9

APPLICATION OF RADIATION IN MEDICINE, INDUSTRY AND RESEARCH

After Apsara and CIRUS reactors in Trombay started producing significant quantities of radioisotopes in early sixties, there was a phenomenal growth in the application of isotopes in medicine, industry and research. Soon it became apparent that the use of radiation sources in public domain warranted much greater attention than the DAE facilities which were all under the surveillance of Health Physics Division of BARC. In parallel the country was also witnessing regular induction of huge number of X-ray machines into the market virtually without any regulatory control. In fact, until the promulgation of the Atomic Energy Act in 1962, there was no agency identified with the responsibility to ensure protection from radiation generating plants such as medical X-ray units. The Section 17 of the Act specifically referred to making rules to ensure safe use of radiation generating plants and clearly it was DAE's responsibility to ensure the safety of the application of radiation sources in the public domain.

The need to educate and train the non-DAE personnel handling radiation sources and radioactive materials became imperative. It was to provide an effective radiation protection programme, Bhabha set up the Directorate of Radiation Protection (DRP) in 1963. DRP, headed by P.N. Krishnamoorthy, was under Electronics Group led by A.S. Rao as Director. P.N. Krishnamoorthy, well known for administrative acumen and organizational skill went ahead with organizing a nation wide radiological protection programme. The responsibilities of DRP included radiation surveillance in hospitals, industries and research institutions, authorization to procure sources, approval of site plan, provision of personnel monitoring services, preparation of safety standards and organization of radiation safety training programmes. In fact it was Head, DRP who was designated as competent authority under the Radiation Protection Rules, 1971.

Thus when AERB was formed in 1983, there already existed a fairly well organized safety framework in BARC in the form of DRP for the safety of radiation installations outside the Department of Atomic Energy and more importantly, P.N. Krishnamoorthy joined the Board as its Member Secretary. AERB secured several senior scientists from DRP to form a core group to jumpstart the regulatory activities in non-DAE installations. This group included I.S. Sundara Rao, K.S. Parthasarathy, D. Singh, R.N. Kulkarni, Masood Ahmad and K.R. Das.

The Board reviewed the regulatory activities carried out by DRP over the years and established a road map to streamline the activities. As per the constitution order setting up AERB, DRP/BARC was required to assist the Board in some of the essential activities. The Board noted that DRP had been playing more an advisory role than a regulatory role for the regulatory control of medical x-ray equipment and installations. AERB realized the need for establishing a firm legal basis and strong regulatory framework which included all radiation sources. This would mean promulgation of required rules, preparation of appropriate codes and guides and establishment of regulatory standards.

AERB set up an Advisory Committee on Radiological Protection in January, 1985. AERB soon issued surveillance procedures for medical application of radiation which elaborated the requirements for enforcing radiation safety stipulations in medical diagnostic and therapeutic applications of radiation. These documents were forerunners to publication of codes on teletherapy, brachytherapy and nuclear medicine.

Safety Review Committee for Applications of Radiation (SARCAR)

AERB constituted a Committee known as Licensing and Appellate Committee in October, 1987 and reconstituted it again in August 1989

with a view to streamlining the implementation of Radiation Protection Rules in all the institutions using radioisotopes and radiation sources in the country. M.V. Ramaniah (Former Chairman, DAE-SRC, BARC) was the first Chairman of the Committee.

The Committee recommended approval of Radiological Safety Officers, provided guidelines for education and training in radiation safety, reviewed and recommended "Type Approvals" of all radiation equipment as well recommended issuance of "No Objection Certificates" to such equipment imported from abroad. The committee reviewed and approved installation of plants for X-ray machines and Teletherapy units, evolved procedures for licensing of radioactive materials and registration of X-ray equipment. It reviewed and recommended applications for transport certificates for radioactive materials and reviewed the emergency preparedness plans for transport of radioactive materials. It provided norms for penal action and also to hear appeals from contending parties.

