IDM Subject Code : CHM 2042

Nuclear
Disaster Management

NUCLEAR HAZARDS/ NUCLEAR POLLUTION

Topic to be discussed

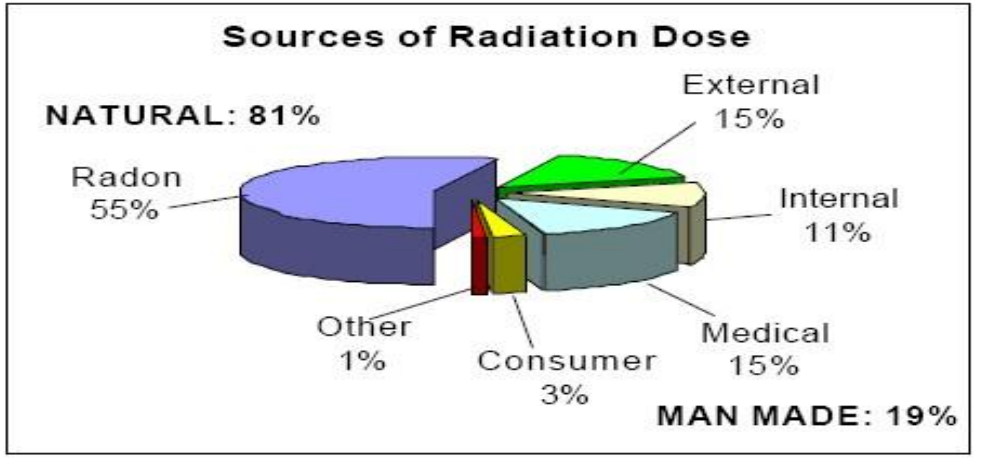
- Introduction
- Sources of radio active pollution
- Nuclear energy, fission and fusion process
- Safety of Nuclear Plants
- Types of radiation
- Pathways Of Exposure to Human
- Effects of Ionizing Radiation on living system
- Some example of nuclear pollution and their consequences
- Control measure to nuclear pollution
- Conclusion

Radioactive Pollution

It is a invisible energy of wave (radiation) or particles pollute air and water; example alfa, beta, gama particle

- *One of the most important and dangerous type of pollution is nuclear pollution.*
- *Nuclear pollution is produced by nuclear explosion which are carried out for performing nuclear tests.*
- *Produced by generation of energy by nuclear fission or nuclear fusion.*

Sources of nuclear pollution



Sources of Nuclear Pollution

NATURAL SOURCES

- Cosmic rays from outer space.
- Emissions from radioactive materials in the earth's crust (rocks, marine sediments etc.)

MAN-MADE SOURCES

- Mining and processing of radioactive ores
- Use of radioactive materials in power plants
- Use of radioactive isotopes in medical technology (x-ray machines, radioisotopes used in medicine)
- Industrial applications include wastes from nuclear reactors
- Research applications: radioactive fallouts during nuclear weapons testing.
- In a nuclear power plant, any leak or accident taking place emit nuclear radiation.
- Nuclear tests conducted under the ground or under oceans which also release radiation.
- Uranium mining and milling, Nuclear reactors and reprocessing of nuclear fuel cause nuclear pollution

- **Natural sources (81%)** include radon (55%), external (cosmic, terrestrial), and internal (K-40, C-14, etc.)
- **Man-made sources (19%)** include medical (diagnostic x-rays- 11%, nuclear medicine- 4%),

Causes of Nuclear disaster

- Nuclear power plant accidents
- Nuclear reactor attacks
- Trafficking and thefts
- Worldwide nuclear weapon testing
- **Political issues** like war, nuclear power aspirations,
- fight between countries to become super power

Example: disaster events such as Hiroshima nuclear explosion, Syrian civil war, growing militarization of oceans and outer space.

Categories of nuclear accidents

- Nuclear reactor meltdown
- Criticality accidents
- Decay heat
- Transport
- Equipment failure
- Human error
- Lost source

Nuclear reactions

Nuclear disaster is due to meltdown of nuclear reactor plant and release of massive amount of radiation and radioactive materials into the environment .

It is a type of explosion deriving its force from nuclear reactions- fission and fusion .

It may be due to human error, system failure, earthquake, cyclone, flood etc.

Nuclear energy

Nuclear Fission:

- Nuclear energy is known for its high destructive power as evidenced from nuclear weapons.

