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SAFETY AND SECURITY OF RADIOACTIVE SOURCES

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भारत सरकार
Government of India
भाभा परमाणु अनुसंधान केंद्र
Bhabha Atomic Research Centre
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60 *Abstract :* A Task Group was appointed by Chairman, AERB to review the current practice and recommend procedures for ensuring the Safety and the Security of Radioactive Sources in India. The Task Group identified the issues involved and concluded that the current regulatory procedure relating to licensing was adequate in view of the stress placed on pre-licensing requirements and the undertakings obtained from the licensee and ensuring that appropriate radiation monitors and trained personnel are available at the licensee's institution. Each licensee is required to submit periodic reports confiriming the safety and the security of the sources in the possession of the institution. It is important to conduct regulatory inspection of the institutions frequently. In order to optimise the regulatory effort involved, the report recommends frequencies of inspections commensurate with the potential hazard associated with the source. For this purpose the sources are brought under three categories which are largely based on the categorization recommended by the International Atomic Energy Agency (IAEA), Vienna with deviations introduced on the basis of rationalized hazard potential associated with the sources. The importance of technical coordination between AERB and BARC is emphasised.

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ABSTRACT

A Task Group was appointed by Chairman, AERB to review the current practice and recommend procedures for ensuring the Safety and the Security of Radioactive Sources in India. The Task Group identified the issues involved and concluded that the current regulatory procedure relating to licensing was adequate in view of the stress placed on pre-licensing requirements and the undertakings obtained from the licensee and ensuring that appropriate radiation monitors and trained personnel are available at the licensee's institution. Each licensee is required to submit periodic reports confirming the safety and the security of the sources in the possession of the institution. It is important to conduct regulatory inspection of the institutions frequently. In order to optimise the regulatory effort involved, the report recommends frequencies of inspections commensurate with the potential hazard associated with the source. For this purpose the sources are brought under three categories which are largely based on the categorization recommended by the International Atomic energy Agency (IAEA), Vienna with deviations introduced on the basis of rationalized hazard potential associated with the sources. The importance of technical coordination between AERB and BARC is emphasised.

PREFACE

A Task Group with Dr. B.C. Bhatt, Head, RPAD, BARC as Chairman and Shri P. K. Ghosh, Head, IPSD, AERB and Dr. A. N. Nandakumar, RSD, AERB as members was constituted by the Chairman, Atomic Energy Regulatory Board, in April 2000 to review the current practice and recommend procedures for ensuring the Safety and the Security of Radioactive Sources in India, to examine the Code of Conduct on the subject which was proposed by the International Atomic Energy Agency, Vienna and suggest modifications/ additions, if any, and formulate an action plan for implementation of the Code.

This report is largely a result of the report submitted by the Task Group which was accepted by AERB. The Task Group had detailed and exhaustive deliberations on the issues involved and prepared a report.

CONTENTS

THE SAFETY AND THE SECURITY OF RADIOACTIVE SOURCES

1. INTRODUCTION

Application of radiation sources in medicine, industry, agriculture and research has registered a phenomenal growth in number and variety over the years. Some of the devices incorporating radioactive sources are-

- gamma irradiators
- teletherapy units
- brachytherapy units
- gamma chambers
- industrial gamma radiography exposure devices
- industrial ionising radiation gauging devices and
- consumer products such as Ionisation Chamber Smoke Detectors (ICSD).

There are, besides, many X-ray and accelerator installations, which are being used for medical, industrial and research applications.

The number of radiation sources which are deployed in various fields of application in India, are estimated to be –

- industrial radiography sources : 1100
- gamma irradiator sources (^{60}Co) : 12
- telecobalt units : 243
- tele caesium units : 9
- brachytherapy sources (^{60}Co, ^{192}Ir, ^{90}Sr, ^{137}Cs, ^{226}Ra) : 183
- nucleonic gauges housing different radiation sources (^{241}Am, ^{241}Am-Be, ^{137}Cs, ^{60}Co, ^{90}Sr, ^{147}Pm, ^{14}C, ^{55}Fe, ^{85}Kr) : 7500

Two types of sources are considered in the following discussions, viz. unsealed sources and sealed sources.

Unsealed Radiation Sources

Generally most of the unsealed sources are used up during their "useful life", for example, unsealed sources used in nuclear medicine and industrial radiotracer studies. The process of authorization assures the safety and the security of the unsealed sources. Except in the case of devices incorporating long-lived radionuclides (e.g. radium painted dials), the use of unsealed source does not pose a significant safety and security problem.

