



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 stage. Based on the satisfactory review of the arrangements made by the plant for safe management of radioactive wastes, AERB issues authorisation 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 '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 (1mSv/year) to public. While specifying these limits, it is ensured that the discharge is controlled within public exposure limit of 1000 micro-Sievert 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 seen 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.

The independent Environmental Survey Laboratories (ESL) of the Health, Safety and Environment Group, 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 2017 from the operating units were only a small fraction of the prescribed technical specification limits.

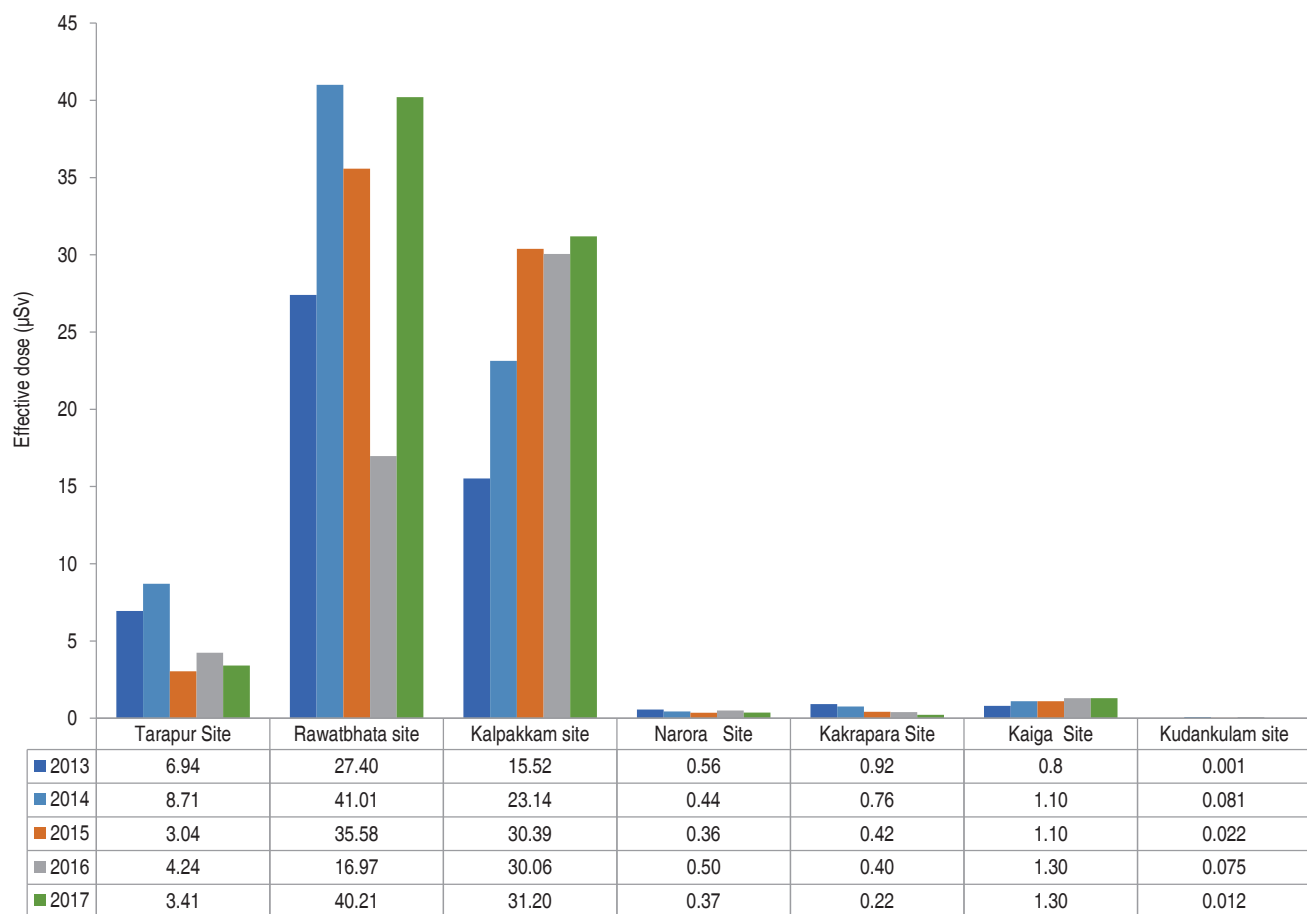
Typical values for radioactive effluent discharges from Indian 540 MWe PHWR (TAPS-3&4) for the year 2017 are given below, which are comparable to the reported discharges from other international nuclear power plants of this type.