Nuclear Fission: In this example, a stray neutron strikes an atom of U235. It absorbs the neutron and becomes an unstable atom of U-236. It then undergoes fission. These neutrons can strike other U-235 atoms to initiate their fission

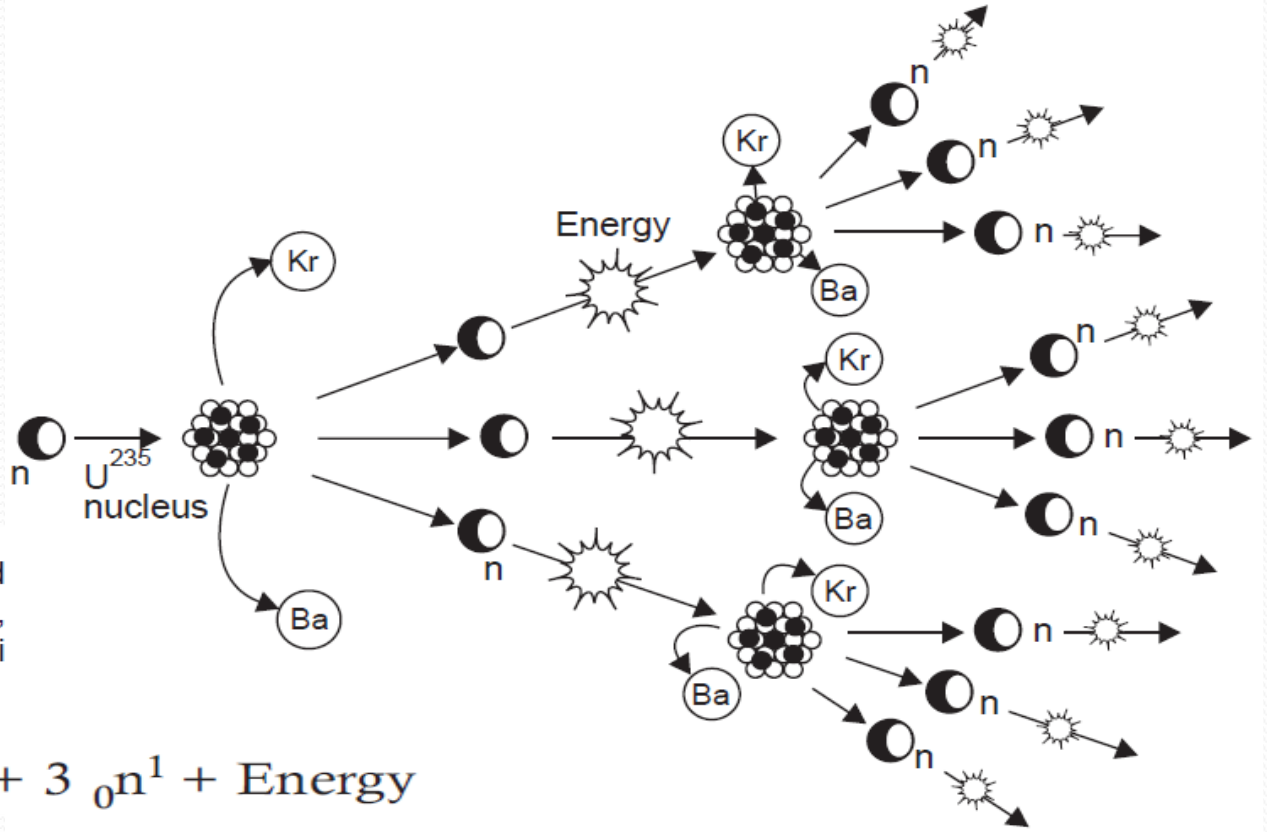
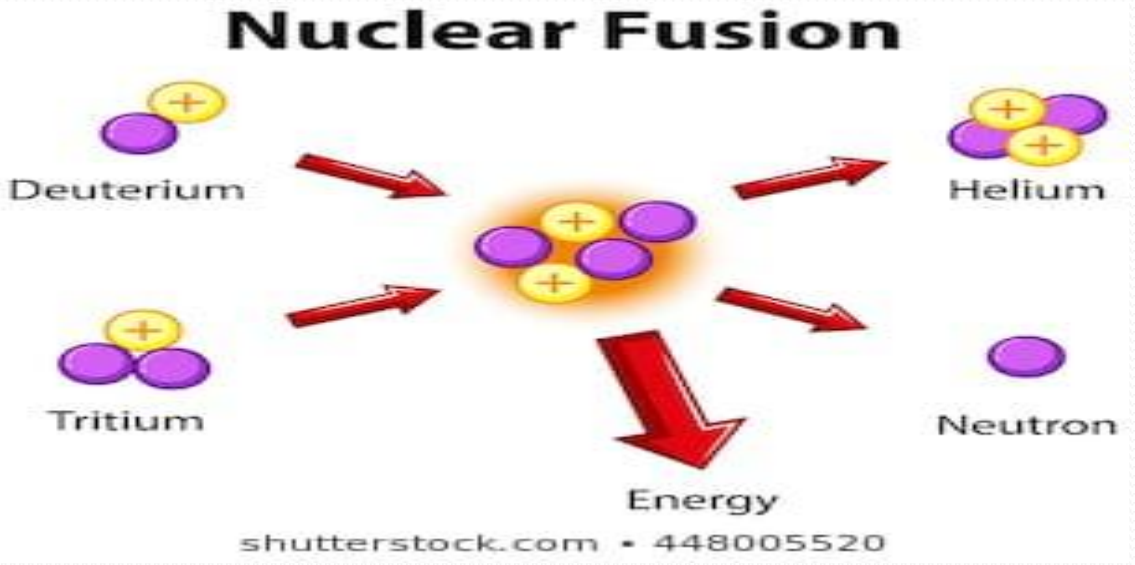


