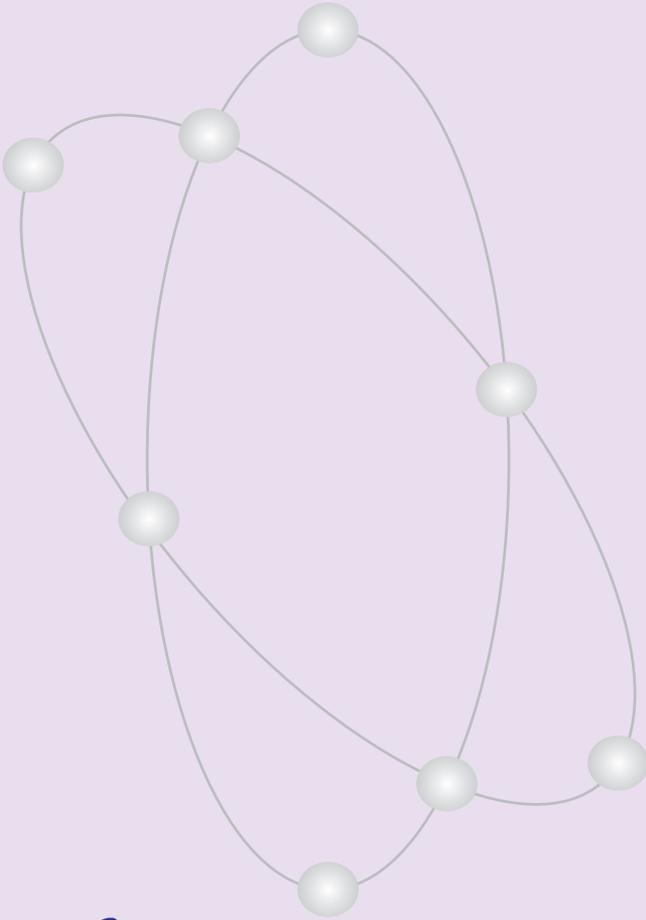


# FACT SHEET ON RADIOLOGICAL SAFETY AND ENVIRONMENT



एनपीसीआईएल  
NPCIL

**NUCLEAR POWER CORPORATION OF INDIA LIMITED**





**FACT SHEET  
ON  
RADIOLOGICAL SAFETY  
AND  
ENVIRONMENT**



एनपीसीआईएल  
NPCIL

**NUCLEAR POWER CORPORATION OF INDIA LIMITED**





TAPS 1&2



RAPS 1&2



MAPS 1&2

**INTRODUCTION:**

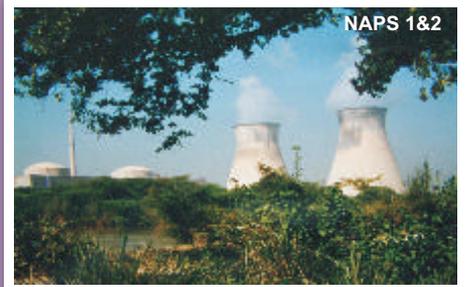
Nuclear Power Corporation of India Limited (NPCIL) is a public sector undertaking under the administrative control of Department of Atomic Energy (DAE), Government of India. NPCIL was formed in the year 1987.

Tarapur Atomic Power Station with twin boiling water reactors (BWRs) of 160 Mwe each, is the first nuclear power station in Asia outside erstwhile USSR.

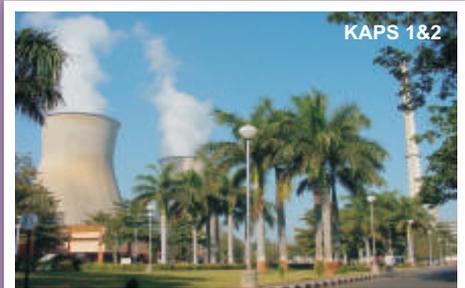
In India, first Pressurised Heavy Water Reactors (PHWRs) were set up with Canadian collaboration at Rawatbhata near Kota, Rajasthan in 1971.

Two more PHWRs were commissioned at Kalpakkam, Tamil Nadu in 1983 with greater indigenous content.

The nuclear reactors commissioned at Narora — NAPS-1&2 (Uttar Pradesh), Kakrapar — KAPS-1&2 (Gujarat), Kaiga — KGS-1 to 4 (Karnataka), Tarapur — TAPS-3&4 (Maharashtra) and Rawatbhata — RAPS-3to6 (Rajasthan) are indigenous design of international standard.



NAPS 1&2



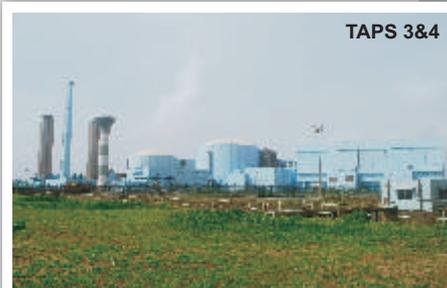
KAPS 1&2



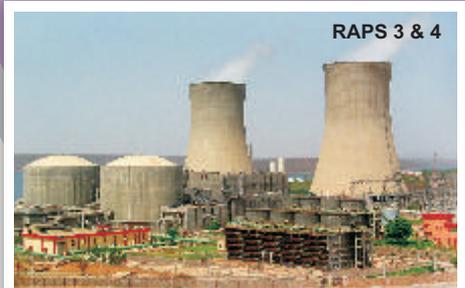
KAIGA 1, 2 & 3, 4



RAPS 5&6



TAPS 3&4



RAPS 3 & 4

The present total installed nuclear capacity of NPCIL is 4780 MWe with 20 units in operation.

TAPS-1	BWR	160	Tarapur (Maharashtra)	28/10/1969
TAPS-2	BWR	160		28/10/1969
TAPS-3	PHWR	540		18/08/2006
TAPS-4	PHWR	540		12/09/2005
RAPS-1	PHWR	100	Rawatbhata (Rajasthan)	16/12/1973
RAPS-2	PHWR	200		01/04/1981
RAPS-3	PHWR	220		01/06/2000
RAPS-4	PHWR	220		23/12/2000
RAPP-5	PHWR	220		04/02/2010
RAPP-6	PHWR	220		31/03/2010
MAPS-1	PHWR	220	Kalpakkum (Tamil Nadu)	27/01/1984
MAPS-2	PHWR	220		21/03/1986
NAPS-1	PHWR	220	Narora (U.P.)	01/01/1991
NAPS-2	PHWR	220		01/07/1992
KAPS-1	PHWR	220	Kakrapar (Gujarat)	06/05/1993
KAPS-2	PHWR	220		01/09/1995
Kaiga-1	PHWR	220	Kaiga (Karnataka)	16/11/2000
Kaiga-2	PHWR	220		16/03/2000
Kaiga-3	PHWR	220		16/04/2007
Kaiga-4	PHWR	220		20/01/2011

KKNPP unit -1 has attained the criticality on 13 July 2013 and unit -2 is under advance stage of commissioning.

