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Implementation of ICRP-60 Recommendations on Dose Limits to Radiation Workers in India.

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INTRODUCTION

The handling of radioactive materials and radiation generating plants in India is regulated by the Atomic Energy Act, 1962 and rules issued under the Act. The radiation installations in the country include uranium mines and mills, thorium processing plants, fuel fabrication facilities, nuclear power reactors, research reactors, fuel reprocessing plants and waste management facilities. Nearly fifty percent of the 40,000 radiation workers in India are employed in medical, industrial and research institutions using radiation. .

The Atomic Energy Regulatory Board, set up in 1983, is the competent authority to enforce radiation safety related rules in the country. One of the functions of the Regulatory Board is to "prescribe acceptable limits of radiation exposure to occupational workers and members of the public". The Radiation Protection Rules, 1971 empower the competent authority to notify "operational limits" defined as limits on levels of radiation or on levels of contamination as the competent authority may specify from time to time. This is a very flexible procedure. According to the legal framework, if the competent authority is convinced that the limit will have to be changed he is empowered to change it by issuing a notification. This paper explains the regulatory mechanism to enforce radiation safety requirements in India, the way in which the latest recommendations of the International Commission on Radiological Protection (ICRP) was implemented in different institutions and the steps taken by various agencies in this direction.

RADIOLOGICAL SAFETY SURVEILLANCE

For the sake of administrative convenience all radiation installations in India are divided into three categories. The radiation installations where nuclear fuel cycle operations are being carried out and those in which ionising radiation is applied for medical, industrial or research purposes. The Safety Review Committee for Operating Plants (SARCOP) and Safety Review Committee for Applications of Radiation (SARCAR) carry out safety Review of these two categories of institutions respectively.

SARCAR issued a Manual on Radiation Protection for Nuclear Facilities. The manual provides the conceptual framework, classification of areas, dose limits and constraints, monitoring and assessment requirements for dose records and implementation of radiation protection measures, emergency plans and intervention levels among other items.

Each nuclear facility has a dedicated health physics unit administratively independent of the management who operates the installation. The health physics units distribute personnel monitoring badges keep track of radiation exposures and advise the management on radiation safety matters. The personnel monitoring devices are provided and evaluated by another independent agency.

The radiological safety surveillance in institutions using radioactive substances and radiation generating plants for medical, industrial and research purposes is carried out with the assistance of Radiological Physics and Advisory Division, Bhabha Atomic Research Centre (BARC). According to the mandatory provisions stipulated by the Radiation Protection rules, 1971, each radiation installation shall have a radiological safety officer approved by the competent authority. The Rules demand that every employer have to nominate one of his qualified employees to function as radiological safety officer for carrying out the functions stated in the Rules. Accordingly, the Board has classified the Radiological Safety Officers to be designated in different radiation installations as RSO level-I, RSO level-II and RSO level-III. The classification is based on a detailed review of the types of sources to be handled and their hazard potential. All radiotherapy centres including nuclear medicine therapy centres, high-energy particle accelerator facilities, industrial gamma irradiator facilities and major industrial radiography installations shall have an RSO level-II. Nuclear medicine facilities where radiotherapy is not carried out and industrial gamma radiography sites shall have an RSO level-II. Research institutions using unseated radioactive sources, users of nucleonic gauging devices gamma chamber and diagnostic X-ray installations shall have RSO level-I. One of the main duties of Radiological Safety Officers is to take all necessary steps to ensure that the dose limits are not normally exceeded.

AERB Safety Directives

During 1989, it was clear that the dose limits recommended by the International Commission on Radiological Protection were likely to be revised downward. The Atomic Energy Regulatory Board reviewed the radiation doses received by radiation workers in nuclear, medical, industrial and research fields. The review provided useful information on the impact of restricting the maximum individual exposure to different values of dose limits. When the ICRP issued the publication No. 60, the Board decided to implement the recommendations in a phased manner. As a first step the Board issued directives to all radiation installations reducing the dose limit to 40 mSv for 1991. The dose limits were reduced to 35 mSv in 1992 and 30 mSv in 1993 by issuing safety directives every year.To meet the recommendations contained in publication No. 60 of ICRP, the Board issued the following Safety Directive for the five-year block for 1994-98.

