



4.1 ENVIRONMENTAL SAFETY

Environmental safety is ensured through control on radioactive discharges into the environment from the nuclear installations during the operation of the facility and environmental monitoring.

The waste management aspects are reviewed throughout the lifecycle of the plants, from the siting stage, to construction, commissioning, operation and decommissioning stage. 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 after the satisfactory review of the arrangements made by the plant for safe management of radioactive wastes.

The requirements for safe management of radioactive wastes are specified in Safety Code 'Management of Radioactive Waste (AERB/SC/RW)'. 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 other relevant standards.

AERB has specified that the radiation dose to the members of public 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

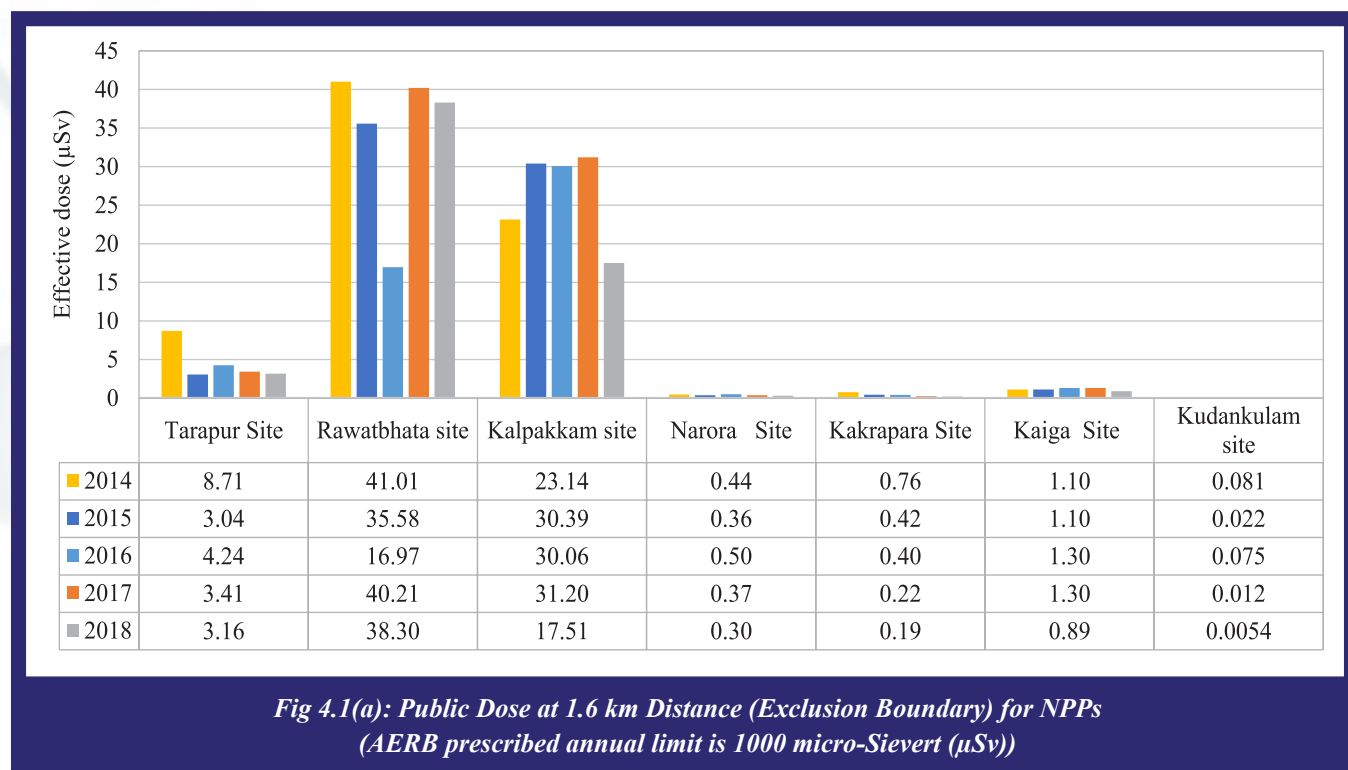
limit, AERB specifies limits on effluent discharges through gaseous and liquid routes, in the Technical Specifications for operation of NPPs. These limits are set far below the dose apportionment to the public for the specific radionuclide. In specifying these limits, it is ensured that the discharge is controlled within public exposure limit of 1 mSv/y following the principles of 'As Low as Reasonably Achievable' (ALARA).