The projects at different stages of construction/commissioning — KKNPP-1&2 (at Kudankulam, Tamil Nadu), and KAPP 3&4 (at Kakrapar, Gujarat) — are shown below:



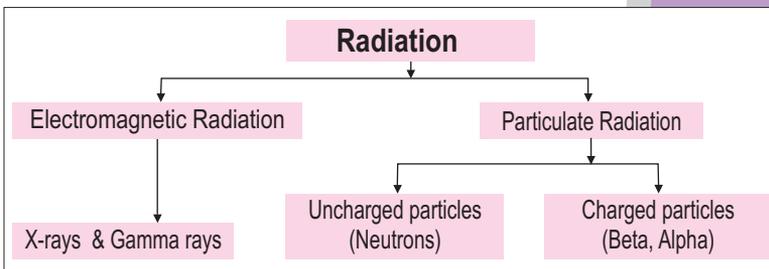
KKNPP 1&2



KAPP 3&4

**RADIOACTIVITY AND RADIATION:**

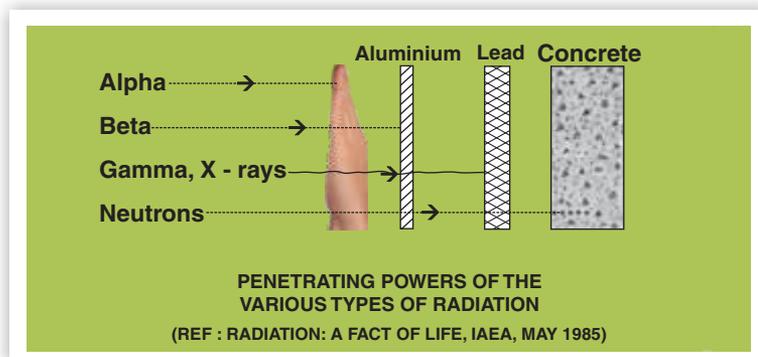
Every element is made up of atoms. An atom consists of protons, neutrons and electrons. Protons and neutrons together form the nucleus of atom surrounded by electrons in orbits. In a stable nucleus, the number of protons and neutrons are balanced and bound together by nuclear forces so strong that no nucleon can escape. But when the number of neutrons is out of balance, the nucleus became unstable and possesses excess energy which may be released in the form of stream of particles or electromagnetic waves along with stream of particles. This release of energy particle is called radiation and the process of emission is called radioactivity. The unit of radioactivity is Becquerel (Bq), which denotes disintegration per second. The types of radiation are alpha, beta, gamma and neutrons. Their properties like mass, charge, range in air and relative penetration power, are shown in the table and figure below. Half-life is the time in which the activity of a radioactive mentioned reduces to ½ of its original value. Half-life may vary for various radionuclide from a fraction of a second to billions of years. Radiation exposure causes energy absorption in the medium, which is termed as absorbed dose. The unit of absorbed dose is Gray (Gy), which is 1 Joule/kg.



**Characteristics of Nuclear radiation**

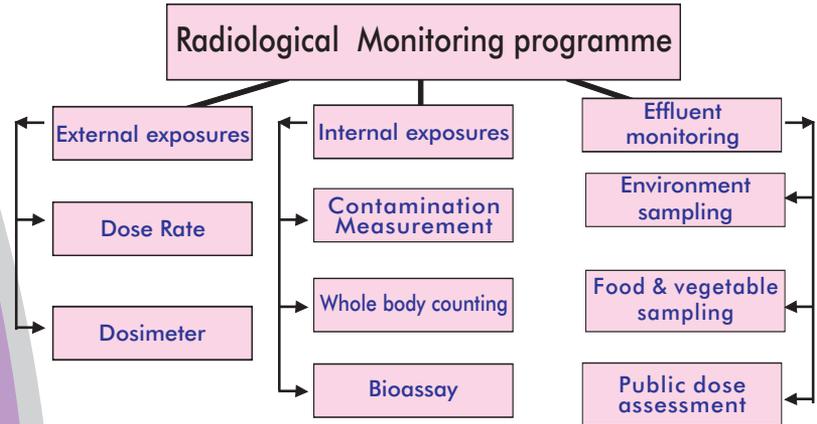
Radiation / Symbol	Relative Mass & Charge	Range in Air	Suitable Shielding
Alpha ( $\alpha$ )	4 amu      (++)	few cms	Paper.
Beta ( $\beta$ )	Mass of electron is Negligible (-)	few meters	Plastic or Aluminium
Gamma ( $\gamma$ )	Electromagnetic Radiation, No Charge.	Very large	Lead, Water or Concrete
Neutron ( $n^0$ )	1 amu. No Charge	Very large	Cadmium or Boron for slow neutrons and Paraffin followed by Cadmium or Boron for fast neutrons.

1 amu. (Atomic Mass Unit) =  $1.66 \times 10^{-27}$  Kg



**RADIOLOGICAL MONITORING PROGRAMME:**

Radiological monitoring programme has been implemented at all power plants to minimise the external exposure (source of radiation is outside the body) and internal exposure (source of radiation is inside the body) for plant workers and public in the neighbourhood.



**EXTERNAL DOSE RATE MONITORING INSTRUMENTS:**

**Geiger Muller (GM) survey meter: (Range 0-20mGy/h)**

This is a low-range gamma and beta radiation monitoring equipment. Area ambient radiation levels and equipment radiation levels are monitored by this.



**Teletector: (Range 0-10Gy/h)**

This telescope-type radiation monitoring equipment used to monitor equipment and locations showing high radiation dose rate.



**Target Identifier**

This is a hand held, digital gamma spectrometer. It includes a NaI detector plus & GM tube for high gamma dose rate measurement. It has a range of 0-1000mSv/hr.