AERB classified the Radiological Safety Officers (RSOs) into three levels Level I, Level II and Level III. Among these Level III RSO is the most qualified. The Licensing and Appellate Committee reviewed the safety requirements of sources used in each application of radiation along with its hazard potential and decided the level of RSO to be designated in each category. High Intensity sources such teletheraphy units, accelerators and radiation processing units require an RSO at Level III, diagnostic nuclear medicine applications require RSO at Level II and simple diagnostic radiography unit needs to employ an RSO at Level I.

This Committee was re-constituted in September, 1991 as Safety Review Committee for Applications of Radiation (SARCAR) with A. Nagaratnam, formerly Director, Defence Laboratory, Jodhpur as Chairman. At present, A.R. Reddy, Formerly Director, Defence Laboratory, Jodhpur, is the Chairman.

SARCAR recommends granting of design/type approval of transport packages, radiation sources, radiation devices, consumer products, equipment and facilities based on safety review and assessment of applications submitted by the designers/manufactures/vendors. This Committee reviews and advises AERB on education and training programmes to meet the present and future requirements of qualified and trained manpower for radiation safety.

In addition to these functions, it reviews and recommends granting of authorizations for disposal of radioactive wastes generated in medical, industrial, agriculture and research applications under the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 and reviews the dosimetry in food irradiation and recommends granting of certificate of approval under the Atomic Energy (Control of Irradiation of Food) Rules, 1996. It examines the cases of safety violations and recommends corrective measures.

What is SARCOP to DAE installations is SARCAR to non-DAE installations. The only difference is that SARCOP is delegated with some powers to enforce regulatory restrictions on DAE installations. The recommendations of other committees serving the functions of Radiological Safety Division (RSD) are sent to SARCAR for review and follow up. Recommendations of SARCAR are forwarded to Chairman AERB for further regulatory action.

Medical X-Ray Installations

Regulation of medical X-ray units in the country posed an immediate challenge to AERB soon after its formation. AERB set up a seven member group in 1986 to review the existing status of radiation protection measures in medical X-ray installations. The committee evaluated the effectiveness of the existing programme by visiting a cross section of institutions. The committee observed several deficiencies such as improper layout, lack of protective accessories, inadequate training of staff, etc., prevalent in various X-ray installations.

AERB organized a national seminar in March 1986 on "Radiation Exposures in Medical X-ray Practices: Consequences and Control". The invitees included Health Secretaries, Directors of Health Services and Directors of Medical Education from State Governments, representatives from regulatory agencies, standards organizations and professional associations, eminent radiologists, X-ray equipment manufacturers, physicians, radiological safety officers, medical physicists and other professionals.

Recognizing the need to evolve a broad consensus on the regulatory steps to be enforced, A.K. De, Chairman, AERB set up a specialist committee in 1985 under the Chairmanship of Arcot Gajaraj, an eminent radiologist and the then Director of Barnard Institute of Radiology, Chennai to prepare a comprehensive report on the implementation of radiological safety requirements of medical X-ray equipment and installations. The Committee had representation from the Directorate General of Health Services, AERB and BARC. The detailed report of the committee provided practical insights into various issues and was immensely useful to AERB to draw up future course of action.

AERB decided in 1986 that certain regulatory controls were necessary to ensure safety in the design, manufacture, installation and use of medical X-ray equipment. AERB supported the Bureau of Indian Standards in the development of Indian Standards for medical X-ray equipment. The Bureau issued the following standards in 1986:

1. Standards specification for diagnostic X-ray equipment, Part 3 -Radiation safety requirements.
2. Standards specification for radiation safety of dental X-ray equipment.

The total number of X-ray installations in India was not known accurately then. A. Gopalakrishnan, then Chairman AERB secured the support of Council of Scientific and Industrial Research (CSIR) and

Defence Research and Development Organization (DRDO) through a memorandum of understanding for the registration of medical X-ray machines all over the country. Six laboratories of CSIR and 15 laboratories of DRDO participated in the programme.