"AERB SAFETY DIRECTIVE – 6/94
Dose Limits for Occupational Exposures

AERB has been issuing Safety Directives from 1991 to reduce the occupational exposures to radiation in a phased manner in order to meet the dose limits recommended in ICRP-60 (1990). In pursuant of this, for the five-year block beginning with January 1, 1994, the following stipulations shall be implemented.

I *<u>Effective Dose Limits</u>*

a) The cumulative effective dose constraint for five years from January 1, 1994 to December 31, 1998 will be one hundred millisievert (100 mSv) for individual radiation workers.

b) The annual effective dose to individual workers in any calendar year during the five-year block shall not exceed the limit of thirty millisievert (30 mSv).

II Investigation Levels

Individual effective dose exceeding twenty millisievert (20 mSv) in a year shall henceforth be investigated by a Committee to be constituted by Chairman, AERB for this purpose. The Committee shall ensure that the five-year constraint of not exceeding one hundred millisievert (100 mSv) is met in all cases ***(Dose limits implemented by AERB is in a way more conservative than those of ICRP as the maximum dose annual limit is 30mSv instead of 50 mSv proposed by the ICRP. From January 1, 1999 the para I a) of the Directive was made applicable to consecutive five year blocks)***

As a follow up measure, AERB set up an apex review committee presided over by a member of the Board. The committee consisted of one specialist from health physics, radiation oncology, radiology, industrial hygiene, medical physics and an expert in industrial relations and personnel management. The committee is empowered to call employers, radiological safety officers, radiation workers and other related persons and to ask for relevant records from various radiation exposure review committees as appropriate.

Radiation doses to workers in different categories.

There was near total compliance with the AERB dose limits by the radiation installations in the country. Gradual reduction in persons receiving doses in excess of dose limits was clearly seen. For instance, in 1989, the number of radiation workers in nuclear power plants who exceeded the dose level of 20 mSv/year was 9% of the total. This gradually declined to 2.2% in 1993 and 0.3% in 1997. During 1998 only 9 out of the 10,145 exceeded 20mSv/year (Please see Table1). In medical, industrial and research applications of radiation the number of workers exposed to 20mSv/year and above was 0.27% in 1989 gradually lowering to 0.18% in 1998. The corresponding number of workers in industrial applications of radiation is 1.92% in 1989 to 0.45% in 1998. Several administrative steps helped in the implementation of the directives of AERB on dose limits

Over exposure investigations.

All exposures exceeding certain prescribed values are investigated promptly and reported to AERB. Separate committees for the nuclear fuel cycle facilities and for institutions using radiation sources for industrial, medical and research purposes carried out the investigations. Apart from examining the genuineness or otherwise of the radiation exposures, the committee recommended ways and means of controlling radiation exposures. These committees interacted with all concerned personnel at local level and kept track of exposure trends to alert the employers of areas of special concern. Since several pressurised heavy water reactors are operated in India, attention was paid to the dose contribution due to intake of tritium through inhalation of vapours of tritiated heavy water.

In all nuclear installations exposures above specified limits are investigated in detail. In case the exposures are found to be non-genuine by the investigation committee they will be reviewed at a higher level. In a similar way, all exposures above 10mSv and those above 20 mSv in non-nuclear installations are reviewed by a committee of specialists. The apex committee of AERB further reviewed the investigation reports of exposures above prescribed limits. The apex committee met as often as required. The managements operating the facilities were attentive to the activities of the apex committee and committed them to the need to reduce exposure of workers to, as low a value as is reasonably achievable. The muti-tier review mechanism in place did contribute significantly in implementing the dose limits prescribed by AERB. The review of all exposures above prescibed limits at various levels was an important factor in implementing dose control measures.

RADIATION CONTROL MEASURES

General procedure

1. Each nuclear power station has produced a dose control procedure to ensure individual dose control. Generally, the station management has prescribed monthly, quarterly, yearly and 5 yearly block limits, which are more restrictive than AERB limits.