Fig. 2.5.7. (*a*) Nuclear fission—a chain reaction initiated by one neutron that bombards a Uranium (U^{235}) nucleus, releasing a huge quantity of energy, two smaller nuclei (Ba, Kr) and 3 neutrons.

$$_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{36}Kr^{92} + {}_{56}Ba^{141} + 3\ {}_{0}n^{1} + \text{Energy}$$

Nuclear fusion

(ii) **Nuclear fusion:** Here two isotopes of a light element are forced together at extremely high temperatures (1 billion °C) until they fuse to form a heavier nucleus releasing enormous energy in the process. 0.42Mev



$$_1H^2 + {}_1H^2 \longrightarrow {}_3He^2 + {}_0n^1 + \text{Energy}$$

One neutron and a huge amount of energy.

$E = MC^2$

$1.674927471\times10^{-27}$ X $(3X10^8)^2$

Fig. 2.5.7. (*b*) Nuclear fusion reaction between two hydrogen-2 nuclei, which take place at a very high temperature of 1 billion °C; one neutron and one fusion nucleus of helium-3 is formed along with a huge amount of energy.

It is difficult to initiate the process but it releases more energy than nuclear fission.

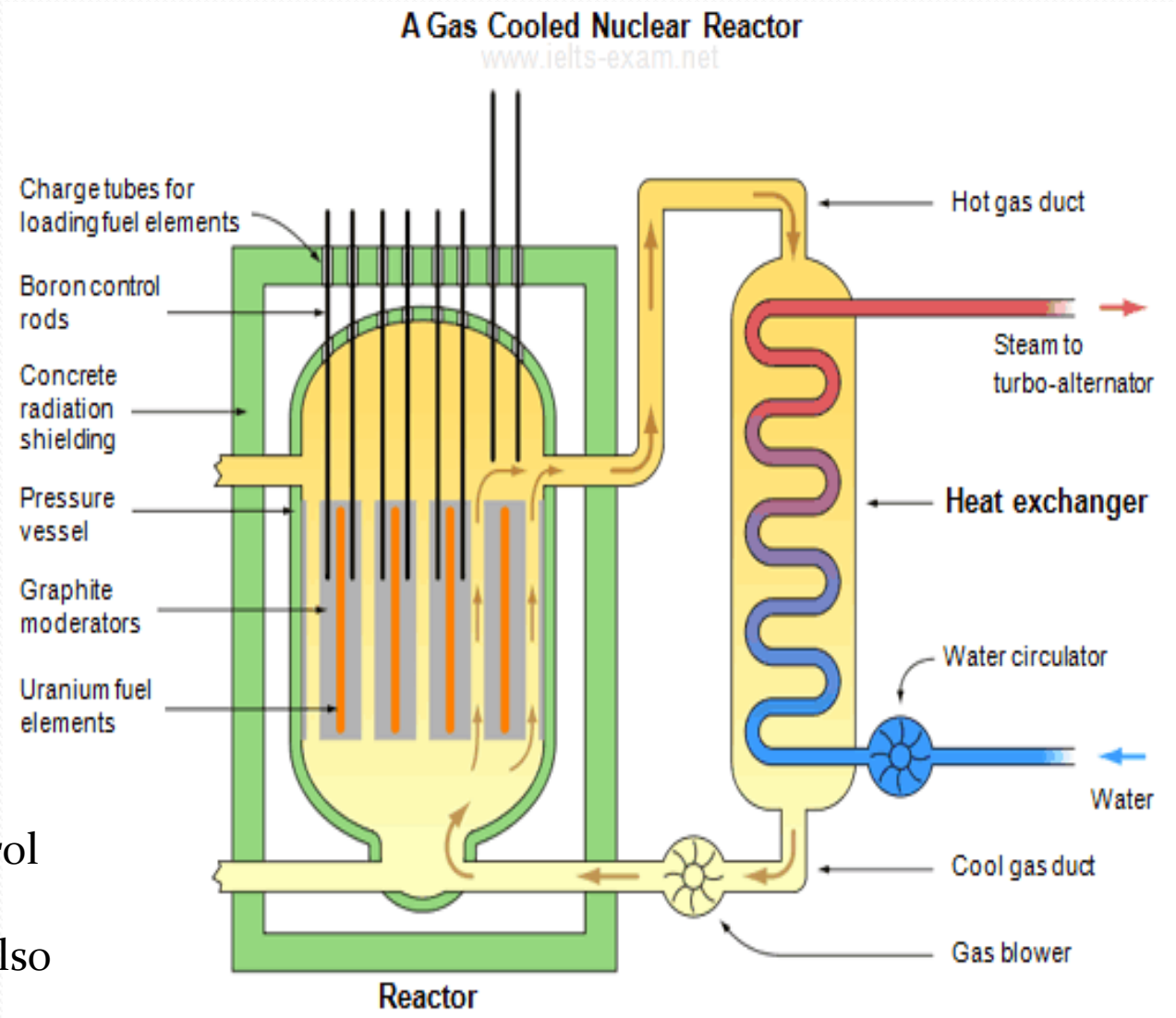
There are four nuclear power stations with an installed capacity of 2005 MW.
These are located at Tarapur (Maharashtra), Rana Pratap Sagar near Kota (Rajasthan), Kalpakkam (Tamil Nadu) and Narora (U.P.).

