

CHAPTER

4

# ENVIRONMENTAL SAFETY AND OCCUPATIONAL EXPOSURES





## 4.1 ENVIRONMENTAL SAFETY

Environmental safety in the vicinity of nuclear installations is ensured through control on radioactive discharges into the environment and environmental monitoring. These radioactive discharges are mainly in the form of liquid and gaseous radioactive effluents released during the operation of the facility.

The waste management aspects are reviewed throughout the lifecycle of the plants, right from the siting stage to construction, commissioning, operation and decommissioning stages. Based on the satisfactory review of the arrangements made by the plant for safe management of radioactive wastes, AERB issues authorization under the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 with respect to the quantity and activity content of the radioactive effluents.

AERB has specified the requirements for safe management of radioactive wastes in form of Safety Code titled 'Management of Radioactive Waste' (AERB/SC/RW) and has issued several guides thereunder providing guidance on various aspects to meet the requirements of the Code. The Safety Code deals with the requirements for radiation protection aspects in design, construction and operation of waste management facilities and the responsibilities of different agencies involved. The Code is also applicable to the management of radioactive waste containing chemically and biologically hazardous substances, even though other specific requirements may additionally be applicable as per relevant standards.

AERB has specified that the radiation dose to the members of public near the operating NPPs due to the discharges from the plants shall not exceed annual limit of 1 mSv (i.e. 1000 micro-Sievert). This is in line with the limits recommended by International Commission on Radiological Protection (ICRP). Based on this limit, AERB has further specified limits on effluent discharges through gaseous, liquid routes, in the Technical Specifications for

operation of NPPs. These technical specification limits are set far below the dose apportionment to the public for the specific radionuclide. The radionuclide specific dose apportionment is small fraction of the annual dose limit (1000 micro-Sievert) to public. While specifying these limits, it is ensured that the discharge is controlled within public exposure limit following the principles of "As Low as Reasonably Achievable" (ALARA). The limits specified in the technical specifications actually ensure that the dose to the public is well below the specified limit of 1000 micro-Sievert for NPP Site. The actual discharges from the plants are observed to be well below the limits specified.

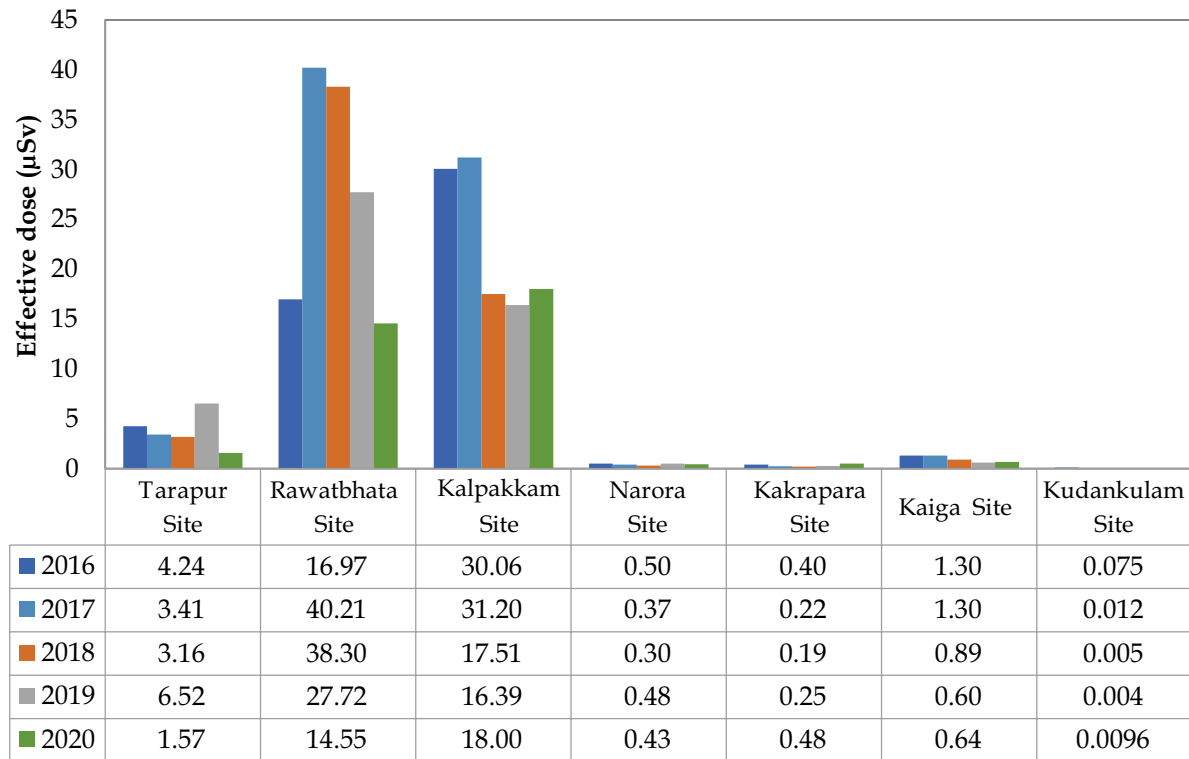
Periodic reports including effluent discharges are submitted by the plant sites to AERB in prescribed forms. AERB also conducts regular inspection of these plant sites to verify compliance with the laid down requirements. Every five years, prior to renewal of licence for operation of these facilities, the adequacy of waste management arrangements, effluent release and their impact on the environment are thoroughly reviewed.