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, viz. 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 2013 to 2017) due to the release of radioactive effluents from the plants are presented in the Figures 4.1 (a) and 4.1 (b).

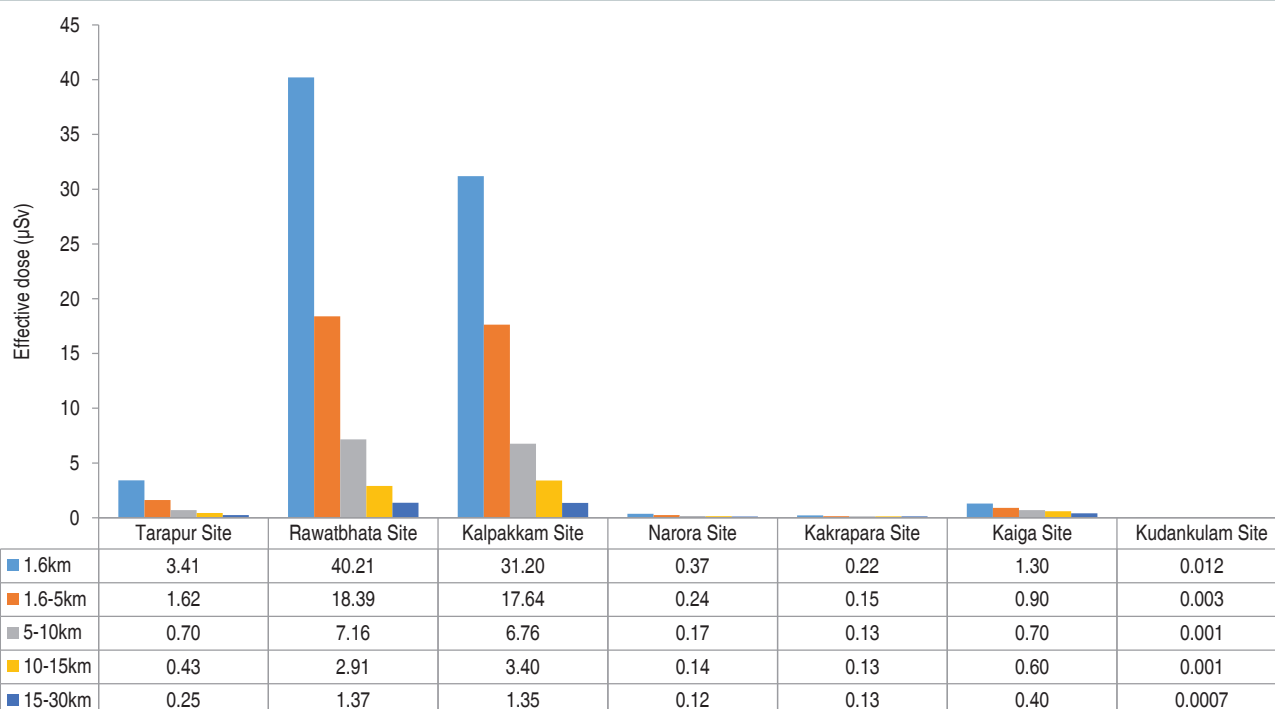
Liquid Effluents	Gaseous Effluents		Solid Rad. Waste Produced	
Tritium (Bq/Unit)	Tritium (Bq/Unit)	FPNG (Bq/Unit)	Volume (m ³ /Unit)	Activity (Bq/Unit)
2.47E+13	5.10E+13	2.78E+13	30.1	8.53E+13

Fig. 4.1 (a): Public dose at 1.6 km distance for Nuclear Power Plants (AERB prescribed annual limit is 1000 micro-sievert (μSv))



Note: 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.