**PERSONEL DOSE MONITORING DEVICES:**

**Gamma and Beta radiation monitoring devices:**

1. Direct reading dosimeter (DRD)
2. Thermo-Luminescent Dosimeter (TLD)
3. Electronic Personnel Dosimeter.



**Neutron Monitoring Devices:**

1. Neutron film badge (Columbia Resin-CR-39)

**Internal Dose Monitoring Set-up:**

Measurement of internal dose includes direct and indirect methods. Direct method employs whole-body counting, where the radioactivity inside the body is detected/counted by sensitive instruments. Indirect method relates radioactivity content of biological samples like urine, faeces, breath, etc. with body content by appropriate metabolic model termed as bioassay.



**OCCUPATIONAL DOSE LIMITS:**

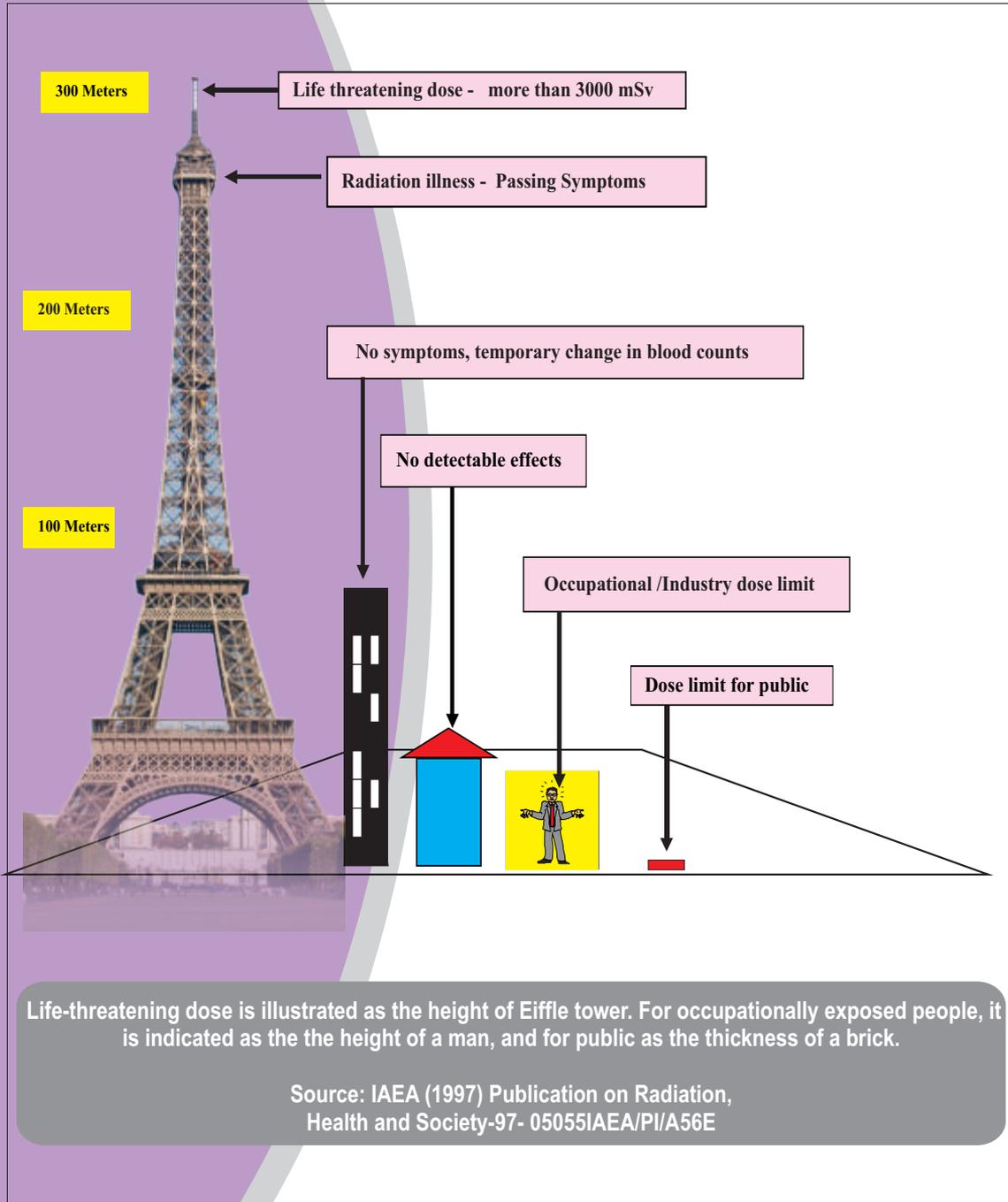
The Atomic Energy Regulatory Board (AERB) prescribes the occupational dose limits. The limits of effective dose for occupational exposure are the sum of effective doses from external and internal sources in the same period. A calendar year is used for dose limitation purpose.

The occupational exposure of any worker is so controlled that the following limits are not exceeded.

Category	Life Time Effective Dose Limit (Sv)	Dose Constraints		Annual Equivalent Dose Limits			Intake
		For Medical Review (Sv)	Annual Dose (mSv)	Lens of Eye (mSv)	Skin (mSv)	Extremities (mSv)	
Radiation Workers	1.0	0.5	30 (100 mSv in 5 years)	150	500	500	1 ALI*
Apprentices & Trainee	-	-	6	50	150	150	30% of ALI
Temporary Workers	-	-	15	75	250	250	-
Member of Public	-	-	1	15	50	-	-