AERB arranged six orientation programmes in 1994 covering various safety related aspects to train 125 inspectors from CSIR and DRDO for collecting the above data. Chairman, AERB wrote to all State Chief Secretaries and Health Secretaries requesting their support and cooperation for the registration programme. Chairman, AERB also brought to their notice the need for enforcing AERB guidelines and requirements in the medical X-ray installations in the hospitals under their control.

AERB sent the information on AERB guidelines for medical X-ray installations to all district authorities in India through the NICNET system of National Informatics Centre requesting their cooperation. The district authorities sent addresses of medical X-ray installations located in their area. This provided the initial input to the X-ray registration programme. The inspectors from CSIR and DRDO collected data on 30,583 X-ray installations. The programme did have a tremendous impact. Now in the year 2008 the number of diagnostic X-ray units registered is around 50,000. The staff of AERB made a detailed analysis of the data collected and sent letters to all the above institutions and where deficiencies were observed, directions were given to remedy the deficiencies.

In order to improve the status of radiological safety in medical X-ray installations, quality assurance test of each X-ray unit had to be carried out and the deficiencies found were to be remedied. A quality assured X-ray unit would result in optimizing the radiation dose to patients and minimizing radiation exposure to radiation workers. AERB and Radiological Physics and Advisory Division (RPAD), BARC organized a few QA workshops for the benefit of staff in radiation units of the hospitals.

Effective control on such a widely used diagnostic tool is possible only if the regulatory responsibility is decentralized. Exercising the powers conferred by the Radiation Protection Rules, 1971 Chairman, AERB authorised Director, Directorate of Radiation Safety, Government of Kerala to carry out inspection of medical diagnostic X-ray installations in Kerala. The Directorate has been functioning for the past many years and has been submitting to AERB periodic reports about its inspection activities. AERB has been urging other State Governments to start similar Directorates to enforce the mandatory requirements in their medical X-ray installations. AERB web page carries information on registration procedure and also a list of type approved X-ray machines.

Radiation Therapy and Nuclear Medicine

With the life expectancy of the population increasing steadily over the years, there is a corresponding increase in the number of cancer patients in the country. To meet the growing demands for treatment of cancer, more and more numbers of hospitals and therapy units are added, For example, in the past five years fifty more hospitals, fifty more telecobalt units, fifty more nuclear medicine centres and sixty more accelerators have been added. Also the newer machines have several novel treatment and safety features. AERB with the help of RPAD has been carrying out the safety assessment of these units.

Gamma Radiation Processing Plants

High intensity gamma irradiators are widely used in the world on industrial scale for many radiation processing applications. These include sterilization of medical products, irradiation of food materials to prevent sprouting or rotting or to delay ripening, treatment of sewage, etc. Though the first few gamma irradiator plants were designed and operated by a DAE unit, subsequently several such units operated by private companies have come up in various states in the last two decades. In view of the very large inventory

(10^{15} to 10^{17} Bq) of Co-60 sources involved and high potential for severe exposures, gamma radiation processing plants undergo a multi-tier safety review process. AERB has issued a Safety Code on Land Based Stationary Gamma Irradiators, which specifies the various regulatory requirements to achieve safety. The safety of the gamma irradiator plants are reviewed by a Safety Committee on Gamma Irradiation Processing Facilities (SCOGRAPP) chaired by A.R. Sundararajan, former Director, RSD, AERB. The recommendations of the committee are reviewed by SARCAR before authorizations are issued by Chairman, AERB.

Particle Accelerators

Accelerators used for accelerating various atomic particles like electron, protons and heavy ions are used not only for experimental studies in nuclear physics but also for several applications in medicine and industry.

DAE facilities

Department of Atomic Energy had established a Variable Energy Cyclotron Centre (VECC) at Kolkata in 1970. This Centre has a Variable Energy Cyclotron which can accelerate protons, deuterons and other heavy ions at various energies ranging from tens to hundreds of MeV. A super conducting cyclotron, set up within the VECC premises and meant to accelerate heavy ions with energies in Giga electron volt range is in its initial stage of commissioning. VECC has also proposed to install a medical cyclotron to accelerate proton ions up to 30 MeV at 500 micro amperes current for production of PET and SPECT isotopes. This facility will also have beam lines catering to the experimental requirements of BARC and IGCAR. The project is in its construction stage.