Nuclear reactor

- If each neutron releases two more neutrons, then the number of fissions doubles each generation. In that case, in 10 generations there are 1,024 fissions and in 80 generations about 6 x 10 ^{23} (a mole) fissions.
- A nuclear reactor is a device in which nuclear chain reactions are initiated, controlled, and sustained at a steady rate,

Nuclear bomb, in which the chain reaction occurs in a fraction of a second and is uncontrolled causing an explosion.

Graphite: slow down the newtron and controller is to control the number of neutron
Boron: capable of absorbing many neutrons and control fission
Lead: molten lead or lead-bismuth eutectic coolant also absorb alfa, beta and gamma radiation



Nuclear reactor meltdown

Nuclear disasters are usually associated with reactor meltdowns.

A core **meltdown** accident occurs when the heat generated by a **nuclear reactor** exceeds the heat removed by the cooling systems

If the core continues to heat, the steel wall of the core would melt.

In a complete reactor meltdown, the temperature may exceed 2700° C

Safety of Nuclear Plants

- Steel-reinforced concrete and a dome-shaped containment buildings surround all US reactors (inner wall several feet thick and outer wall at least 15 inches thick)
- Designed to withstand hurricanes, earthquakes, high winds
- Reactors have detectors to quickly shut down in event of tremor (about 20% are in regions with seismic activity like Pacific Rim)
- In considering safety, must address…
    - Faults in plant design
    - Human error
    - Risks associated with terrorism/political instability

Types of Radiation

- 2)Man-made Radiation:These are the radiations which induce the ionisation of atoms and molecules.
- Ionisation of a molecule produces two fragments.

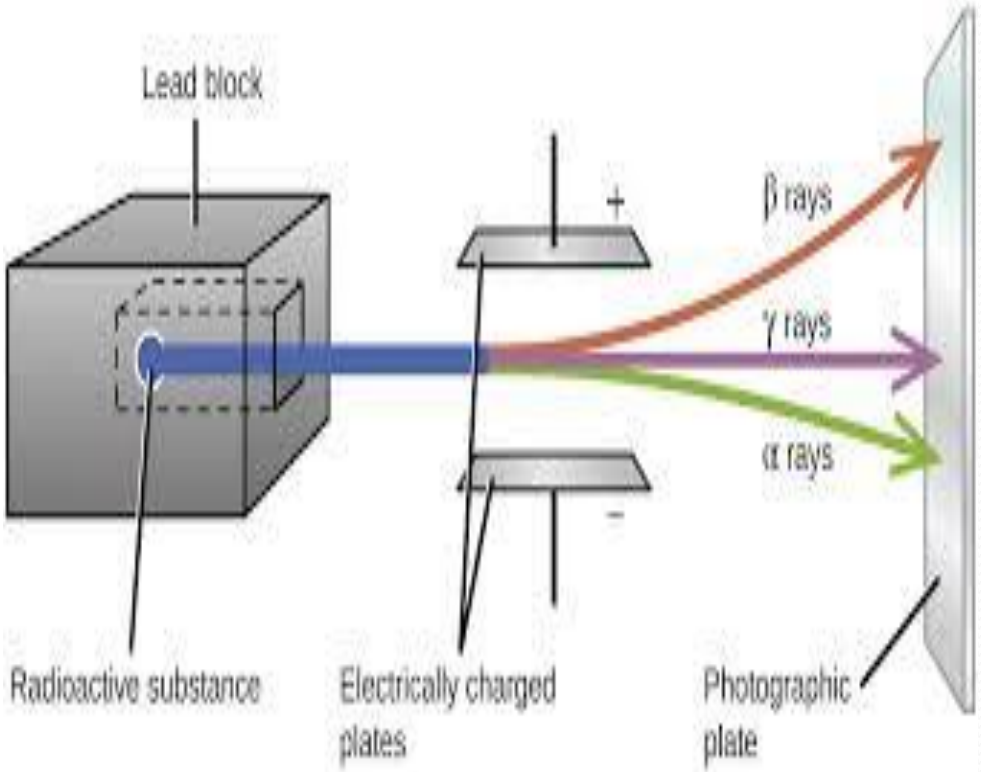
Eg:

Alpha (α) Radiation: Alpha radiation contains energetic - alpha particles.