\* ALI - Annual Limit on Intake

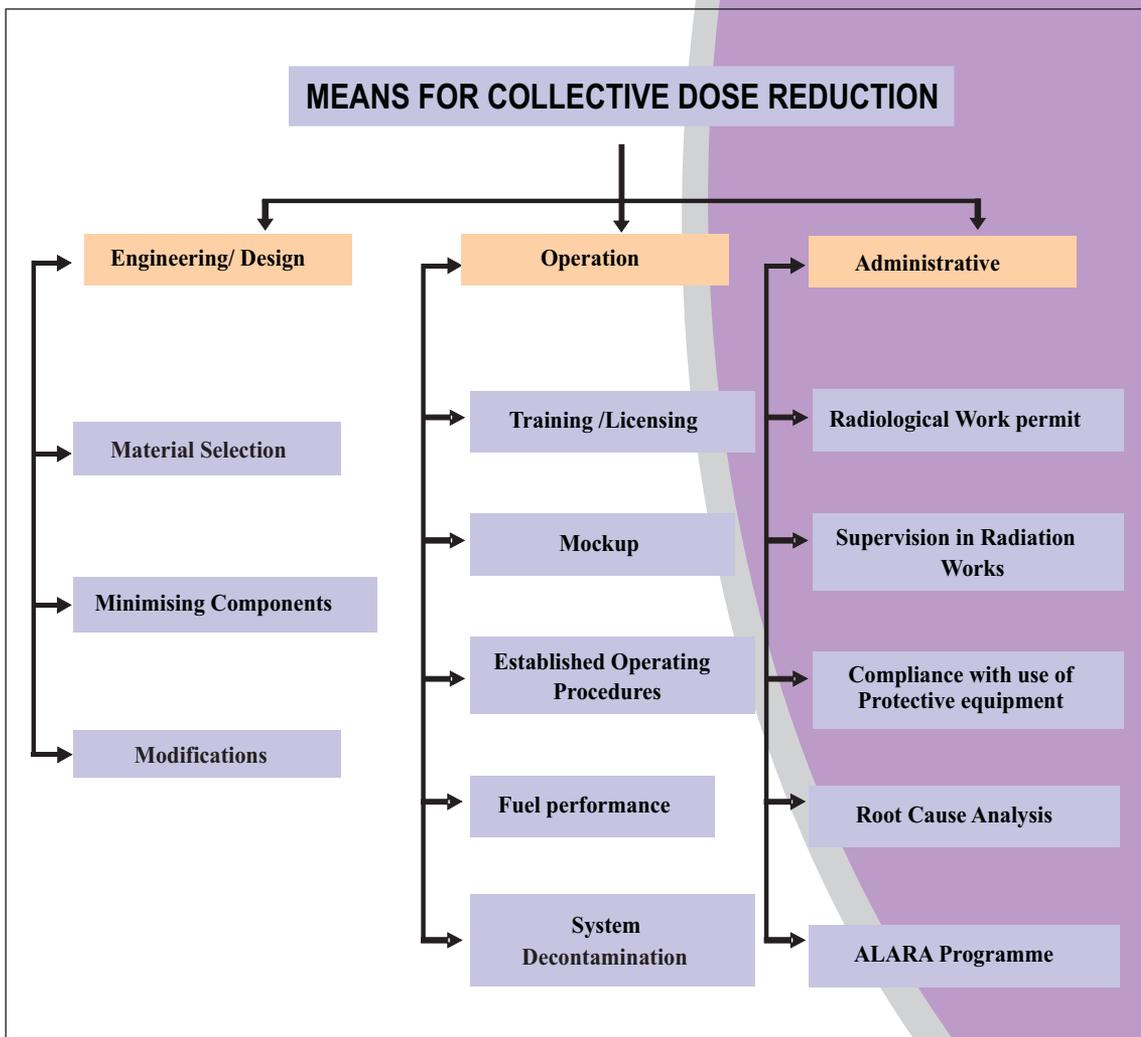
**RADIATION DOSE - A PERSPECTIVE:**



**MANAGEMENT OF COLLECTIVE DOSE:**

Collective dose is the sum of individual doses for a group /section/station. It is a performance indicator to control the total dose. The exposure of each worker is restricted and controlled by an online-Dose Management System (DMS) integrated with Computerised Maintenance Management System (CMMS).

Dose management software is used by Health Physics units at sites for managing the individual dose records and controlling the exposure. To integrate the DMS of individual units, a new system, National Occupational Dose Registry is being developed by BARC. It has 16-digit unique TLD number for each individual. This system acquires various dose data with respect to radiation worker either in nuclear power plants or medical facilities and other nuclear laboratories/installations.

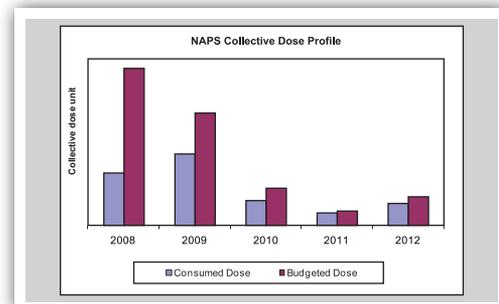
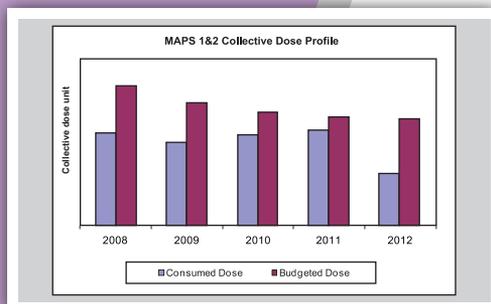
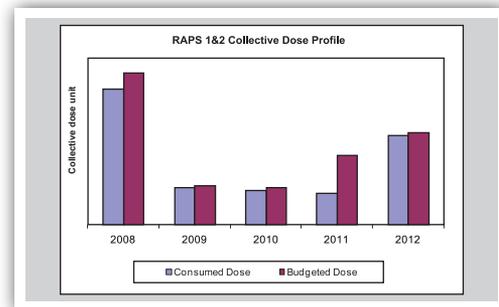
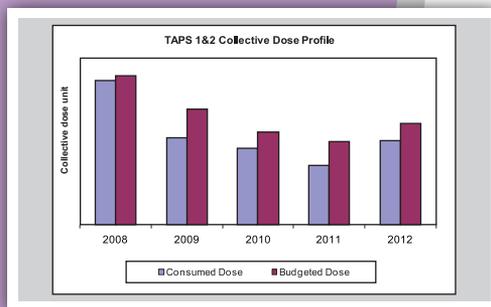


## COLLECTIVE DOSE PROFILE AND DOSE REDUCTION MEASURES AT NPPS:

The collective dose for operation of NPPs has showed considerable reduction during last five years.