The Centre for Advanced Technology, presently known as Raja Ramanna Centre for Advanced Technology (RRCAT) was established in 1983 at Indore. The Centre now houses several accelerator facilities like microtron, linear accelerator, DC accelerator

and synchrotron facility known as INDUS-I with 450/700 MeV at 30 mA. The second synchoroton facility INDUS-2 with 2.5 GeV capacity at 300 mA is presently in commissioning stage.

The safety review of both, VECC and RRCAT facilities is carried out by VECC-RRCAT Safety Committee (VRSC) chaired by M.R. Iyer, former Head, Radiation Standards and Systems Division (RSSD), BARC.

Non-DAE Facilities

There are also many accelerators in the private sector essentially catering to industrial and medical applications. Accelerators are fast replacing radiotherapy machines using Co-60 sources. Electron beam accelerators are used for cross linking and chain scission of polymers to improve the strength of the insulators of the cable and also to enhance their water repellant properties. M/s Radiant Electron Beam Technology Centre at Hyderabad has three electron beam accelerators with energy upto 2.5 MeV and M/s NICCO Cables Pvt. Ltd. at Kolkata has one electron beam accelerator of 3.0 MeV for irradiation of electrical cables. Also a number of medical cyclotrons have been installed in the recent times for production of medical isotopes like F-18, Ga-67, Tl-201, etc. All these units have been reviewed by Safety Committee for Medical, Industrial and Research Accelerators (SCMIRA) chaired by M.R. Iyer.

Safety in Transport of Radioactive Materials

A large number of radioactive consignments, nearly 80,000 per year, containing radioactive materials in different forms, varying nature and quantities are being transported within the country for use in medicine, industry, agriculture and research, and also for nuclear fuel cycle activities. In addition, radioactive materials are also imported and exported or pass through the country in transit. Radiation Surveillance Procedures for the safe transport of radioactive materials were formulated in 1987, which stipulated the requirements for ensuring safety to persons, property and

environment associated with such transportation. Ever since, the competent authority is approving every package deployed for shipment and only the packages of approved design are being used. Designers, manufacturers, consigners and users of such packages comply with the requirements including submission of safety report on the package design, test reports. and quality assurance manual as applicable to specific packaging or shipment. Certain shipments such as those for teletherapy sources, high activity radiation sources used for certain exposure devices, high intensity irradiators, etc., cannot be carried out without prior approval from AERB.

A Committee on Safe Transport of Radioactive Material (COSTRAM) has been constituted in May 2003 by Chairman AERB to review various safety aspects of transport of radioactive material chaired by R.G. Agarwal, Head, RTD, BARC.

Regulatory Inspection of Radiation Facilities

Inspection and enforcement activities are important components of regulatory functions of AERB. The objective of the inspection is to ensure that the stipulated regulatory requirements related to handling of radiation sources are fulfilled in practice. The then Industrial and Radiation Safety Division (IRSD), under the Directorate of Regulatory Inspection and Enforcement (DRI&E) was responsible for carrying out such inspections of all the non-DAE institutions where radioactive materials and radiation generating plants were handled and used. Subsequent to the re-structuring of divisions of AERB, the Radiological Safety Division (RSD) is responsible for carrying regulatory inspections of all non-DAE radiation facilities. RSD prepares the schedule of inspections as per the category of radiation facility which depends on its potential hazard. Plants with high intensity sources like gamma radiation processing plants are inspected once a year while radiotherapy units are inspected once in three years.

In 1994, IRSD had arranged eight teams to carry out the first ever large scale surprise inspection of about 25 industrial radiography sites located in and around the cities of Surat, Bharuch, Baroda and Ahmedabad in Gujarat State to ascertain whether the radiography sources were handled in a safe manner. Since then, such surprise inspections are periodically carried out and about 100 radiography sites / institutions located all over the country are covered yearly in this surveillance programme.

