

Monitoring methods

External: Absorbed dose is measured using TLD (Thermoluminescence Dosimeters), OSLD (Optically Stimulated Luminescence Dosimeters), DRD (Direct Reading Dosimeters) and digital dosimeters

Internal: Internal exposure is assessed using whole body counting (in vivo) and urine/faecal/breath sample analysis (in vitro) by estimating retained radionuclides in the body. Secondary limits such as Annual Limit on Intake (ALI) (eg., ALI of tritiated water = 1×10^9 Bq) and Derived Air Concentration (DAC) are used to control the internal exposure. Radiation workers without any protective gear working in an air borne radiation area of 1 DAC-hr for 2000 hrs (1 ALI intake), receive an annual dose of 20 mSv.

Contamination: Contamination monitoring is carried out using radiation contamination monitors capable of detecting, β and radiation in cps m^{-2} or cpm m^{-2}

Biodosimetry: Dicentric chromosomal aberration analysis is used for any suspected over exposure cases to confirm genuineness of exposure and quantify the dose.

Applications of radiation

Industries: Radiation and radio-isotopes are extensively used in applications such as nucleonic gauges, industrial radiography, radiotracers, X-ray baggage scanning, etc.

Agriculture: High intensity radiation sources are used in developing new strains of food crops and plants that give better yield and improved quality.

Medicine: Nuclear imaging techniques (using radioisotopes), diagnostic applications using X-rays and CT, radiation therapy for cancer treatment and sterilization of medical products. Most of the isotopes used for the benefit of mankind are produced in nuclear reactors.

Nuclear Power Plants (NPPs) produce electricity without polluting the environment.

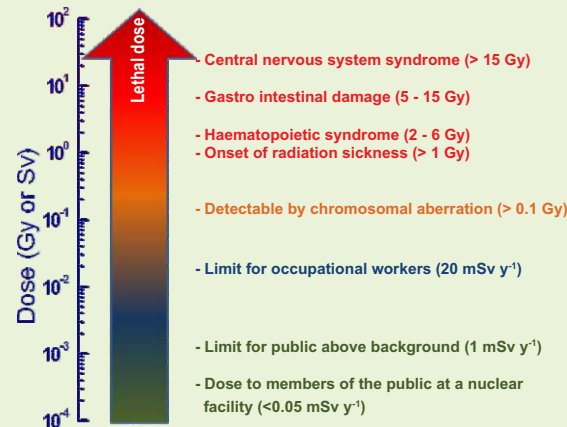
Food preservation: Food products are irradiated to increase shelf-life as it helps in sprout inhibition, insect dis-infestation and pathogen control.

Consumer goods: Smoke detectors containing tiny alpha-emitting radiation source are installed for the detection of smoke and fire protection.

Effects of radiation

Health effects are not observed for doses below 100 mSv. Epidemiological studies on radiation workers and people living in high background radiation area even exposed for lifetime have not shown any increase in the incidence of cancer and genetic effects. Ionizing radiations are known to cause health effects at acute high doses.

As a safety precaution, principle of ALARA (As Low As Reasonably Achievable) along with dose limitation and justification of practices are followed in nuclear facilities to



minimize radiation exposure to occupational workers and public.

Summary

- Radiation is to be dealt with care, not fear
- Radiological safety is ensured in nuclear facilities, discharges to the environment are kept much below the regulatory limits. The annual effective dose to members of the public is less than 0.05 mSv (< 5% of the limit) compared to the regulatory limit of 1 mSv
- Nuclear facilities are designed and operated ensuring safety of workers as well as public. The engineered safety features, containment and emergency preparedness are to ensure negligible additional risk due to radiation, even under accidental situations
- Food products such as potato, onion, mango etc, irradiated with radiation, are not radioactive, have longer shelf life and are safe for human consumption
- Sensitive radiation monitors installed at nuclear facilities ensure prevention of inadvertent movement of radioactive materials. Radiation workers also check themselves for contamination before leaving their facilities.
- It is to be noted that natural cancers are observed in population all over the world irrespective of their proximity to nuclear facility or high background radiation area.

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INDIAN ASSOCIATION FOR
RADIATION PROTECTION

INFORMATION ON RADIATION AND RADIOLOGICAL SAFETY

Issued by IARP for awareness of employees and public

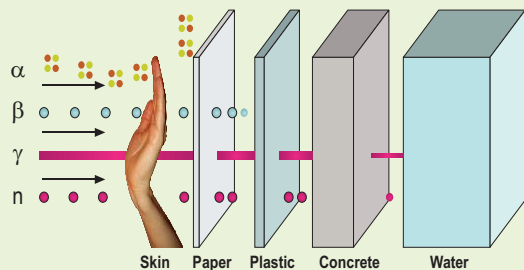
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Basic principles of ionizing radiation

Time immemorial, radiation has become an inseparable part of the life. Besides the natural radiation sources, there are man-made sources of radiation, which include radioisotopes, X-ray units, nuclear reactors, reprocessing plants and accelerators.

Alpha (α), beta (β), gamma (γ), X-ray and neutrons are classified as ionizing radiation because of their ability to induce ionization in media they interact with. Microwaves, radio-waves and ultraviolet rays are classified as non-ionizing radiation.