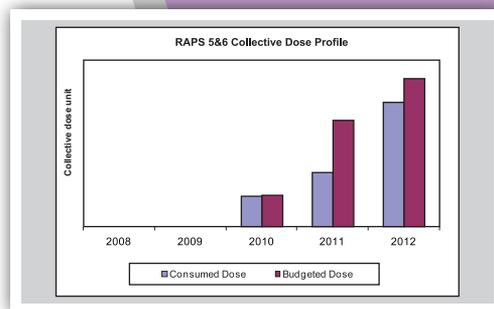
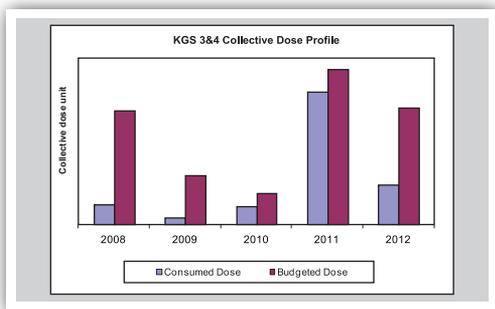
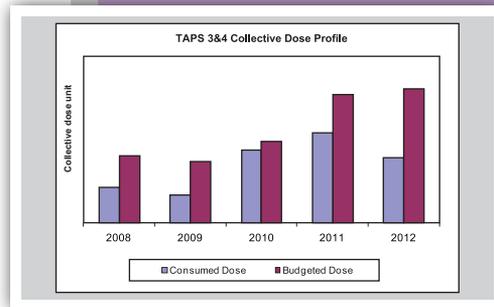
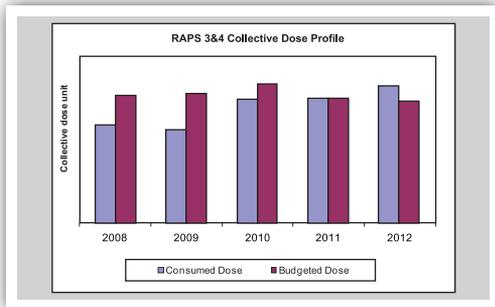
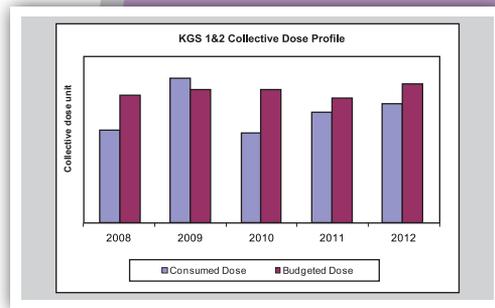
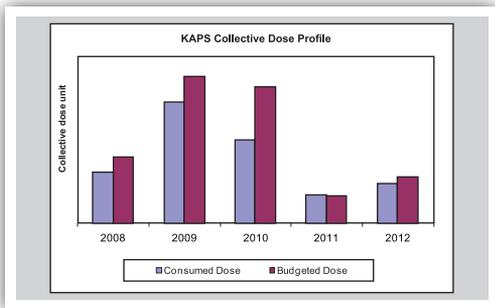
Dose reduction measures at NPPs are:

- Use of cobalt free materials.
- Better fuel performance, good operating procedures and practices to reduce the number of short Shutdown /unit off time.
- Continual improvement in radiological conditions in the plant.
- Efficient shutdown planning with reduced outage duration.
- ALARA awareness. Task Force on systematic survey and reduction of activity concentration in air and follow up actions.
- Enhanced house keeping and waste management.
- Fuel performance improvement with enhanced quality assurance programme.
- Nuclear grade materials for piping.
- Enhanced surveillance .
- System decontamination.



- Enhanced heavy water dryer performance.
- Recovery and reuse of heavy water by up-graduation system.

Continuous reduction in collective dose is expected in the coming years due to continual improvement of station performance and good maintenance practices at stations. The formation of two-tier ALARA committees and task force on systematic radiation survey will reduce radiation level and airborne concentration in operating areas.



### RADIOACTIVE WASTE MANAGEMENT:

The three basic concepts applied to radioactive waste management are: -

- Delay and decay.
- Dilute and disperse .
- Concentrate and contain.

### LIQUID WASTE:

Sources of liquid waste from pressurised heavy water reactors (PHWRs):

- Personnel showers, active laundry etc., (potentially active).
- Heavy water Upgrading plant, Reactor Building sump, Heavy water clean up (Tritiated waste).
- Laboratories, Decontamination center, etc., (Active Chemical waste).

The liquid waste generated during reactor operation is treated in Treatment and Disposal System (TDS) of Waste Treatment Plant (WTP). TDS is equipped with facilities like chemical treatment, purification by ion-exchange, etc. Treated low-level active liquid waste is discharged to the water body after adequate dilution with condenser cooling / blow-down water and continuously monitored.

**GASEOUS WASTE:**

In PHWRs, gaseous wastes mainly originate from fuel and heavy water. Gaseous wastes are filtered through pre-filter, absolute filter, charcoal filters and discharged through a 100 m-tall stack. The atmospheric dispersion provided by stack is of the order of  $10^{-8}$  sec per  $m^3$  at a distance of 1.6 km. This concentration is about 100 times less compared to the concentration resulting from ground-level release.

The discharged gaseous waste is sampled and analysed for radioactivity online by an elaborate stack monitoring system.

The radioactive gaseous wastes discharged from nuclear power plants over last five years are far less as compared to the technical specification limit for each plant Stipulated by Regulatory Authority (AERB).

**SOLID WASTE :**

In PHWRs, the solid waste mostly comprise refuse, contaminated materials (like paper, cloth, wood, plastic sheets/bags etc.), dry and wet filters, metallic components, spent ion-exchange resins, desiccants sludges and slurries. The solid waste is categorised on the basis of radiation dose rate on surface and physio-chemical characteristics.

Radioactive solid waste is disposed in near-surface disposal repository having engineered barriers.

**ENVIRONMENT SURVEILLANCE PROGRAMME:**

Each NPP site has an Environment Survey Laboratory (ESL), which is operated by Health Physics Division of Bhabha Atomic Research Center and accredited by Atomic Energy Regulatory Board (AERB).

The primary aim of the environmental monitoring programme is to monitor the environment and the radiation exposure to the public due to the operation of nuclear power plants.

The radioactivity content in the environmental matrices is assessed using sophisticated radio-chemical analysis and highly sensitive instruments.