It is seen that the effective dose to public around all NPP sites is far less than the annual limit of 1mSv (1000 micro-Sievert) prescribed by AERB.

The independent Environmental Survey Laboratories (ESL) of the Health, Safety and Environment Group (HS&EG), BARC, carry out environmental surveillance at all the operating nuclear power plant Sites. The liquid and gaseous radioactive wastes discharged to the environment during the year 2020 from the operating units were only a small fraction of the prescribed technical specification limits.

Radiation dose to members of the public near the operating plants is estimated based on gaseous release and measurements of radionuclide concentration in items of diet, i.e. vegetables, cereals, milk, meat, fish etc., and through intake of air and water. It is seen that the effective dose to public around all NPP sites is far less than the annual limit of 1mSv (1000 micro-Sievert) prescribed by AERB.

The effective doses to the members of the public (Year 2016 to 2020) due to the release of radioactive effluents from the plants are presented in the Figures 4.1 (a) and 4.1 (b).



**Fig 4.1(a): Public Dose at 1.6 Km distance (Exclusion Boundary) for NPPs (AERB prescribed Annual Limit is 1000 micro-Sievert (µSv))**

- Note: 1. Public dose at Rawatbhata and Kapakkam sites are relatively higher as compared to other reactor sites, due to release of Ar-41 from RAPS-2 and MAPS (which are within the prescribed technical specification limits).
2. The 1.6 km boundary for Kaiga site is located at 2.3 km.