The major violations observed during the inspections include source movements from one radiography site to another site without prior approval of the Competent Authority, operation of radiography exposure devices by uncertified persons (trainee radiographers), inadequate physical security to source storage rooms, improper radiation survey instruments, non-availability of emergency accessories / safety records and not using personnel monitoring badges while carrying out radiography work. These violations are categorized into four different classes from minor to extremely serious violations with a view to streamlining the enforcement actions.

Based on these inspections and the findings thereof, AERB took action against those institutions which were found to be violating the safety norms. In some instances, the radiography sources were recalled from the offending company for a minimum period of three to six months, while further investigations continued. Radiography personnel such as Site-In Charge, Radiographer etc. who failed to carry out their duties as per AERB stipulations were asked to surrender their authorization certificates. Radiography work was suspended in a few cases by sealing the radiography exposure devices at site and directing that they should not be used until further instructions.

Enforcement and Follow-up

AERB enforces regulatory actions as per the Atomic Energy (Radiation Protection) Rules (RPR), 1971 which was revised in 2004, on the basis

of assessment of radiological risk to the radiation workers and members of the public from violations observed. The show-cause notices and warning letters are issued before enforcement of any regulatory actions. The regulatory actions to be enforced are recommended by the Standing Committee for Industrial Radiography (SCIR) which was first constituted in January, 1995 chaired by G. Venkataraman. Since then, SCIR has been re-constituted twice and now renamed as the Standing Committee for Investigation of Unusual Occurrences in Radiation Facilities (SCURF) chaired by B.C. Bhatt, former Head, RPAD.

Two radiography agencies and one of the radiography personnel challenged the regulatory actions enforced by the Competent Authority in the judicial Courts. However, in all these cases the Court has upheld the actions enforced by the Competent Authority proving the necessity of enforcement of actions in the interest of public safety.

Action against Hospital in New Delhi

In view of the lack of compliance with several safety requirements, AERB had sent a directive to the Medical Superintendent of a Hospital in New Delhi and to the Health Secretary, Delhi State on April 6, 1995 to stop accepting or scheduling any new patient for radiotherapy until such time radiation protection requirements are fully complied with. The violations by the hospital included non-appointment of a Radiological Safety Officer, in spite of repeated reminders, failure to provide personnel monitoring badges and failure to calibrate therapy dosimetry units. AERB lifted the ban imposed on the Hospital with effect in January 1996 when these deficiencies were corrected. A very similar situation prevailed in yet another hospital in Delhi in October 2003 necessitating a ban on the treatment from AERB for about a month.

Recovery of Lost Radioactive Source in Coovum River

While discharging its regulatory function, AERB did encounter a

few ticklish problems to handle and which also caught the attention of the press and the public. One such case is mentioned here.

Three radioactive sources consisting of two americium-beryllium (Am-Be) neutron sources of strength 684.5 GBq and 18.5 GBq and one caesium-137 (Cs-137) source of strength 55.5 GBq were allegedly stolen from the premises of a foreign company based in India, engaged by Oil & Natural Gas Commission (ONGC) for oil well-logging operations. The authorization to import these sources was issued by BARC to ONGC in January, 1990. The first information report (FIR) regarding theft of the sources was received on September 23, 1993 by Madras Police.

Preliminary investigations indicated that the company which was expected to keep three high activity, long half-life sources in safe and secure custody had not complied with this obligation. ONGC, the party to whom import authorization was issued, had also failed to oversee the operations to ensure the security of these sources. In view of this, AERB ensured by a directive that the foreign company suspended all its well logging operations using radioactive sources in India.

Several teams of scientists were mobilized by AERB to survey all potential areas where the miscreants could have thrown or hid these sources, extensively covering in this process over 450 km of roads in the city and surroundings. Police inquiries eventually indicated that the sources were lying in a slushy area in the Coovum river bed within Madras city limits. Specialists from the Atomic Energy Regulatory Board (AERB), Bhabha Atomic Research Centre (BARC), Oil and Natural Gas Commission (ONGC), Larsen & Toubro (L&T), Madras and the Indian Institute of Technology (IIT), Madras deliberated on various options to recover the lost sources safely. The sources were finally recovered intact after erecting a coffer dam around the region in which the sources were lying, to allow local dewatering,

and after a prolonged and tedious 'fishing' operation. There were instances in India and elsewhere in which such sources were lost in an irrecoverable manner either in the oil well itself or in areas such as sea beds. There are standard practices to manage such incidents.