Ionizing radiation are known for their penetrating power with large degree of variation. Penetration power increases with increase in energy for a given type of radiation. α and β particles can be completely stopped with a small thickness of absorbing material (shield), while X and γ rays require larger thickness of shielding.



Radiation monitors are required to detect and quantify ionizing radiation. Exposure to radiation can be minimized by spending less time, keeping distance and use of appropriate shielding between source and person.

Radiation units

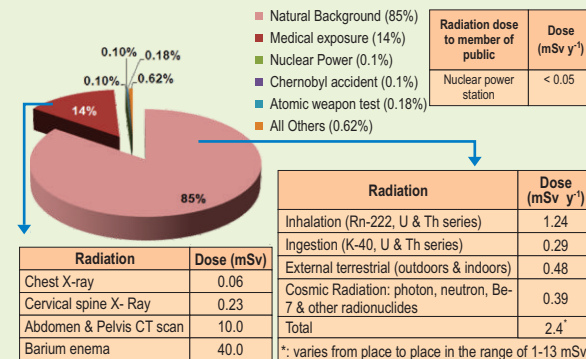
Radiation and radiation emitting isotopes are quantified with following units.

Quantity	Definition	Unit Symbol
Activity	becquerel = 1 disintegration per sec	Bq*
	curie = 3.7×10^{10} Bq (activity of 1 g of ^{226}Ra)	Ci
Specific activity	Activity per unit mass of substance	Bq kg ⁻¹ * or Ci g ⁻¹
Exposure	Exposure unit = 1 coulomb kg ⁻¹	C kg ⁻¹ *
	roentgen = 1esu of charge produced in 1 cc (0.001293 g) of air at STP	R
Absorbed dose	gray = 1 J kg ⁻¹	Gy*
	rad = 100 erg g ⁻¹ (100 rad = 1 gray)	rad
Dose rate	Dose per unit time	Gy h ⁻¹
Equivalent dose	sievert (J kg ⁻¹) = Absorbed dose x Radiation weighting factor (w_R) $w_R=1$ for β and ; 20 for α	Sv*
	roentgen equivalent man (100 rem = 1 Sv)	rem
Effective dose	sievert = Equivalent dose x Tissue weighting factor (w_T)	Sv*
Fluence	Number of particles cm ⁻²	cm ⁻²
Flux	Number of particles cm ⁻² s ⁻¹	cm ⁻² s ⁻¹

* SI unit

Natural radiation

Composition of total radiation dose to the population



- Human beings and biota are continuously exposed to ionizing radiation from natural radioactivity
- The natural sources of radiation are ^{238}U , ^{232}Th and their daughter products, ^{40}K and cosmogenic radionuclides like ^{14}C and ^3H
- A person weighing 70 kg contains about 4500 Bq of ^{40}K (emits 1.46 MeV γ and 1.33 MeV β), which gives self an effective dose of 0.16 mSv y⁻¹ (1 g of K = 31 Bq of ^{40}K)
- In addition, human body also contains other natural radionuclides like ^{238}U (1 Bq), ^{226}Ra (2 Bq), ^{210}Po (18 Bq), ^{232}Th (0.1 Bq) etc.
- Intake of ^{40}K through food consumption is about 100 Bq per day for an adult person, which maintains the ^{40}K under equilibrium
- Some of the dietary sources rich in ^{40}K are milk (~ 20 Bq L⁻¹), green leafy vegetables (~ 100 Bq kg⁻¹), banana (~ 15 Bq per piece)
- Consumption of one banana every day will lead to 0.04 mSv per annum
- Normal ambient background dose rate is about 0.1 $\mu\text{Gy h}^{-1}$. The natural ambient gamma dose rates in High Background Radiation Area (HBRA) of the world are: some

parts of Kerala (2 $\mu\text{Gy h}^{-1}$), Ramsar, Iran (4 $\mu\text{Gy h}^{-1}$), Guarapari, Brazil (5 $\mu\text{Gy h}^{-1}$)

- Some of the residents of these HBRA receive doses more than the annual dose limit for radiation workers (20 mSv y⁻¹)
- A pilot of airlines receives about 2 μGy during an hour of flight due to cosmic radiation.

Caution symbols



Symbol used to indicate radioactive source or radiation area



Symbol used to indicate intense radioactive source, usually on the source housing

Dose limits

Dose limits set by Atomic Energy Regulatory Board (AERB) based on the recommendations of International Commission of Radiological Protection (ICRP) are:

Type of limit	Occupational workers (18-65y)	Apprentices (16-18y)	General public (all ages)
Whole body exposure (Effective dose)			
Annual dose limit	100 mSv in 5 years [†] : Average 20 mSv y ⁻¹ with a maximum of 30 mSv in a year	6 mSv in a year	1 mSv in a year
For parts of the body/extremities (Equivalent dose)			
Lens of the eye	150 mSv	50 mSv	15 mSv
Skin[‡]	500 mSv	150 mSv	50 mSv
Hands and feet	500 mSv	150 mSv	50 mSv

Sum of the dose received in the year of assessment and sum of doses in previous four years should not exceed 100 mSv.

† For skin, not more than 1 cm² area is considered for averaging while for hands and feet, not more than 150 cm² area is considered. Dose limits to extremities are to avoid possible deterministic effects.