2. Training is imparted to all radiation workers in basic radiological protection, emergency procedures and lessons learnt from operating experiences.

3. ALARA committees to achieve doses as low as reasonably achievable are set up to monitor doses. Procedures to issue radiological work permits are in place in regulating the entry of workers in high radiation field areas. On line computerised dose management system enables to get up-to-date dose data information of each individual. Exposures to workers are to be authorised appropriately when monthly in-house limit is exceeded. These authorisations are issued by higher authorities after careful review of the exposures received till then.

4. Reduction of iodine activity in primary heat transport system, reduction of Argon 41 leakage, control of crud level in heat transport system, ventilation balancing in various accessible and shut down accessible areas, reduction of heavy water leakage, shielding of hot spots, improvement of water chemistry regimes, prompt detection and removal of failed fuel bundles are some of the important steps taken to reduce radiation fields. These steps helped to reduce all unwanted exposures.

5. Decontamination of the pressurised heat transport system and substitution of cobalt free materials have helped to lower radiation fields. The seals of pumps in the pressurised heat transport system have been replaced with dynamic seals, which is not made from stelite. Circulating crud in the PHT system was removed by appropriate filtration. Tritiated water has been replaced periodically with virgin water to reduce tritium activity.

Specific Steps

Several steps were taken to reduce intake of tritium. These are very important, as tritium intake through tritiated water is a major pathway contributing internal dose to radiation workers in pressurised heavy water reactors. The following steps are noteworthy.

1.In some areas dedicated dryers were provided.
2.Diaphragm valves, which were prone to leak, were replaced with non-diaphragm type valves.
3.Leak prone equipment was checked more frequently.
4.Additional airline mask connections were provided in different locations.

Interzonal radiation monitors helped to control spread of contamination. Whenever high dose consuming jobs were to be carried out mock up facilities were provided in inactive areas. Jobs involving high radiation fields were carried out remotely. Remote air sampling set up for tritium, particulate and iodine sampling in each shift was provided to reduce exposure time, use of vacuum mopping to reduce tritium intake are the other steps taken at plant level.

Year	Total number of radiation workers	Those with annual dose exceeding					
		20 mSv		25 mSv		30 mSv	
		Number	%	Number	%	Number	%
1989	7947	672	9.00	432	5.40	235	3.00
1990	8179	260	3.20	122	1.5	46	0.60
1991	9734	464	4.80	163	1.7	65	0.70
1992	8781	322	3.70	94	1.1	13	0.15
1993	7854	169	2.20	9	0.1	2	0.03
1994	10830	53	0.40	5	0.05	4	0.04
1995	9851	31	0.30	7	0.07	1	0.01
1996	11090	95	0.85	20	0.18	2	0.02
1997	10008	39	0.30	4	0.04	3	0.03
1998	10145	9	0.09	1	0.01	3	0.03

Number of workers in nuclear plants exceeding 20 mSv Annual Doses.

Year	Total number of radiation workers	Those with annual dose exceeding									
		20 mSv		30 mSv		35 mSv		40 mSv		50 mSv	
		Number	%	Number	%	Number	%	Number	%	Number	%
1989	6191	119	1.92	45	0.73	26	0.42	19	0.31	8	0.13
1990	6180	76	1.23	21	0.34	23	0.23	7	0.11	1	0.02
1991	5714	60	1.05	19	0.33	13	0.23	5	0.09	2	0.04
1992	5375	54	1.00	20	0.37	11	0.20	9	0.17	3	0.06
1993	5212	49	0.94	18	0.35	12	0.23	5	0.10	2	0.04
1994	5122	32	0.62	15	0.29	11	0.21	9	0.18	8	0.16
1995	5325	25	0.47	5	0.09	5	0.09	5	0.09	4	0.08
1996	5296	19	0.36	7	0.13	7	0.13	6	0.11	6	0.11
1997	5154	18	0.35	6	0.06	3	0.06	2	0.04	2	0.04
1998	5390	24	0.45	15	0.22	12	0.22	10	0.19	7	0.13

Number of Radiation workers in Industrial Institutions with Annual Dose Exceeding 20mSv and above.