After this event AERB did an extensive study of the issues involved in such operations and prepared a comprehensive document on the safety requirements for well logging operations. The Board instituted additional measures to ensure safety of such sources.

Withdrawal of Radium from Indian hospitals

Radiotherapy using radium was the most widely used mode of treatment for cancer in the early days until safer substitutes arrived. Radium was also the most hazardous of all the sources used in a therapy centre.

The earliest stock of radium in India arrived at the Radium Institute, Patna, in 1930. Sixty-five hospitals had totally about 20 grams of radium contained in the form of a fine powder in hundreds of platinum-iridium tubes and needles with a wall thickness of 0.5 mm. During those early years, several sources became leaky due to uncontrolled heat sterilisation and inadvertent rough handling. Many needles got bent when physicians applied them directly by piercing tissue. There have been several instances of mishandling of radium including the release of the body of a cancer patient without removing the sources. Many hospitals had lost their sources. Some radium sources might have leaked due to gas pressure developed internally. Starting 1957, scientists from BARC visited these hospitals to separate leaky sources. They recommended once in six months leak testing of all radium sources.

The Board of Radiation and Isotope Technology (BRIT) distributed kits loaded with caesium-137 as a safe replacement for radium. In 1988, AERB directed the withdrawal of radium from hospitals and its safe disposal in the interest of overall radiation safety. BARC collected

and disposed of the sources safely. Withdrawal of radium from India was a unique project. AERB could achieve it with the support of BARC in collecting the sources and disposing them of safely. In many countries unused radium is remaining in hospitals as final disposal is expensive and no one is willing to take the responsibility to accept them for disposal.

Management of Cadavers with Residual I-131 activity

There were a few cases where the patients administered with I-131 therapeutic doses died with high residual activities in the body. Relatives of the patient always would like to have the body for cremation immediately but from radiological safety angle, the bodies with high residual activities could not be released. These cases were managed under strict radiation protection program which included wrapping of the body in double polyethylene bags, maintaining a safe distance during transportation and burial.

Radioactivity in Foodstuffs: Regulatory Steps

The accident at the Chernobyl nuclear power station occurred on April 26, 1986. Shortly thereafter, radioactive fallout had shown up in foodstuffs in various countries. Public got concerned about the health impact of these contaminated food items. Food restrictions in European countries fuelled the fears.

Many felt that contaminated food items may be sold or gifted to third world countries. As a proactive measure, the Atomic Energy Regulatory Board (AERB), the competent authority to enforce radiation protection in India, enforced regulatory measures to protect the public from undue radiation exposures.

In order to evolve a consensus opinion of a wide cross section of specialists on radiation protection policies, AERB organized in 1987 a national meeting of senior specialists from the Ministries of Agriculture, Food and Civil Supplies, Health and Family Welfare, Commerce, Environment and Forests, Bureau of Indian Standards,

Marine Products Export Development Authority, Export Inspection Council, Tea Board, Indian Dairy Corporation, National Institute of Nutrition, Consumer Guidance Society of India, Research Institutes dealing with Food Technology, Fisheries and Toxicology and Bhabha Atomic Research Centre (BARC).

The International Commission on Radiological Protection (ICRP) had stipulated dose limits for members of the public. In the absence of other precedents to go by, the specialists group in India decided that the contribution from man made radionuclides in food items should only be a small fraction of this dose limit. This led to overly conservative values of concentrations. Based on the recommendations of the specialists, AERB prescribed the permissible levels of Iodine-131, Strontium-90 and Caesium-137 in food items.