**Fig. 4.1 (b): Total Effective Dose in different Zones during the Year 2017
(AERB prescribed annual limit is 1000 micro-sievert (μSv))**



Note: 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.

4.2 OCCUPATIONAL EXPOSURES

In each NPP, a Radiological Safety Officer (RSO) and alternate RSO are designated by the Competent Authority to implement 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 and 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.

Monthly dose - 10 mSv

Quarterly dose - 15 mSv

Annual dose - 20 mSv

The information on number of workers in NPPs who received dose between 20 to 30 mSv and above 30 mSv during the year 2017 is given in Table: 4.1. In the year 2017, there was no case of individual radiation exposure above the prescribed annual dose limit of 30 mSv.

Table 4.1: Radiation Doses Received by Workers in Nuclear Power Plants (2017)

NPP	Number of Monitored Persons	Average Dose for Monitored Person (mSv)	Number of Exposed Persons	Average dose for Exposed Persons (mSv)	Number of Workers received Dose in the range		
					< 20 (mSv)	20-30 (mSv)	>30 (mSv)
TAPS-1&2	1321	2.23	1058	2.78	1321	0	0
RAPS-1&2	823	0.85	546	1.29	823	0	0
MAPS-1&2	1251	2.05	1111	2.31	1251	0	0
NAPS-1&2	1111	0.86	757	1.26	1111	0	0
KAPS-1&2	1554	2.28	1264	2.81	1553	1	0
KGS-1&2	1433	0.98	1069	1.31	1433	0	0
RAPS-3&4	1362	0.24	703	0.47	1362	0	0
TAPS-3&4	1487	1.66	1230	2.01	1487	0	0
KGS -3&4	1191	0.51	655	0.93	1191	0	0
RAPS 5&6	1005	0.19	392	0.48	1005	0	0
KKNPP	2286	0.19	457	0.95	2286	0	0

Figure 4.2 gives collective dose for operation and maintenance of NPPs for last 5 years.