Year	Total number of radiation workers	Those with annual dose exceeding							
		20 mSv		30 mSv		35 mSv		40 mSv	
		Number	%	Number	%	Number	%	Number	%
1989	16457	44	0.27	15	0.09	7	0.04	5	0.03
1990	17053	37	0.22	11	0.06	7	0.04	3	0.02
1991	16834	36	0.21	6	0.04	5	0.03	4	0.02
1992	16231	32	0.20	16	0.10	12	0.07	9	0.06
1993	15021	24	0.16	9	0.06	7	0.05	4	0.03
1994	14079	29	0.20	17	0.12	14	0.10	12	0.08
1995	15882	37	0.23	11	0.07	8	0.05	7	0.04
1996	16069	12	0.07	5	0.03	4	0.02	2	0.01
1997	14982	19	0.13	14	0.09	7	0.05	7	0.05
1998	14169	26	0.18	17	0.12	16	0.11	15	0.11

Number of Radiation workers in medical Institutions with Annual Dose Exceeding 20 mSv and above

Table-1: No. Of persons exceeding 20 mSv and above in various categories.

Fuel design Changes and Replacement of Parts

Failure of fuel can lead to increase in radiation levels in the PHT system. Several design changes were introduced in fuel design to improve the fuel-clad integrity. These included lowering of the length to diameter ratio of fuel pellets, chamfering of fuel pellets with dished ends, increase in clad thickness and increase in helium pressure. Appreciable reduction in fuel failure helps to lower radiation fields. The activity in water is reduced. Air-borne radioactivity in plant areas and effluent discharges to the environment are also reduced. Several highly active piping and equipment were replaced. These included clean up heat exchangers, reactor vessel drain lines, overhead drain lines etc. Replacement of asbestos insulation over primary system with mirror insulation helped to reduce radiation levels.

Mineral Handling and processing

In monazite handling facilities, radiation dose to workers were reduced by reducing manual handling of active materials and by controlling internal exposures by engineered systems. Deployment of personnel in locations of high exposures was restricted. The health physics personnel identified operations, processes and situations causing high exposures by continuous surveillance. Several steps were implemented to reduce exposures. Sun drying of sand by employing manual labour was avoided. Monazite rich streams were segregated in process layout and monazite bins were shielded. Monazite was collected and stored directly in concrete silos and earthen trenches. Manual filling, stitching and loading of monazite was replaced by containerisation.

Monazite storage was located away from occupied areas. Wind table operations were stopped. Plate and frame filters used in filtering mixed hydroxide slurry, thorium concentrates and radium bearing mixed cake was replaced with rotary vacuum filters. Thorium concentrates were pumped directly into silos. In the monazite processing plant zoning of work areas was carried out on the basis of contamination potential. Shoe barriers were erected. Walls and other surfaces were epoxy painted. Shielding walls were erected to isolate the deactivation areas and concrete structures for storage of thorium concentrates and solid wastes. Implementing some of these recommendations in monazite handling and processing industries was not appreciated initially as these facilities were considered to be “chemical” plants. The presence of radioactivity was not recognised in the early years.

In uranium mines the most important contribution to radiation doses arises from the inhalation of radon decay products and to a lesser extent long lived alpha activity from airborne dust. Ventilation has been augmented in all the mines to reduce air-borne activity. In the ore handling sections of the uranium mill, the existing dust extraction system has been augmented. Al tanks containing process solutions have been covered and connected to the existing augmented ventilation system.

CONCLUSIONS

The directives of AERB on the dose limits to radiation workers could implemented in a phasedmanner because of the dedicated efforts of teams of radiation protection specialists and health physicists. The presence of independent health physicists in various installations is an important factor. These teams had collected exhaustive data on the radiation fields in different locations in the plants. Dedicated health physicists were in place in all important radiation installations many years before the setting up of a regulatory organisation. The muti-tier review of radiation exposures to workers, at the plant level and at the level of the Board helped to focus the attention of the management in implementing various suggestions to control radiation doses.

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