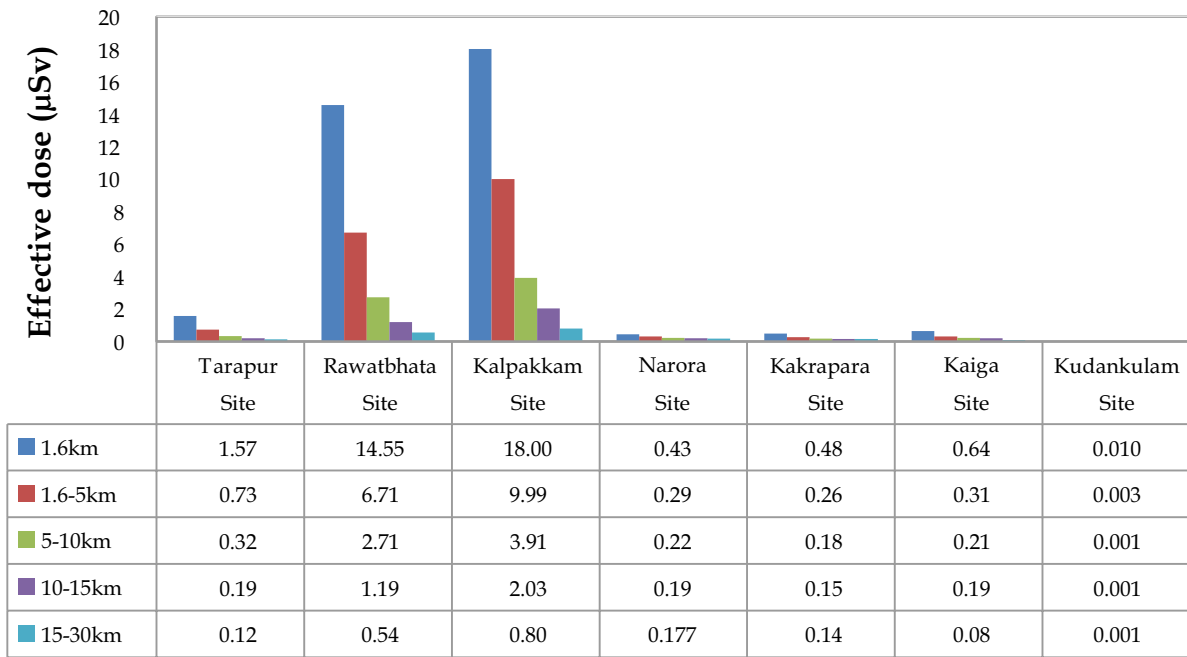
## 4.2 OCCUPATIONAL EXPOSURES

In each NPP, a Radiological Safety Officer (RSO) and alternate RSO are designated by the Competent Authority for implementation of the radiation protection programme. The RSOs are entrusted with the responsibility for providing radiological surveillance and safety support functions. These include radiological monitoring of workplace, plant systems, personnel, effluent monitoring, carrying out exposure control, exposure investigations, and analysis & trending of radioactivity in plant systems.

All NPPs have established radiological surveillance programme and work procedures intended to control the occupational exposures.

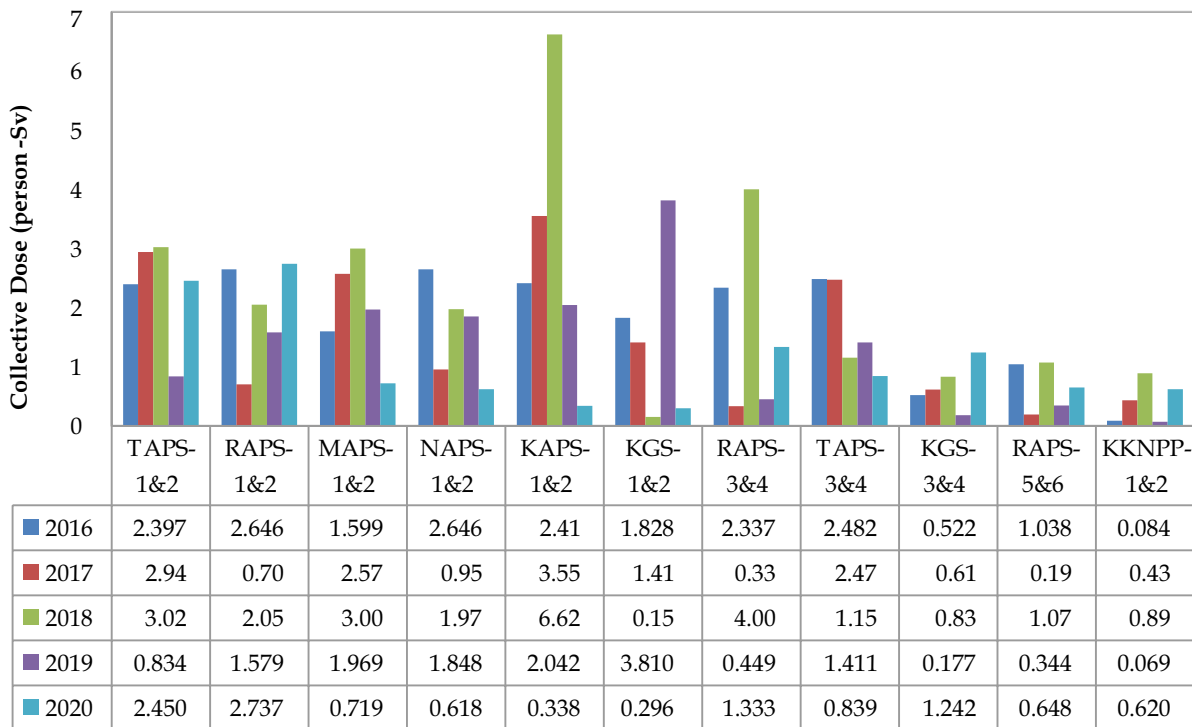
AERB Safety Manual on 'Radiation Protection for Nuclear Facilities' (AERB/NF/SM/O-2 (Rev.4), 2005) specifies Dose Limits and Investigation Levels (IL) for occupational workers to control the individual doses. As per AERB Directives, for an occupational worker, annual dose limit is 30 mSv, with the condition that it should not exceed 100 mSv in a span of 5 years. The specified annual dose constraint for radiation exposure of temporary worker is 15 mSv.