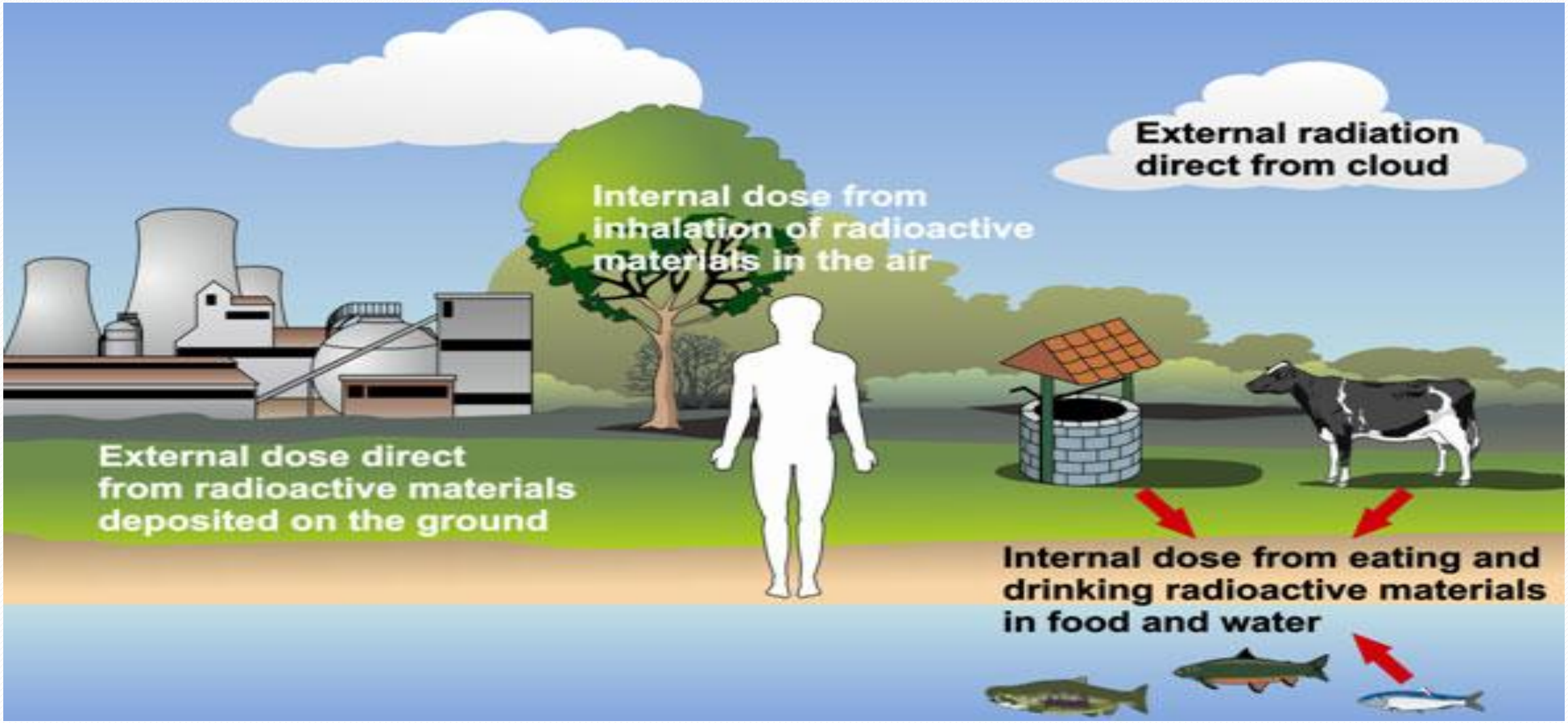
It carries two units of positive charges and strongly interact with living tissues.

beta (β) Radiation: Is made up of energetics electrons. It carries one unit of negative charge and interacts strongly with matter.