AERB recognized three BARC laboratories at Kolkata, Kalpakkam and Trombay for measuring and certifying radioactivity in the food samples sent to them. The Directorate General of Health Services instructed their offices located at ports to send samples of imported food for testing. This covered the bulk imports of food items. BARC laboratories tested thousands of samples over the past several years. On rare occasions, when they found samples containing levels above those prescribed by AERB they issued suitable instructions.

A development, which received wide media coverage, pertained to the safety of 200 Metric Ton of Irish butter imported into India in 1987. Three office bearers of the Maharashtra State Government Employees' Federation approached the High Court of Bombay for an appropriate order banning the import of any milk or milk products and in particular butter from Ireland. After reviewing the procedure followed by AERB, the High Court rejected the petition.

On the same issue there was also a special leave petition in the Supreme Court of India. After hearing the counsels for the petitioners and respondents, the Supreme Court thought it fit to appoint a

committee of three experts namely M.G.K. Menon, P.K. Iyengar and G.V.K. Rao to give its opinion on the safety of milk and dairy products and other food products containing man-made radionuclides within permissible levels prescribed by the AERB. After perusing the opinion of the committee of experts, the Supreme Court dismissed the petition.

Currently there are many laboratories, both DAE and non-DAE which have been accredited by AERB to measure low levels of radioactivity in commodities including food materials.

In line with International Regulations

AERB derives its radiological safety standards from those of International Organizations like International Atomic energy Agency (IAEA) or International Commission on radiological Protection (ICRP). When ICRP issued in 1990 its recommendations on the dose limits to radiation workers and the members of the public, AERB decided to implement them in a phased way. The Board reviewed the data on the radiation exposures to workers in different categories, held meetings with different stake holders and issued a series of Safety Directives over the next few years to implement the recommendations of ICRP. In fact, AERB is one among the handful of countries which implemented them promptly. When AERB finally implemented the recommendations, the dose limit to radiation workers prescribed by it was more conservative than that of the ICRP. Whereas ICRP recommended an annual dose limit of 50 mSv, the limit prescribed by AERB was only 30 mSv.

An important development during the nineties was the publication of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS). These standards were prepared jointly by the International Atomic Energy Agency (IAEA), the International Labour Organization (ILO), the World Health Organization (WHO), the Food and Agricultural

Organization (FAO) and Pan American Health Organization (PAHO). These standards explicitly required licensing of fuel cycle facilities, including nuclear reactors and radiation sources used in medical, industrial and research applications.

The recommendations of BSS were taken into account while framing Radiation Protection Rules, 2004. The rules specify the functions and responsibilities of the employer, the licensee, the workers and the radiological safety officers. The regulatory consenting scheme was decided on the hazard potential of the sources. The highest level of consent was called "Licence" and covered nuclear fuel cycle facilities, high intensity radiation sources such as gamma irraditors, teletherapy units accelerators, computed tomography units, interventional radiology units, etc. The other consents were authorization, registration and approval.

Current Scenario

In the last two decades the number of radiation installations and devices has registered a phenomenal increase, be it in the application in medicine or in industry. The radiation sources/installations include 300 telecobalt therapy units, 100 accelerators, over 2,000 Computed Tomography scan units, 150 nuclear medicine centres, 1400 industrial radiography cameras, 8000 nucleonic gauges and 14 gamma radiation processing plants.

AERB has put in place an elaborate scheme to ensure that in the use of all these installations and devices, both the occupational workers and members of the public do not receive undue radiation exposures. As part of this scheme, all devices including radiation generating equipment and those incorporating radioactive sources are subjected to a type approval procedure. AERB permits only type-approved devices to be marketed in India. AERB stipulated the criteria for type approval in the Standards Specifications (SS) documents for a variety of devices. These SS documents are periodically reviewed and

revised, where necessary, in order to be in tune with internationally accepted and current standards.

Yet another major initiative AERB undertook in recent times was the creation of extensive computerized data base on the entire inventory of radiation sources used in medicine, industry and research. The system allows the tracking of any radiation source from its procurement to disposal and thus ensuring its safety and security.

Major Inputs by: *K.S. Parthasarathy, A.R. Sundararajan, S.P. Agarwal and A.U. Sonawane*