For better exposure control, individual cases are investigated and controlled at an early stage so as to remain within the AERB specified dose limits. The following Investigation Levels (ILs) are applicable to the nuclear facilities.



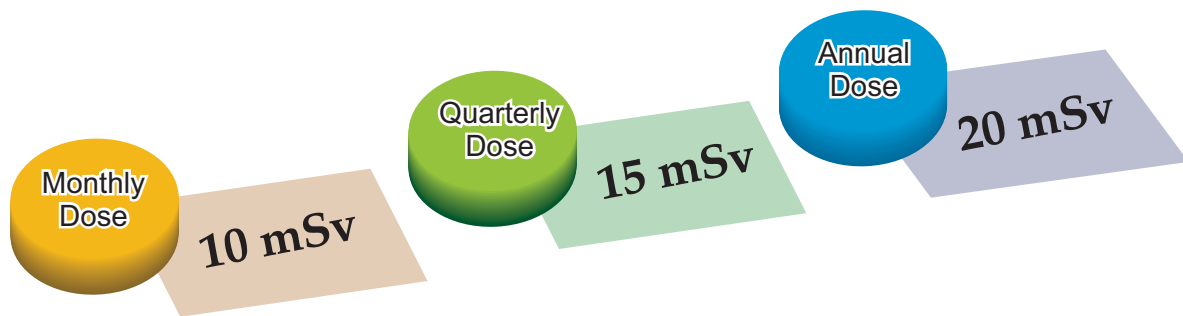
**Fig. 4.1 (b) : Total Effective Dose in different Zones during the Year 2020 (AERB prescribed Annual Limit is 1000 micro-Sievert (µSv))**

- Notes : 1. Public dose at Rawatbhata and Kalpakkam sites are relatively higher as compared to other reactor sites, due to release of Ar-41 from RAPS-2 and MAPS (which are within the prescribed technical specification limits).
2. The 1.6 km boundary for Kaiga site is located at 2.3 km.



**Fig.4.2 Collective Dose (Person-Sv) at NPPs**

Note : KAPS-3 not shown in the chart as it was started in the year 2020



The information on number of workers in NPPs and Fuel Cycle Facilities who received dose below and above 20 mSv during the year 2020 is given in Table 4.1 and 4.2 respectively.

In the year 2020, there was no case of individual radiation exposure above the prescribed annual dose limit of 30 mSv.

Figure 4.2 gives collective dose (Person-Sv) for operation and maintenance of NPPs for last 5 years.

**Table 4.1: Radiation Doses Received by Workers in Nuclear Power Plants (2020)**

NPP	Number of Monitored Person	Average Dose for Monitored Person	Number of Persons Received Dose	Average Dose Among Dose Receivers	Number of Workers Received Dose in the Range	
					< 20 mSv	>20 mSv
TAPS - 1&2	1149	2.13	897	2.73	1149	0
RAPS - 1&2	1074	2.55	870	3.15	1074	0
MAPS - 1&2	869	0.83	694	1.04	869	0
NAPS - 1&2	1142	0.54	648	0.95	1142	0
KAPS - 1&2	979	0.82	642	1.24	979	0
KGS - 1&2	911	0.32	454	0.65	911	0
RAPS - 3&4	1292	1.03	870	1.53	1292	0
TAPS - 3&4	1135	0.74	786	1.09	1135	0
KGS - 3&4	1318	0.943	902	1.38	1318	0
RAPS - 5&6	1123	0.58	735	0.88	1123	0
KKNPP - 1&2	2160	0.287	569	1.09	2160	0
KAPP - 3&4	1310	0.0277	127	0.2858	1310	0
<b>Total</b>	<b>14,462</b>	<b>---</b>	<b>8,194</b>	<b>---</b>	<b>14,462</b>	<b>0</b>