Periodic reports including effluent discharges are submitted by various facilities to AERB. AERB conducts regular inspection of these facilities to verify compliance to the requirements. 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.

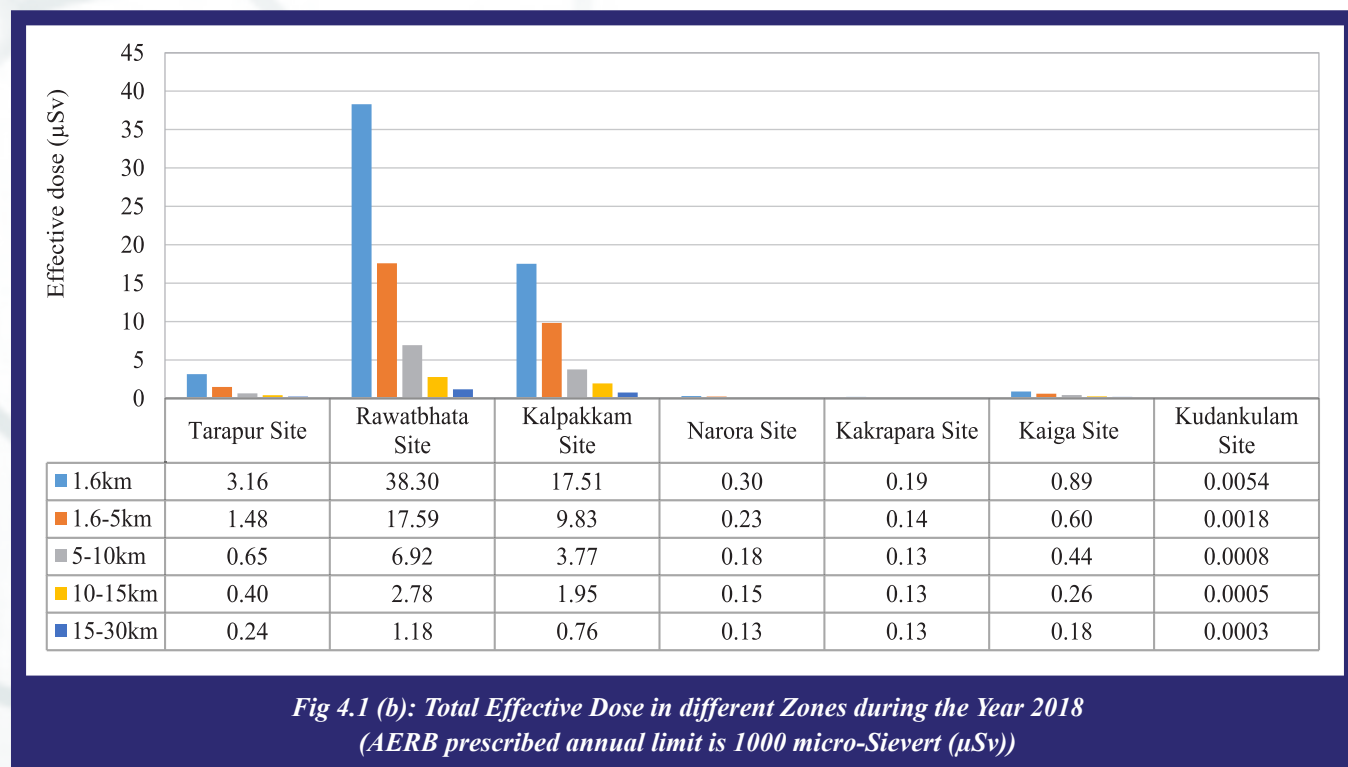
The independent Environmental Survey Laboratories (ESL) of the Health Safety and Environment Group (HSEG), BARC, carry out environmental surveillance at all the operating nuclear power plant sites. The liquid and gaseous radioactive wastes discharged to the environment during the year 2018 from the operating units were only a small fraction of the prescribed technical specification limits.

Radiation dose to the 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 the public around all NPP sites is far less than the annual limit of 1mSv prescribed by AERB. The effective doses to the members of the public (Year

2014 to 2018) due to the release of radioactive effluents from the plants are presented in the Figures 4.1 (a) and 4.1 (b).



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 (which are within the prescribed technical specification limits).



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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.

