer so that it can not be reassembled

- Transport of sources as per the transport regulation for radioactive material
Availability of forms and procedures

- All regulatory forms and procedures are available at our website

www.aerb.gov.in

- Various other regulatory documents are also available in this website
THANK YOU

Any container bearing this symbol probably houses a radioactive material.