LIQUID SCINTILLATION COUNTING SYSTEM



PORTABLE H3 SAMPLING SET-UP



PORTABLE H3 SAMPLING SET-UP

**AQUATIC, ATMOSPHERIC AND TERRESTRIAL SAMPLES COLLECTION:**



COLLECTION OF WATER SAMPLE

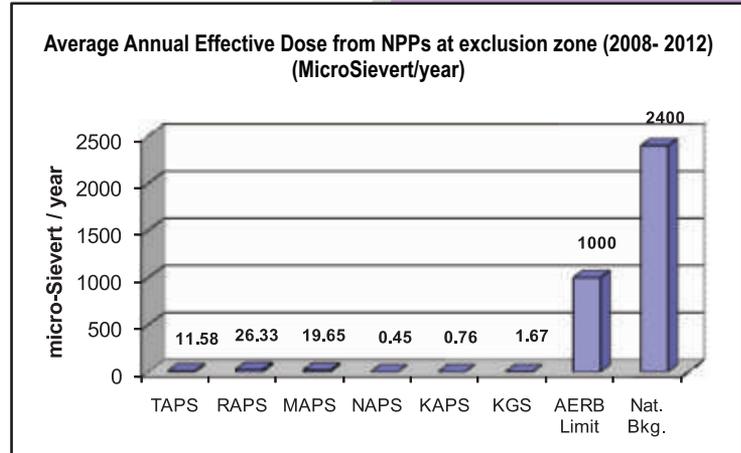


COLLECTION OF VEGETATION SAMPLE

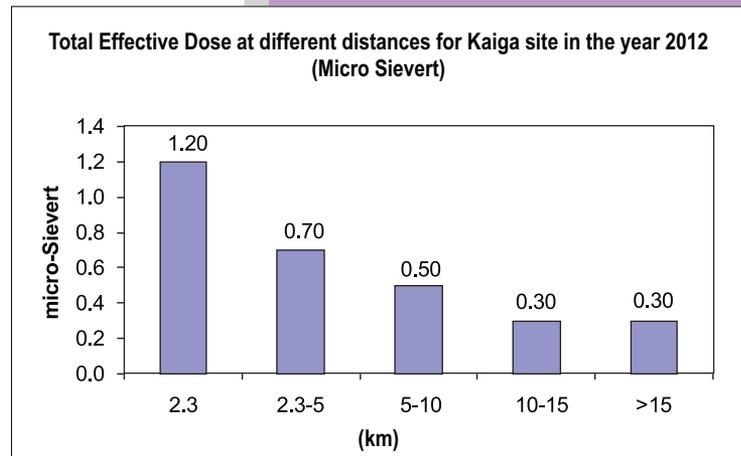


COLLECTION OF FOOD SAMPLE

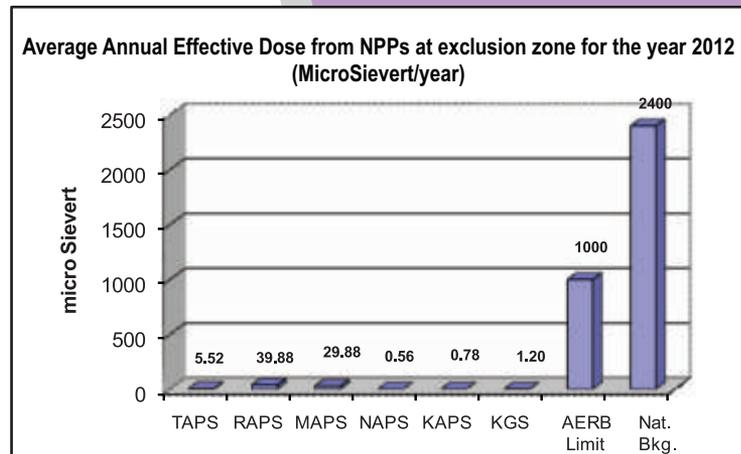
The computed dose received by hypothetical person staying at exclusion zone boundary from NPP operation is about 1-3% of the authorised dose limit and is a small fraction of the natural background radiation.



The doses at further distances are still lower as illustrated in figure.



The computed annual effective dose to a hypothetical person at exclusion zone boundary is less than the dose limit of 1000  $\mu$ Sv per year prescribed by the International Commission on Radiological Protection (ICRP) and stipulated by The Atomic Energy Regulatory Board (AERB).



**NUCLEAR POWER PLANT AND ENVIRONMENT:**

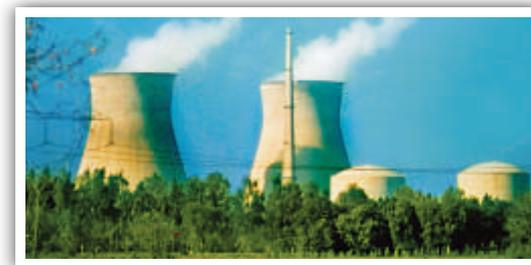
NPCIL has also taken up a program to develop and implement Environmental Management Systems(EMS) at its operating NPPs for Environmental and Occupational Health and Safety in line with ISO-14001 and ISO-18001. The major achievements of implementation of ISO 14001 standard based on EMS are,

- Large reduction in radioactive solid waste generated and disposed due to better segregation of active and non-radioactive solid waste.
- Change in the employee’s attitude towards resource saving, waste handling and improvement in work practices.
- Canteen wastes are treated by a vermiculture method and biomedical waste is incinerated.
- Reduction in the use of paper, generating less paper by introducing e-mail system with LAN. Reports are issued on LAN with limited hard copies.

NPCIL undertakes green-belt development by planting trees every year around its facilities. Narora, Kakrapar and Kaiga sites have developed green belts around the stations by planting more than 150,000 trees during last few years. Green-belt development at the upcoming Kudankulam project site is being done in collaboration with M.S. Swaminathan foundation. A new technique has been adopted at KKNP project due to very low fertility of the soil around the project. About 10,000 trees have been planted so far.