\* KAPP-3 achieved first criticality on July 22, 2020.

### Radiation Facilities

In each radiation facility, a Radiological Safety Officer(s) (RSO) is designated by employer and approved by the Competent Authority. The RSO is entrusted with the responsibility for providing radiological surveillance and safety support functions. These include radiological monitoring of workplace & personnel, effluent monitoring (in handling of open sources), excessive exposure investigations and analysis etc.

As per AERB Directives, for an occupational worker, annual dose limit is 30 mSv, with the condition that it should not exceed 100 mSv in a span of 5 years. For better exposure control, individual cases are investigated and controlled at an early stage so as to remain within the AERB specified dose limits. However, any person exceeding radiation dose of 10 mSv in a monitoring period is investigated to establish the root cause, work practice and assignment of dose.



**Table- 4.2 Radiation Doses Received by Workers in Front End Fuel Cycle Facilities (2020)**

Type of Facilities	Location	Number of Persons Received Dose	Average Dose for Monitored Persons (mSv)	Maximum Dose of Monitored Persons (mSv)	No of Workers Received Dose in the Range	
					<20 mSv	>20 mSv
<b>Uranium Mines (UCIL)</b>	Jaduguda	669	5.88	9.88	669	0
	Bhatin	22	0.58	0.96	22	0
	Narwapahar	717	4.00	6.48	717	0
	Turamdih	549	3.33	6.20	549	0
	Bagjata	384	2.94	6.35	384	0
	Banduhurang	364	2.09	3.47	364	0
	Mohuldih	302	3.57	5.77	302	0
	Tummalapalle	1363	3.89	8.31	1363	0
<b>Uranium Mills (UCIL)</b>	Jaduguda	836	2.13	4.95	836	0
	Turamdih	676	1.93	4.15	676	0
	Tummalapalle	692	0.37	0.74	692	0
<b>Thorium Mines and Mills (IREL)</b>	Chavara	91	0.20	2.29	91	0
	Manavalakurichi	145	1.48	14.67	145	0
	OSCOM-Chatrapur	417	2.67	10.15	417	0
	Udyogamandal	180	0.73	4.31	180	0
<b>Fuel Fabrication (NFC)</b>	Hyderabad	1246	0.69	6.5	1246	0
	<b>Total</b>	<b>8653</b>	<b>2.61</b>	<b>14.67</b>	<b>8653</b>	<b>0</b>

The information on number of workers in medical, industrial and research institutions, who received various doses during the year 2020 is given in Table-4.3(a).

**Table 4.3 (a) : Radiation Doses Received by Workers in Medical, Industrial and Research Institutions (2020)\***

Category of Radiation Worker	No. of Monitored Persons	Average Dose for monitored Persons (mSv)	No. of Persons Receiving Dose	Averaged Dose among Dose Receivers (mSv)	No. of Workers Received Annual Individual Dose Excluding zero Dose (mSv)				No. of Persons who Received Cumulative Dose >100 mSv during 5-year block (2015 to 2019)
					0<D ≤20	20<D ≤30	30<D ≤50	D>50	
Diagnostic X- rays	122796	0.17	29941	0.69	29933	8	0	0	19
Radiation Therapy	14865	0.09	3070	0.42	3070	0	0	0	0
Nuclear Medicine	2457	0.32	1019	0.78	1019	0	0	0	1
Industrial Radiography	7342	0.32	1898	1.24	1895	3	0	0	8
Radiation Processing Facility	134	0.03	10	0.35	10	0	0	0	0
Research	3920	0.06	680	0.35	680	0	0	0	0
<b>Total /Avg</b>	<b>151514</b>	<b>0.17</b>	<b>36618</b>	<b>0.69</b>	<b>36607</b>	<b>11</b>	<b>0</b>	<b>0</b>	<b>28</b>

\* Data (External dose) as on March 3, 2021 with National Occupational Dose Registry System (NODRS). The data does not include excessive exposure cases above investigation levels which are currently under investigation.