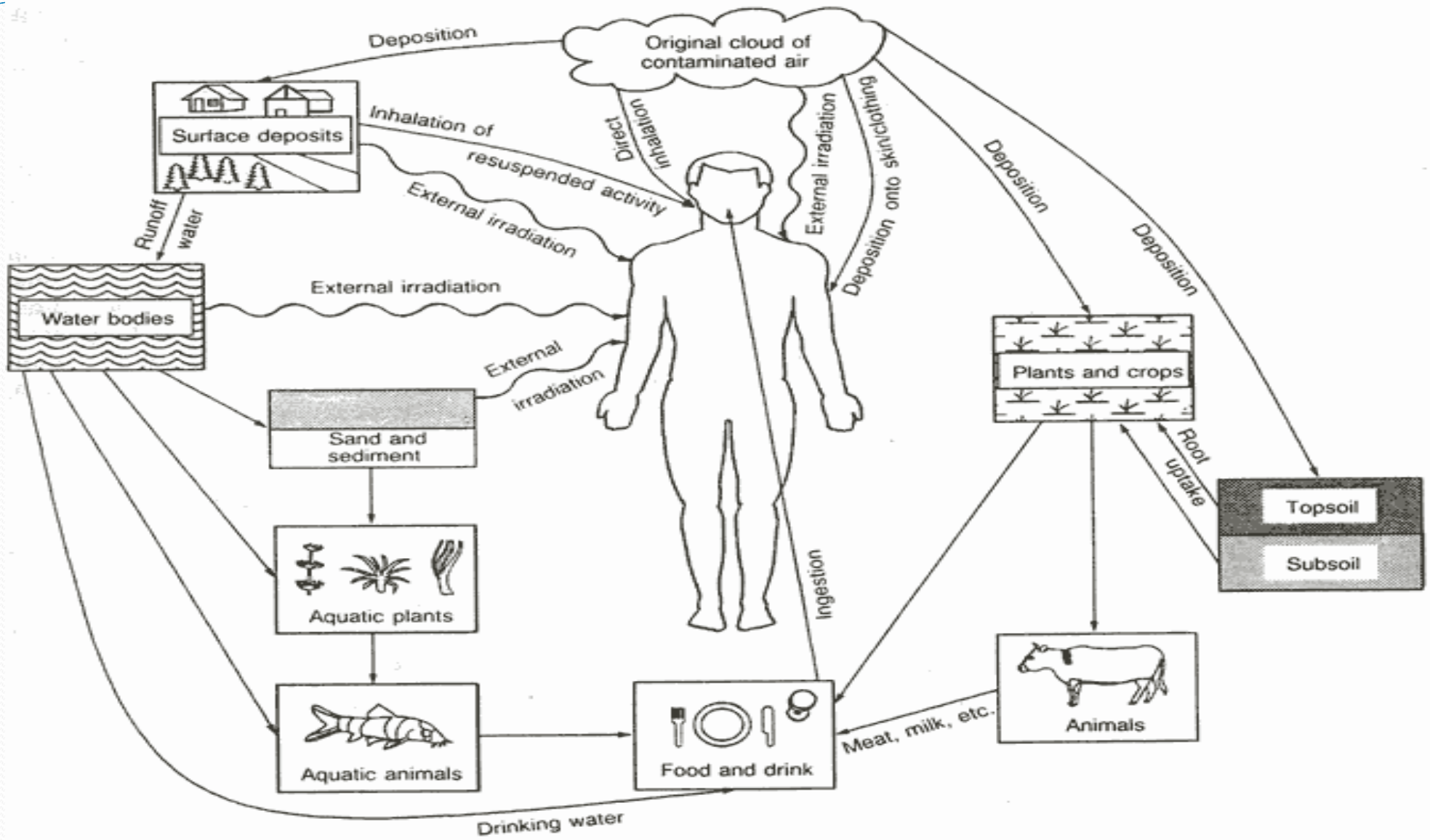
gamma (γ) Radiation: Gamma radiations are made up of high energy photons. Photons bring about strong electro-magnetic interaction with matter.



Pathways Of Exposure to Human



Pathway of Human radiation exposure



Main environmental pathways of human radiation exposure

Effects of Ionizing Radiation on living system

- Ionizing radiation has sufficient energy to knock bound elections out of an atom or molecule
- Includes alpha/beta particles and gamma/x-rays
- Can form highly reactive **free radicals** with unpaired electrons
  - For example, $H_2O \rightarrow [H_2O\cdot] + e^-$
- Rapidly dividing cells in the human body are particularly susceptible to damage by free radicals
  - Radiation can be used to treat certain cancers and Graves disease of the thyroid
  - However, ionizing radiation can also damage healthy cells
  - Biological damage determined by radiation dose, type of radiation, rate of delivery, and type of tissue

Effects of nuclear pollution on animals

Radiation effects can be **somatic or genetic**.

1. SOMATIC EFFECTS:

Somatic effects the function of cells and organs. It causes damages to cell membranes, mitochondria and cell nuclei resulting in abnormal cell functions, cell division, growth and death.

Effects on Humans:

- *1)Skin Diseases*
- *2)Damage of Reproductive Organs*
- *3)Causes of Abnormality in Bone Marrow*
- *4)Destroys Retina of Eyes*
- *5)Shortening of Life Span*

2. GENETIC EFFECTS:

Genetic effects the future generations. Radiations can cause mutations, which are changes in genetic makeup of cells. These effects are mainly due to the damages to DNA molecules. People suffer from blood cancer and bone cancer if exposed to doses around 100 to 1000 roentgens. Instantaneous deaths on exposure in the event if disasters are many.