BEFORE GREEN BELT DEVELOPMENT AT NAPS



AFTER GREEN BELT DEVELOPMENT AT NAPS

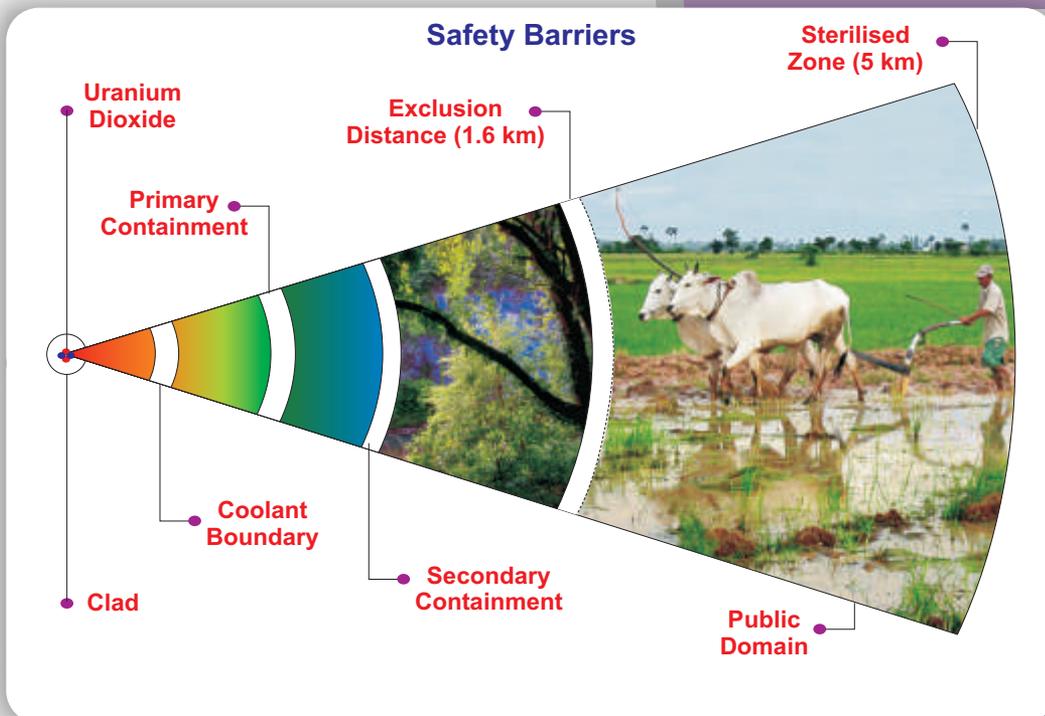
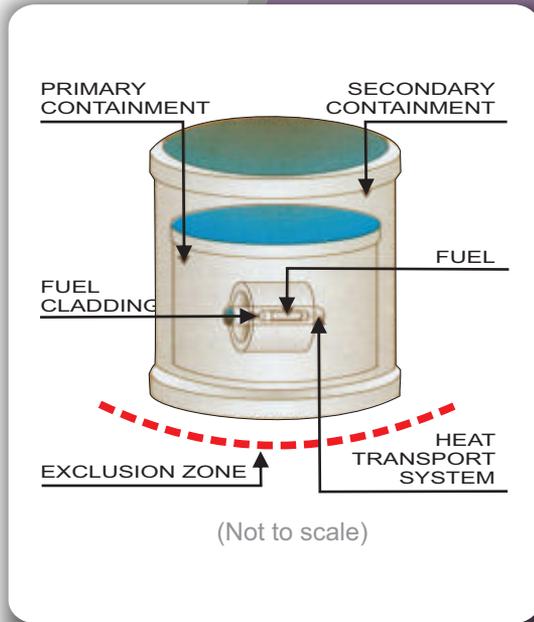
Fuel consumption and waste generation for 1000-MWe energy by thermal plant and nuclear plant is given below:

1000 MWe station			
Category		Thermal power plant	Nuclear power plant
Fuel use in tones / year		1,500,000	25
Wastes ( in tones / year)	Ash	6,25,000	Nil
	CO <sub>2</sub>	6,500,000	Nil
	SO <sub>2</sub>	9,000	Nil
	NO <sub>x</sub>	4,500	Nil

“NUCLEAR POWER IS CLEAN AND ENVIRONMENT FRIENDLY ”

**SAFETY IN NUCLEAR POWER REACTORS:**

Safety is given paramount importance in design, construction and operation of nuclear power stations. To ensure the safety of reactor, defense-in-depth philosophy is followed, which leads to multiple barriers, diversity, redundancy, independence and fail-safe design of safety-related systems. Safety of nuclear power stations is ensured through sound design using international standards and codes, stringent quality assurance, approved operating procedures, in-service inspection and maintenance of safety systems, etc.



## RADIATION EMERGENCY:

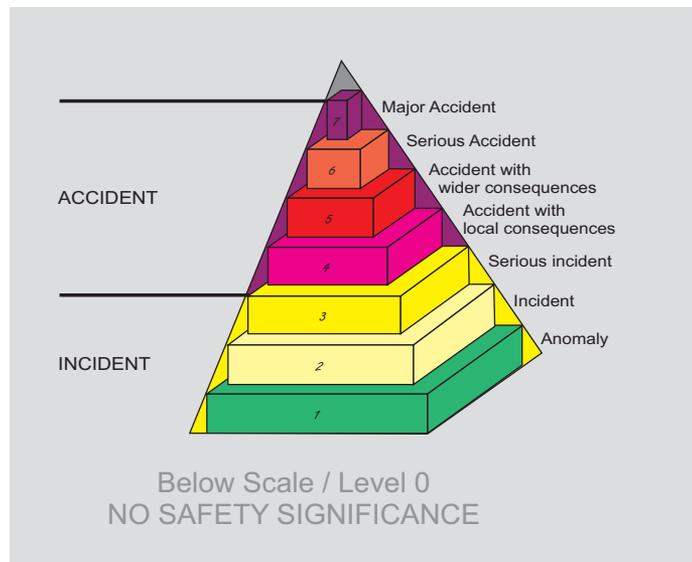
Radiation emergency in a nuclear power plant is a situation having the potential of unplanned radiation exposure to workers and public due to an event which results in uncontrolled release of radioactivity either within the plant and/or from the plant to the surrounding environment and calls for intervention.

Emergency Preparedness:

To take care of accidental situations, emergency plans are drawn-up in advance by the nuclear installation for following three objectives.

- To restrict the exposure as low as reasonably achievable and avoid exposures above the limit.
- To obtain information about the causes of the incident and assess the consequences of the incident.
- To bring the situation back under control, as early as possible.