During 2020, total 8 radiation workers in diagnostic radiology (X-ray) and 3 workers in Industrial Radiography received radiation dose between 20 to 30 mSv due to non-standard operating practice.

exceeded radiation exposures in different ranges during the year 2019, was given in Table 4.3(a) of AERB Annual Report for the year 2019. The information for the year 2019 is now updated incorporating the outcome of excessive exposure cases that have been concluded and is given in Table 4.3(b) below.

The information on number of workers in medical, industrial and research institutions, who

**Table 4.3 (b): Radiation Doses Received by Workers in Medical, Industrial and Research Institutions (2019\*)**

(updated after investigations on workers who have received doses above investigation levels and receipt of more data)

Category of Radiation Worker	No. of Monitored Persons	Averaged Dose for Monitored Persons (mSv)	No. of Persons Receiving	Average Dose among Dose Receivers (mSv)	No. of Workers Received Annual Individual Dose Excluding zero Dose (mSv)			
					0<D ≤20	20<D ≤30	30<D ≤50	D>50
Diagnostic X-rays	139075	0.29	47224	0.86	47165	49	8	2
Radiation Therapy	16636	0.17	4843	0.6	4840	2	1	0
Nuclear Medicine	2788	0.63	1741	1.01	1741	0	0	0
Industrial Radiography	7791	0.48	2592	1.43	2583	6	1	2
Radiation Processing Facility	113	0.11	20	0.61	20	0	0	0
Research	4539	0.14	1228	0.52	1228	0	0	0
<b>Total /Avg.</b>	<b>170942</b>	<b>0.29</b>	<b>57648</b>	<b>0.86</b>	<b>57577</b>	<b>57</b>	<b>10</b>	<b>4</b>

#### 4.3 BASIS FOR ACCEPTABLE DOSE TO OCCUPATIONAL WORKERS AND ENVIRONMENTAL RELEASES

The dose limits for exposure from ionizing radiation for occupational workers and the members of the public are prescribed by AERB in its Directive No.01/2011 under Rule 15 of the Atomic Energy (Radiation Protection) Rules, 2004. These dose limits are based on the ICRP recommendations and IAEA Safety Standards on Radiological Protection and are in line with the international practice and standards.

The estimated dose to the members of the public due to discharge of radioactive effluents from nuclear facilities at a site shall not exceed an effective dose of 1 mSv in a year.

##### (i) Observance of Dose Limits

The exposure control consists of application of primary dose limits, action levels such as investigation level and operational restrictions. Operational restrictions are established based on dose, dose rate, air activity and surface contamination levels etc., at workplace such that the exposure of workers does not exceed the applicable dose limits. Individual exposures exceeding the investigation levels are investigated and reported to AERB. All cases of exposures exceeding the annual limits are reviewed by AERB Committee on Excessive Exposures.

##### (ii) Authorised Limits of Environmental Releases/Discharge

The discharge of radioactive waste from an NPP is governed by the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987. It is mandatory for each licensed nuclear facility to obtain authorization under these rules from the Competent Authority for disposal of radioactive wastes and file a return annually to AERB indicating the actual quantity of radioactive waste discharge.

Discharge constraints are set at a much lower value than the authorized limits to achieve effluent releases at ALARA level. These discharge constraints are usually set at 50-65% of authorized discharge limits taking into cognizance differences in NPP system design. The operating data shows that releases from NPPs have been a small fraction of the specified release limits.

#### 4.4 INITIATIVES TAKEN BY AERB FOR DOSEREDUCTION

##### (i) Review of Radiation Protection Aspects during Project Stage

During design and commissioning stages, it is ensured that an elaborate radiation monitoring system consisting of area radiation monitors, process monitors, environmental monitors and effluent monitors is made available to give history, trend and instantaneous readings of the monitors for exposure control. Based on the operating experience, many design modifications for exposure control have been incorporated progressively in the Indian NPPs.