Sealed Radiation Sources

Since the sealed sources are not completely "consumed" during their application, every source supplied to an authorised user, upon completion of its "useful life", is required to be sent, by the user, to the agencies authorised to accept radioactive material for safe disposal. This requires continual accounting of these sources. Thus, the safety and the security of sealed radioactive materials demand considerable regulatory efforts. The national inventory of all sealed radiation sources is being maintained and updated periodically. The inventory is updated every time a new or an additional source is authorised to be supplied to a licensee and also when a decayed source is returned for safe disposal. There are 70 high-energy medical, industrial and research accelerators some of which incorporate depleted uranium as the shielding material in the head of the units. Though depleted uranium does not pose a significant radiological hazard, an inventory of accelerators is maintained.

2. THE EXISTING REGULATORY FRAMEWORK IN INDIA

ACT and RULES

The basis of legislative control of use of radiation in India is the Atomic Energy Act, 1962[1] and it provides the basic regulatory framework for all activities related to the use of ionising radiation in India. The section 3 (e) empowers the Central Government to provide control over radioactive substance. Sections 16 & 17 deal with the control of radioactive substance and special provision to safety.

Exercising the powers conferred by the Atomic Energy Act, 1962[1], the Central Government promulgated the following rules related to radiological safety:

1. Radiation Protection Rules, 1971(RPR, 1971)[2]
2. Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987[3]
3. Atomic Energy (Control of Irradiation of Food) Rules, 1996[4]

The above rules specify, *inter alia*, the requirements of-

- licensing or authorisation,
- power to revoke or modify or withdraw the licenses,
- the duties and responsibilities of Radiological Safety Officers and their qualifications,
- radiation surveillance procedures[5-7],
- powers of inspection of radiation installation,
- powers to seal and seize radioactive material.

Each of these rules also confers on the Central Government powers to designate a competent authority to enforce the relevant rules. The Atomic Energy Regulatory Board

(AERB), who in the competent authority, prescribes the regulatory requirements for the safety and the security of radioactive sources.

AERB notifications safety specifications

AERB has published several safety standards specifications, codes, guides and manuals. They elaborate safety requirements and ways to achieve them. Surveillance procedures have been notified by the Competent Authority under rule 15 of the Radiation Protection Rules, 1971, for industrial radiography[5], medical application of radiation[6] and in transport of radioactive materials[7]. It is mandatory for any person handling radiation sources to comply with the requirements of the above rules and notifications. The term, 'handle' means manufacture, possess, store, use, transfer by sale or otherwise, export, import, transport or final disposal.

Radiological Physics & Advisory Division (RPAD), Bhabha Atomic Research Centre provides technical and executive support to AERB to ensure compliance with the regulatory requirements in the applications of radiation sources.

Details of the present system to deal with spent sources are provided in the Appendix 1.

3. PROCEDURE FOR THE RECOVERY OF LOST SOURCES

There have been a few instances of lost sources. Sources may be lost due to many reasons. Examples of possible scenarios of lost sources are –

- Theft of radiography sources
- Unsafe handling of brachytherapy sources
- Mishandling of radioactive consignments by carrier
- Disposal of devices such as nucleonic gauges due to long disuse by the licensee
- Unclaimed sources.

The procedure adopted for the recovery of lost sources is discussed in Appendix 2.

4. A NATIONAL STRATEGY FOR THE RECOVERY OF SPENT SOURCES

The regulatory measures taken to ensure effective management of disused sources are implemented in three stages.

Pre-licensing stage

At the time of tendering pre-licensing technical advice to the prospective user of a radioactive material, an undertaking is obtained from the user to the effect that the source,

whether imported or locally procured, would be sent back to the supplier, after its "useful life".

During the "useful life" of the source

Under the terms and conditions of the licence, each licensee is required to send periodic reports to the Competent Authority regarding the radiological safety status of the institution and confirming the safe dispositions of the radioactive sources in their possession.

If it is observed from a periodic status report that a certain source is not in use and is unlikely to be used, the licensee is immediately advised to arrange for the safe disposal of the source. However, if a source remains disused for longer than the stipulated period and is expected to be used eventually, a safety audit is conducted in order to physically verify the presence of the source, the condition of the source holder and its suitability for the intended use. Thus the existing system can identify a disused source without delay. When the periodic status report from an authorised institution is not received within the stipulated period, the consentee is alerted and cautioned that such failure may entail cancellation of the consent to handle the radioactive material. Invariably, the consentee sends the required status report regularly thereafter. During the use of radiation sources, specific prior approval of the Competent Authority is required in respect of every source replacement, sale, transfer, transport, export and disposal.

After the "useful life" of sources

When a source becomes unusable, the user is required to send it to the authorized disposal agency. In order to ensure that the source does not get misplaced during transportation, the consentee is advised on packing the radioactive material in an appropriate transport container, marking, labelling and instructions for handling emergencies, if any, during transport. Prior to the dispatch of the disused source for disposal, consent approval is obtained from the concerned disposal agency to receive the source. Immediately upon receipt of the source in the disposal facility, the national source inventory is updated.