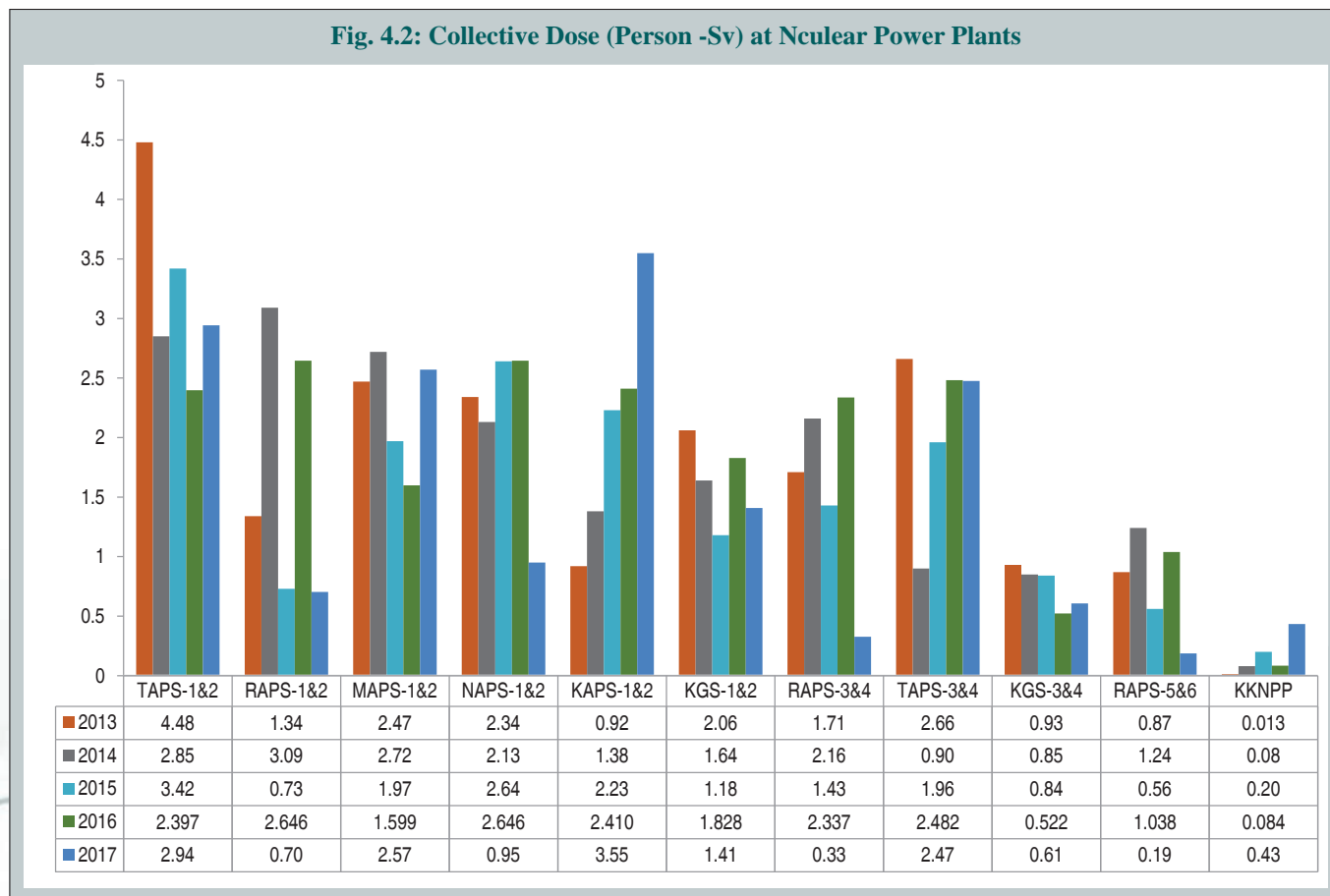


Table 4.2: Radiation Doses (Effective) received by Workers in Medical, Industrial and Research Institutions in the Year 2017*

Category of Radiation Worker	No. of Monitored Persons	Averaged Dose for Monitored Persons (mSv)	No. of Exposed Persons	Average Dose for Persons (mSv)	No. of Workers received Annual individual Dose Excluding zero dose D (mSv)			
					0<D ≤20	20<D ≤30	30<D ≤50	D>50
Diagnostic X-rays	97458	0.23	34959	0.64	34957	2	0	0
Radiation Therapy	13527	0.14	4019	0.48	4019	0	0	0
Nuclear Medicine	2531	0.41	1355	0.77	1355	0	0	0
Industrial Radiography	7152	0.39	2619	1.07	2619	0	0	0
Radiation Processing Facility	71	0.02	7	0.20	7	0	0	0
Research	3890	0.09	962	0.36	962	0	0	0
Total /Avg.	124629	0.23	43921	0.65	43919	2	0	0

* Data (External dose) as on February 16, 2018 with National Occupational Dose Registry System (NODRS). The data does not include excessive exposure cases above investigation levels which are currently under investigation.

The information on number of workers in medical, industrial and research institutions who received various doses during the year 2017 is given in Table 4.2.

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

exceeded radiation exposures in different ranges during the year 2016, was given in Table-3.2 of AERB annual report for the year 2016. The information for the year 2016 is now updated incorporating the outcome of excessive exposure cases that have been concluded and is given in Table 4.2(a) below.

Table 4.2 (a): Radiation Doses (Effective) received by workers in Medical, Industrial and Research Institutions during 2016*

(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 Exposed Persons	Average Dose for Persons (mSv)	No. of Workers received Annual individual Dose Excluding zero dose D (mSv)			
					0<D ≤20	20<D ≤30	30<D ≤50	D>50
Diagnostic X-ray	94732	0.28	37388	0.71	37365	20	3	0
Radiation Therapy	13167	0.19	4966	0.51	4966	0	0	0
Nuclear Medicine	2577	0.51	1568	0.85	1568	0	0	0

Category of Radiation Worker	No. of Monitored Persons	Averaged Dose for Monitored Persons (mSv)	No. of Exposed Persons	Average Dose for Persons (mSv)	No. of Workers received Annual individual Dose Excluding zero dose D (mSv)			
					0<D ≤20	20<D ≤30	30<D ≤50	D>50
Industrial Radiography	7211	0.44	2708	1.17	2698	8	1	1
Radiation Processing Facility	81	0.10	15	0.52	15	0	0	0
Research	4170	0.13	1194	0.47	1194	0	0	0
Total /Avg.	121938	0.28	47839	0.72	47806	28	4	1

*Data (External dose) as on February 16, 2018 with National Occupational Dose Registry System (NODRS). The data does not include excessive exposure cases above investigation levels which are currently under investigation.