During the year 2020, detailed review and analysis of installed radiation monitors, their alarm set points with evolving phases of operation was carried out for KAPP-3 which is under commissioning.

##### (ii) Operation Phase

Radiation protection programme during the operation of NPPs is revised and approved by AERB. This programme comprises of organisational, administrative and technical elements. ALARA measures are put in place for exposure control of the plant personnel and the public. AERB ensures that plant management makes adequate review of the implementation and the effectiveness of the radiation protection programme. Radiological Safety Officer for each NPP is authorized by AERB to carry out radiological safety functions.

The environmental surveillance programme is also reviewed to evaluate the impact of operation of the NPP on the surrounding areas of the plant site and ensure that effluent releases and public exposures are below the regulatory limits.

##### (iii) Collective Radiation Dose Budgeting

Collective Dose Budget (CDB) is prepared by each NPP annually on the basis of jobs (related to radiation) that are likely to be executed, anticipated collective dose in these jobs, collective dose consumed in the previous years as well as the existing radiological conditions, benefits accrued by design improvements, identification of lapses in previous attempt of jobs and corrective actions taken etc. The aim is to optimize the CDB through ALARA principle. AERB carries out review of the CDB. Dose incurred in any



unplanned activity is to be recorded as unanticipated dose which is discussed for justification prior to approval of the same by AERB.

#### **(iv) Review of Radiological Safety Aspects**

Routine quarterly and annual reports on radiological safety aspects are prepared by the RSO of the NPPs and submitted to AERB periodically. These reports are reviewed at AERB and necessary corrective measures as required for exposure control are recommended to respective NPP. In addition, exposure investigation reports, significant event reports (radiological aspects) are also reviewed and corrective actions are recommended.

#### **(v) Regulatory Inspections**

During the regulatory inspection, radiological aspects of NPP operation are reviewed. This includes radiological status of the plant, individual and collective dose, effluent discharges, radioactive waste management, environmental monitoring, adherence to radiation protection procedures by workers, safety culture and quality assurance programme in radiation protection etc. Additionally, AERB also conducts regulatory inspections during Biennial Shutdown (BSD)/Refuelling Shutdown (RSD) of NPPs to ascertain compliance with radiation protection requirements. Any deviation from established procedure is reported in inspection report. These issues are then deliberated in AERB and Stations are asked to address them suitably.

During the year 2020, routine regulatory inspections of NPPs were carried out till March 2020 only. Subsequently inspections could not be carried out physically because of travel restrictions due to COVID-19 pandemic preventive measures. However, review work continued throughout the period. Subsequently, Remote Regulatory Inspections (RRI) were started and plants are being monitored.

#### **(vi) Review of Radiation Exposure to Occupational Workers**

The radiation exposure to the occupational workers is periodically reviewed by AERB based on the health physics reports. The exposure cases exceeding the regulatory constraints/ limits are primarily investigated by the exposure

investigation committee at each NPP. These investigation reports are then reviewed by AERB for appropriateness of investigation and suitable corrective actions.

#### **(vii) Exposure Control and Implementation of ALARA**

AERB ensures that all nuclear plants have radiation safety programs and work procedures intended to control the occupational exposures. Exposures to Site personnel are controlled by combination of radiation protection measures such as:

- (a) All NPPs have ALARA Committees at Station and Sectional level. Periodic ALARA reviews are conducted at the NPPs to identify areas for dose reduction and implement corrective actions.
- (b) The operating experience on radiological events at NPPs in India and in other countries are reviewed and the lessons learned are communicated to all concerned Station personnel.
- (c) Improved collective dose budgeting.
- (d) Restricting the external exposure by means of shielding, remote operation, source control, rehearsing the work on mock ups and minimizing the exposure time.
- (e) Minimizing the internal exposures by source control.
- (f) Periodic review of radioactive work practices.
- (g) Periodic training of radiation workers on radiation protection aspects, and
- (h) Trending and analysis of radiological data pertaining to NPP operations.