AERB Safety Manual on 'Radiation Protection for Nuclear Facilities' (AERB/NF/SM/O-2) 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, the following Investigation Levels (ILs) are specified for 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 below and above 20 mSv during the year 2018 is given in Table: 4.1. In the year 2018, there was no reported case of individual radiation exposure above the prescribed annual dose limit of 30 mSv. Figure 4.2 gives collective dose for operation and maintenance of NPPs for last 5 years.

The information on number of workers in medical, industrial and research institutions who received various doses during the year 2018 is given in Table 4.2.

Table 4.1: Radiation Doses Received by Workers in Nuclear Power Plants (2018)

NPP	Number of Monitored Persons	Average Dose for Monitored Person (mSv)	Number of Persons Receiving Dose	Average Dose Among Dose Receivers (mSv)	Number of Workers Receiving Dose in the Range	
					< 20 (mSv)	>20 (mSv)
TAPS-1&2	1,287	2.34	1,071	2.82	1,287	0
RAPS-1&2	1,112	1.84	810	2.53	1,112	0
MAPS-1&2	1,254	2.39	1,115	2.69	1,254	0
NAPS-1&2	1,351	1.46	1,030	1.91	1,351	0
KAPS-1&2	2,021	3.27	1,840	3.60	2,021	0
KGS-1&2	1,004	0.15	368	0.41	1,004	0
RAPS-3&4	1,745	2.30	1,387	2.89	1,745	0
TAPS-3&4	1,344	0.86	871	1.32	1,344	0
KGS -3&4	1,218	0.68	812	1.02	1,218	0
RAPS 5&6	1,285	0.83	930	1.15	1,285	0
KKNPP	2,455	0.36	684	1.30	2,455	0
Total	16,076	---	10,918	---	16,076	0

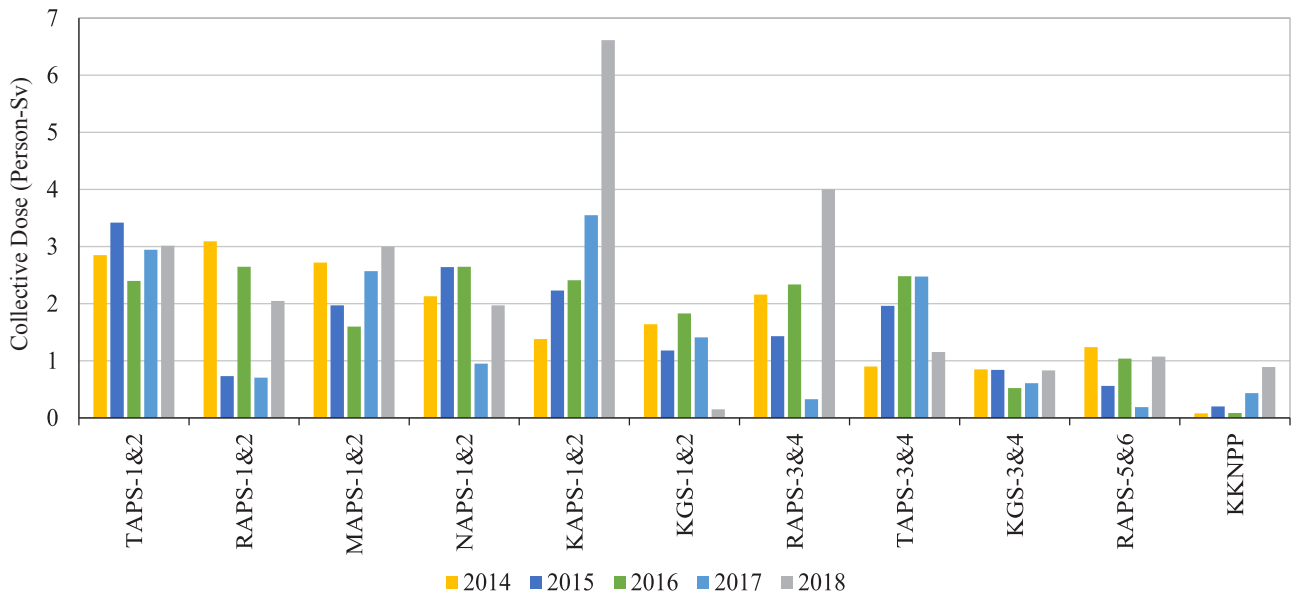


Fig 4.2 Collective Dose (Person -Sv) at NPPs

The information on number of workers in medical, industrial and research institutions, who exceeded radiation exposures in different ranges during the year 2017, was given in Table-4.2 of AERB Annual report for the year 2017. The

information for the year 2017 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: Radiation Doses (Effective) received by Workers in Medical, Industrial and Research Institutions during 2018*