The information on number of workers in various Fuel Cycle Facilities who received radiation doses less than 20 mSv, between 20 to 30 mSv and above 30mSv during the year 2017 is given in Table 4.3.

Table 4.3: Radiation Doses Received by Workers in Front End Fuel Cycle Facilities (2017)

Type of Facilities	Location	Number of Exposed Persons	Average Dose for Exposed Persons (mSv)	Maximum Dose of Exposed Persons (mSv)	No. of workers received dose in the range		
					< 20 mSv	20 – 30 mSv	>30 mSv
Uranium mines (UCIL)	Jaduguda	251	0.33	0.65	251	0	0
	Bhatin	63	0.10	0.34	63	0	0
	Narwapahar	865	4.58	7.54	865	0	0
	Turamdih	456	5.74	10.99	456	0	0
	Bagjata	175	6.95	8.07	175	0	0
	Banduhurang	47	2.58	3.05	47	0	0
	Mohuldih	129	3.84	6.41	129	0	0
	Tummalapalle	805	3.86	9.02	805	0	0
Uranium mill (UCIL)	Jaduguda	696	3.04	7.56	696	0	0
	Turamdih	429	1.50	2.90	429	0	0
	Tummalapalle	506	0.38	0.93	506	0	0
Thorium mines and mills (IREL)	Chavara	68	0.4	2.3	68	0	0
	Manavalakurichi	149	1.69	11.8	149	0	0
	Chatrapur	454	2.83	15.3	454	0	0
	Udyogamandal	255	1	7.51	255	0	0
Fuel Fab. (NFC)	Hyderabad	1258	0.94	8.83	1258	0	0
Total		6606			6606	0	0

4.3 BASIS FOR ACCEPTABLE DOSE TO OCCUPATIONAL WORKERS AND ENVIRONMENTAL RELEASES

The dose limits for exposure from ionising 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.

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.

Authorised Limits of Environmental Releases / Discharge

The discharge of radioactive waste from a NPP is governed by the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987. It is mandatory for the NPP to obtain authorisation 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 authorised limits to achieve effluent releases at ALARA level. These discharge constraints are usually set at 50-65% of authorised

discharge limits taking into cognisance 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 DOSE REDUCTION

(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.

(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 (RSO) for each NPP is authorised 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 is prepared by each NPP annually on the basis of jobs that are likely to be executed and collective dose consumed in the previous years as well as the existing radiological condition in the plant. The aim is to minimise the

collective dose in line with ALARA principle. AERB carries out review of the budget. Any upward revision of the budget requires adequate justification by NPP, review and approval 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. The reports are reviewed at AERB and necessary corrective measures required for exposure control are recommended to respective NPP.

(v) Regulatory Inspection and SOT

During the regulatory inspection, environmental monitoring data, effluent discharge data, radioactive waste disposal data and quality assurance programme in radiation protection are checked. Additionally, AERB also conducts regulatory inspections during Biennial Shutdown (BSD)/ Refuelling Shutdown (RSD) of NPPs to ascertain compliance with radiation protection procedure. Access control to various zones is observed by Site Observer Team (SOT) members. Any violation in safety norms during movement of personnel or material is brought to the notice of plant authorities for appropriate action and it is ensured that there is no repetitive violation.

(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 and subsequently by the AERB Safety Committees.

(vii) Exposure Control and Implementation of ALARA

AERB ensures that all nuclear plants have radiation safety programmes 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 is 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 minimising the exposure time.
- (e) Minimising the internal exposures by source control.
- (f) Periodic review of radioactive work practices
- (g) Periodic training of radiation workers on radiation protection aspects.