Effects on Plants

- *Green plants are extremely sensitive to gamma rays.*
- *Plants response varies according to age, growth stage, plant species, chromosome volume and level of radiation.*

Effects on Animals:

- *It may include tumor, dry, itchy skin, hair loss and discoloration of the skin around the tumor site.*
- *In addition, these particular tumors often release a disagreeable odour as the cancerous cells die.*
- *More serious side effects may include some nerve damage and either the death or hardening (called fibrosis) of healthy tissue.*

SOME LIVE EXAMPLES OF "NUCLEAR POLLUTION"

Chernobyl Accident- April 26, 1986

- World's worst nuclear power plant accident
- Chernobyl in Ukraine on Pripyat River
- Combination of design and operator error during electrical power safety check resulted in cascade of events leading to core breach of Reactor 4 with subsequent chemical (not nuclear) explosion

Chernobyl Accident

- Flow of coolant water interrupted, insufficient
- Graphite used to slow neutrons in reactor caught fire. Water sprayed on graphite, resulting in hydrogen gas formation- chemical combustion reaction and explosion
  - $2H_2O(l) + C(graphite) \rightarrow 2\ H_2(g) + CO_2(g)$
  - $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$
- Large amount of radioactive fission products dispersed into atmosphere for 10 days (about 100X greater than Hiroshima/Nagasaki)
- 150,000 people in 60 km radius permanently evacuated
- several workers immediately, about 30 firefighters/emergency workers from acute radiation exposure, and a smaller # from subacute effects (overall, about 60 deaths)
- About 250 million people exposed to radiation levels which may reduce lifespan

Chernobyl Accident

•Surrounding farmland (1000 square miles) not farmable due to high Cs-137 (exception, one small area in Belarus)

• High levels of Cs-137 found down wind in reindeer meat in Scandinavia

• Contamination effects on plants/animals within 30 km

• Contamination of nearby water bodies and fish

In both the Fukushima and the 1986 Chernobyl accidents, volatile iodine species were released into the environment with tellurium

Iodine has highest fission yield, it effects the Thyroid gland.

Chernobyl Accident

- Initial radiation released primarily I-131 (half life= 8 days), later Cs-137 (half life= 30 years)
- Children particularly susceptible to I-131. Thyroid takes up I^- to produce the hormone thyroxine (T4, growth/metabolism).
  - I-131 decays by beta emission with accompanying gamma ray
  - If ingested, can cause thyroid cancer
  - About 4000 cases of thyroid cancer in exposed children (2000), nine related deaths in this group

http://www.world-nuclear.org/info/chernobyl/info07.htm

Chernobyl Accident

•Preliminary evidence (2006) suggests increased risk of leukemia and possibly other cancers in "liquidator" group and others with higher exposure in the first year- "Among some 600,000 workers exposed in the first year, the possible increase in cancer deaths due to this radiation exposure might be up to a few percent."

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The Fukushima Daichi Disaster

The aftermath

The Fukushima Disaster

On **March 11th 2011** a huge earthquake
caused the cooling of the reactors and the cooling of the spent fuel pools of the Fukushima Daiichi nuclear plants to fail.
A non-stoppable nuclear disaster unveiled.
The release of radioactive material occurred through pressure relief, uncontrolled release of radioactive steam, fires, explosions and leakage and seepage of hundreds of thousands of litres of contaminated water.
Contrary to the Chernobyl disaster (1986) this disaster happened in **multiple reactors** at once – and **it is still ongoing.**

Release and dissemination for radioactive materials

first six weeks of the disaster **42%** of the total amount of **cesium** that was released.

After the explosions also radioactive strontium (up to 250 kilometres from the plants) and plutonium (up to 45 kilometres from the plants) are measured, in addition to iodine and caesium.

Particularly high levels of radiation are measured in the soil outside the 30-km (evacuation) zone. Large parts of Japan are contaminated for at least 300 years) with cesium, mainly in the northeast.

Around 164,000 people were evacuated from the area around the damaged reactors

workers nearly 2000 were found to be contaminated with a radiation dose above 100 mSv – a dose which causes radiation related diseases. Six workers were contaminated with doses from 309 mSv to 678 mSv.

Photograph of Hiroshima and Nagasaki

People who escaped from the hell on the Earth

The Huge Atomic Cloud / The Mushroom Cloud Blowing Up

Shiroyama Primary School Leveled By The Blast

Control and Measures

- *Proper maintenance of nuclear plants.*
- *Preventive nuclear experiments.*
- *Safe Transportation.*
- *Ban usage of nuclear weapons.*
- *Proper Storage.*
- *Minimize use of nuclear elements.*
- *Extraction of radioactive elements from nuclear waste.*
- *Laboratory generated nuclear wastes should be disposed off safely and scientifically.*

Management of Radioactive Waste

- The radioactive waste which comes out from industry, nuclear reactors should be stored and allowed to decay either naturally in closed drums or in very large underground air tight cemented tanks (Delay and Decay).
- The intermediate radioactive waste should be disposed off into the environment after diluting it with some inert materials (Dilute and Disperse)
- Now-a-days small quantities of high activity wastes are converted into solids such as concrete and then it is buried underground or sea. (Concentrate and contain)