Category of Radiation Worker	No. of Monitored Persons	Averaged Dose for Monitored Persons (mSv)	No. of Persons receiving Dose	Average Dose among Dose Receivers (mSv)	No. of Workers receiving Annual individual Dose Excluding zero Dose D (mSv)			
					0<D ≤20	20<D ≤30	30<D ≤50	D>50
Diagnostic X-rays	114126	0.24	41067	0.68	41060	7	0	0
Radiation Therapy	14661	0.14	4700	0.43	4700	0	0	0
Nuclear Medicine	2649	0.44	1410	0.84	1410	0	0	0
Industrial Radiography	7472	0.36	2350	1.14	2348	1	1	0
Radiation Processing Facility	76	0.01	8	0.14	8	0	0	0
Research	4172	0.09	1144	0.34	1144	0	0	0
Total /Average	143156	0.24	50679	0.67	50670	8	1	0

* Data (External dose) as on February 22, 2019 with National Occupational Dose Registry System (NODRS). The data does not include excessive exposure cases above investigation levels which are currently under investigation.

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

(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 Dose	Average Dose among Dose Receivers (mSv)	No. of Workers receiving Annual individual Dose Excluding zero dose D (mSv)			
					0<D ≤20	20<D ≤30	30<D ≤50	D>50
Diagnostic X-rays	107707	0.30	43740	0.74	43718	21	0	1
Radiation Therapy	14665	0.18	5120	0.52	5120	0	0	0
Nuclear Medicine	2698	0.56	1631	0.92	1631	0	0	0
Industrial Radiography	7353	0.49	2812	1.17	2810	1	0	1
Radiation Processing Facility	71	0.03	13	0.19	13	0	0	0
Research	4128	0.14	1392	0.43	1391	1	0	0
Total /Average	136622	0.30	54708	0.74	54683	23	0	2

*Data (External dose) as on February 22, 2019 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 and above 20 mSv during the year 2018 is given in Table 4.3.

Table 4.3: Radiation Doses Received by Workers in Front End Fuel Cycle Facilities (2018)

Type of Facilities	Location	Number of Persons Receiving Dose	Average Dose For Monitored Persons (mSv)	Maximum Dose of Monitored Persons (mSv)	Number of Workers Receiving Dose in the Range	
					< 20 mSv	> 20 mSv
Uranium mines (UCIL)	Jaduguda	371	0.27	0.78	371	0
	Bhatin	77	0.07	0.3	77	0
	Narwapahar	895	4.29	7.01	895	0
	Turamdih	582	5.39	12.07	582	0
	Bagjata	467	5.35	9.00	467	0
	Banduhurang	311	3.07	3.98	311	0
	Mohuldih	305	3.28	5.82	305	0
	Tummalapalle	824	4.54	6.76	824	0
Uranium mill (UCIL)	Jaduguda	750	3.3	9.48	750	0
	Turamdih	739	1.40	3.27	739	0
	Tummalapalle	557	0.17	0.34	557	0
Thorium mines and mills (IREL)	Chavara	83	0.34	2.85	83	0
	Manavalakurichi	144	1.08	7.33	144	0
	Chatrapur	456	3.41	18.63	456	0
	Udyogamandal	207	0.95	8.98	207	0
Fuel Fab. (NFC)	Hyderabad	1379	1.07	10.63	1379	0
	Total	8147			8147	0

4.3 BASIS FOR ACCEPTABLE DOSE TO OCCUPATIONAL WORKERS AND ENVIRONMENTAL RELEASES

The dose limit 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. The estimated dose to the members of the public due to discharge of radioactive effluents from nuclear facilities 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 an 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. 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.

- (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 conditions, benefits accrued by design improvements, identification of lapses in previous attempt of jobs and corrective actions taken etc. The aim is to optimise the collective dose through

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

Quarterly and annual reports on radiological safety aspects are prepared by the RSO of the NPP. The reports are reviewed at AERB and necessary corrective measures 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 disposal, 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 addressed suitably.

(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 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 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 learnt 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, and
- (g) Periodic training of radiation workers on radiation protection aspects.