To simplify the communication of the event occurring in the nuclear installations, IAEA has developed International Nuclear and Radiological Events Scale (INES). The events are rated from One to Seven as shown in the figure. Events are classified on the Scale at Seven levels. The Scale is designed so that the Severity of an event is about ten times greater for each increase in level on the scale. Events of level 1 to 3 are “incidents”. Events of level 4 to 7 are “accidents”. No Nuclear accident as defined by INES of IAEA has occurred so far over 320 reactor years of operations in India.



**Event rating zero below scale:** Means there is an operational deviation but the safety systems worked properly and controlled the deviation without any risk to installation, workers and environment.

**Event rating 7:** Means an event in the nuclear installation causes major nuclear emergency that leads to the damage of installation and environment, loss of human life and resource.

### DEPICTION OF PLUME DISPERSION AND DEPOSITION:

In a highly unlikely accident condition, release of various radioactive materials in the form of volatile gases or particulates into the atmosphere may take place. They would be carried away by the wind and get diluted & dispersed before reaching the public.

Significant amounts of radionuclide concentrations in the air would rapidly decrease in downwind direction from the site and some quantity of radionuclides may be deposited on the ground at considerable distances from site. It may be necessary to initiate some counter-measures to reduce the exposure to the people living near the accident site.



#### Counter measures:

- Sheltering.
- Administration of Stable Iodine tablets.
- Evacuation.
- Relocation.
- Control of access.
- Control of Food and Water.
- Decontamination of affected areas and buildings.

#### Sheltering:

- 1) Sheltering means 'stay indoors' and refrain from going outside until further advice.
- 2) Sheltering is normally assumed for a period of 12 to 24 hours and may precede evacuation.

#### Administration of Stable Iodine tablet:

Prophylaxis is the intake of specific stable chemical compounds which have a reducing or blocking effect on the uptake of certain radionuclides. The most important example is the use of KI or  $KIO_3$  to reduce the uptake of radioiodines (particularly  $I^{131}$ ) by the thyroid gland.

#### Evacuation:

Evacuation is the temporary removal of people from their normal housing for a limited period of time to a pre-designated temporary shelter.

Salient features of the emergency preparedness:

- Provides detailed guidelines for handling the radiation hazards and protective measures during radiological emergency at NPPs.
- Deals with primary responsibilities to handle radiation emergency conditions.
- Defines the organisation and its responsibilities to handle and implement corrective measures.
- Describes the duties and responsibilities of each organisation/individual in handling the emergency.
- Defines Emergency Zones and Sectors.
- Describes the facilities, equipment and organisation assistance required for handling the emergency.

**EMERGENCY CONTROL CENTERS (ECCs):**

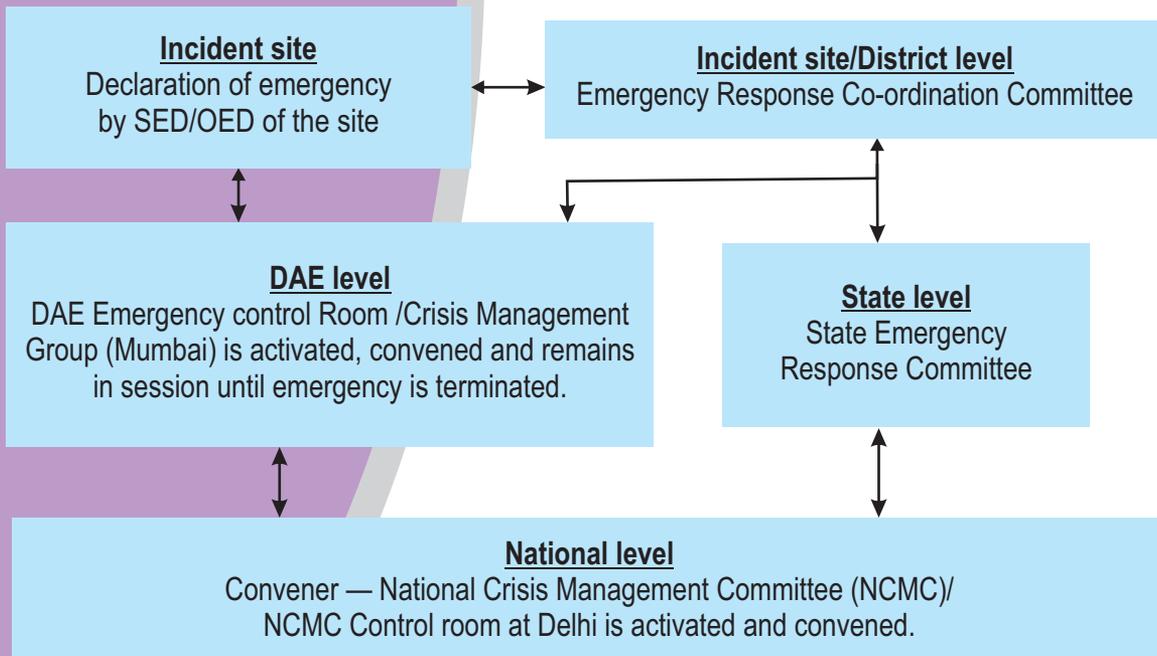
Emergency Control Centers (ECCs) are set up with necessary personal protective devices, radiation monitoring instruments and communication systems required for handling emergency conditions in an effective manner. The ECCs are the places for commanding and directing the emergency corrective measures.

The Emergency Control Centers (ECCs) are :

- Within the plant( Plant Emergency Control Center-PECC)
- Within the site ( Site Emergency Control Center-SECC)
- Beyond exclusion zone - usually in DAE township (Off-Site Emergency Control Center-OECC).

The validation of the established emergency procedure/programme is carried out by conducting emergency exercises at plant level once in three months, at site level once in a year and in public domain up to 16-kilometer radius once in two years.

**Flow of Information during an Off-site Emergency at a nuclear power plant**



SED — Site Emergency Director, OED — Off-Site Emergency Director



# NPCIL MISSION

**To develop nuclear power technology and to produce nuclear power as a safe, environmentally benign and an economically viable source of electrical energy to meet the increasing electricity needs of the country.**



एनपीसीआईएल  
NPCIL

Prepared by

**Health, Safety & Environment Group (HSE)  
Directorate of Technical**

Published by

**Directorate of Corporate Planning & Corporate Communications (CP&CC)**  
6-S-14, Vikram Sarabhai Bhawan, Anushakti Nagar, Mumbai - 400094  
E-mail: cpcc@npcil.co.in, Website: www.npcil.nic.in