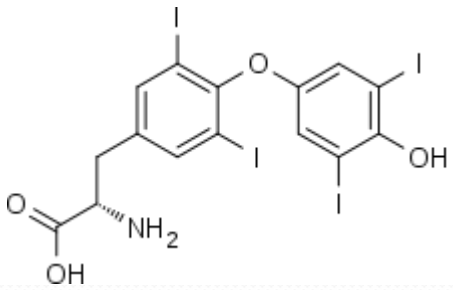
Nuclear disaster mitigation measures

- Stabilize the electricity supply system
- Store spent fuel in dry casks
- Install filtered vent systems
- Nuclear reactors must be enclosed in broad concrete walls to prevent the radiation from emerging out
- Workers should wear protective garments and glass spectacles
- Extreme care should be exercised in the disposal of industrial waste contaminated with radionuclides
- Prevent sabotage at nuclear facilities
- Ratify a treaty to prohibit military attacks

Natural ways to mitigate radiation damage

- Use of potassium iodide tablets available from local drugstore are to be distributed to the people living nearby nuclear facilities .

- This stable form of iodine, which is used by the thyroid gland to produce necessary hormones for metabolism and fatal brain development can protect the thyroid gland from radioactive 131.



KI (**potassium iodide**) is a salt of stable (not **radioactive**) **iodine** that can help block **radioactive iodine** from being absorbed by the thyroid gland, thus protecting this gland from **radiation** injury.

Responses

(Instructions issued by Department of Atomic Energy,) Govt. of India

Dos:

- Go indoors. Stay inside. Close doors/windows
- Switch on radio/TV and look out for public announcement from your local authority
- Cover all food, water and consume only such covered items
- If in the open, cover your face and body with a wet handkerchief/towel. Return home. Have a complete wash and use fresh clothing
- Extend full cooperation with local authorities and obey their instructions.

- **Don’ts:**
- Do not panic
- Do not spread and/or believe in rumours
- Do not go outside
- Avoid water from open well/ponds, exposed crops and vegetables
- Do not disobey any instruction of the district or civil defence authority who are working tirelessly to ensure safety of yourself, your family and property.

Action taken during or immediately after disaster (Crisis management)

- Evacuation, search and rescue, saving lives and identification of dead
- Meeting basic needs of the survivor, ie. Shelter, hospitalization, food and water, personal hygiene, sanitation etc.
- Activating public warning systems
- Rehabilitation and reconstruction of damaged infrastructure

Post disaster recovery plans

- Resilience after a nuclear power plant or other radiation emergency requires response and recovery activities that are appropriately safe, timely, effective, and well organized.
- Use of high-level scientific, medical, communication, and policy expertise
- Health and medical issues are given the central role.
- Restoration of physical, environmental, economic and social stability
- Removal and disposal of contaminated material in sealed underwater cask before transporting the containers to a storage building.

- Today there are about 440 nuclear power reactors operating in 31 countries, meeting 16% of the world's electricity needs, with contribution in some countries ranging from 20% to 70%. As on date, 17 power reactors and five research reactors are in operation in India, six power reactors are under construction, and plans exist to set up thorium-based reactors to meet the ever-increasing energy needs.

International Day for the Total Elimination of Nuclear Weapons: 5 worst nuclear disasters

Nuclear weapons have destroyed more than any other man-made disaster. The International Day for the Total Elimination of Nuclear Weapons is celebrated every year on **September 26** to bring to attention what disasters nuclear weapons are capable of.

Most of us only know of the nuclear bombings at Hiroshima and Nagasaki during World War II and the devastating humanitarian consequences of the use of nuclear weapons.

Let us know about the five worst nuclear disasters in the history of mankind:

1. Hiroshima and Nagasaki:

Two nuclear weapons have been exploded by the United States during the World War II, 1945.

The first event occurred on the morning of **August 6, 1945**, on the Japanese city of Hiroshima.

The second event occurred three days later on the city of Nagasaki.

2. Chernobyl:

The worst nuclear accident in history, that occurred on **April 26, 1986** at the Chernobyl Nuclear Power Plant in Ukraine**.**

3. Fukushima:

The nuclear disaster at the Fukushima Nuclear Power Plant began on **March 11, 2011** and resulted in a meltdown of three of the plant's six nuclear reactors.

4. Three Mile Island:

The Three Mile Island accident was a partial nuclear meltdown that occurred on **March 28, 1979** in one of the two Three Mile Island nuclear reactors in Dauphin County, Pennsylvania, United States.

The first Nuclear test in India

Smiling Buddha (Pokhran-I) was the assigned code name of India's first successful nuclear bomb test on **18 May 1974**. The bomb was detonated on the army base **Pokhran Test Range** (PTR), in Rajasthan, by the Indian Army under the supervision of several key Indian generals.

Conclusion

For Radiation, like other aspects of nuclear science, can be both destructive and beneficial.

The intelligent use of radiation for the treatment of cancer, medical diagnosis, food preservation, and other useful applications requires an informed public.

Likewise, the solutions to the storage of nuclear waste also necessitate public understanding of the effects of nuclear radiation.

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