5. MANAGEMENT OF DISUSED SOURCES

Radioactive waste management in India is governed by the Atomic energy (Safe Disposal of Radioactive Wastes) Rules, 1987[3]. It is mandatory for every user of radioactive material to obtain authorisation from AERB for disposal of disused source or waste. AERB permits the disposal of disused sources only by transfer to an authorised waste management agency for disposal at specially designed facilities. A specialist committee reviews the applications from industrial, medical and research institutions. India has a well-structured regime of safety regulations for radioactive waste management.

6. EMERGENCY SITUATIONS

The occurrence of accidents has been higher in the field of industrial radiography. Mostly, radiography work is carried out in the open field within factory shop-floors or at construction sites. AERB has published a few safety guides on the handling of radiation

emergencies in different applications. AERB has made it mandatory for every user of radioactive material to prepare written emergency procedures. The emergency procedure should include a description of probable typical emergency scenarios that can arise, recommended actions to be implemented by the authorised persons, procedure for the recovery of the radioactive material and provision of shielding along with a list of names & telephone numbers of persons to be contacted in such a situation. Only the Radiological Safety Officer is authorised to handle the radiation emergency and it is the responsibility of the user to intimate AERB immediately, regarding any unusual incident and the actions initiated to normalise the situation. AERB along with BARC extends the necessary co-operation to the user in handling the emergency, if the need arises.

The loss or theft of radiography source is viewed seriously by AERB, because the source can reach the hands of members of public who may be totally ignorant of the hazards associated with radiation. In the case of loss of source, AERB and BARC deploy their technical experts to help locate the source. If the expert team fails in locating the source then the licensee may announce, after obtaining the necessary permission, through the media the details of the loss of source preferably with photographs, radiation symbol and precautions required to be taken by the public, if the source is found in public domain. The search operation of the source is abandoned only after confirming that the source can not reach the hands of the members of the public or is not likely to result in significant radiation doses.

The maximum number of loss or theft of radioactive sources and radiation injuries are reported from the industrial radiography practice which has drawn the attention of regulators to further strengthen the existing regulatory control over safe handling and adequate physical security of radioactive materials in this field. For the physical security of radiography sources, the AERB safety guide recommends source storage rooms of the size 300 cm x 300 cm having at the centre, a storage pit of 90 cm x 90 cm with an MS cover and locking arrangements including fencing around the main storage room. Similar recommendations are specified for other applications of radiation sources and additionally, the prescribed administrative controls are required to be approved by AERB for all the radioactive sources to ensure their physical security.

7. NATIONAL EMERGENCY RESPONSE NETWORK

Nuclear facilities like Nuclear Power Stations of the DAE, operating all over the country, have adequate trained manpower and equipment to handle such emergencies. These facilities have been identified as Emergency Response Laboratories (ERL) and can be contacted at any time during day or night for necessary assistance. The ERLs are so spread out that experts from these facilities would be able to reach any site of accident within 6-8 hours of receiving the intimation about the incident. A central emergency communication room (ECR) has been established by the Crisis Management Group of the DAE at Mumbai. The ECR functions round the clock, all round the year and is equipped with two independent telephone lines, a facsimile facility, and two wireless sets. The contact particulars of the ECR have been brought to the notice of all the concerned public functionaries. Immediately upon receipt of the intimation about the incident, the ECR would contact the Emergency Response Laboratory situated nearest to the site of accident. Action plans for the ERL personnel as well

as the concerned public functionaries have been prepared and issued. Thus the National Emergency Response network would be able to attend to any radiological emergency quickly and effectively.

Certain measures are to be initiated on a formal footing and the relevant recommendations are provided in the Appendix 1.

8. CRITERIA FOR CATEGORISATION OF SOURCES

In the event of the loss or misplacement of the source, individuals may be exposed to radiation from the unshielded source. On this basis, sources may be brought under three categories. The following criteria have been adopted in the categorization[8]:

In the case of category 1 sources the time required to receive 1 mSv at a distance of 1 m from an unshielded source would be less than one minute

In the case of category 2 sources the time required to receive 1 mSv at a distance of 1 m from an unshielded source would be equal to or greater than 1 minute but less than 24 hours.

In the case of category 3 sources the time required to receive 1 mSv at a distance of 1 m from an unshielded source would be equal to or greater than 1 day.

Category 1

Sources used for sterilization and food preservation
Other irradiator sources
Teletherapy sources
Industrial radiography sources
Blood irradiator sources
Some neutron sources used in well-logging

Category 2

Remote after-loading brachytherapy HDR sources
Manual brachytherapy LDR ^{60}Co, ^{137}Cs and ^{192}Ir sources
Well logging sources
Level gauging sources except ^{241}Am
Thickness gauging ^{137}Cs sources
Density gauging ^{137}Cs sources
Conveyor gauging ^{137}Cs sources

Category 3

Industrial gauges involving low activity sources.

A list of some of the important sources, indicating the category to which they belong as per the above criteria is given in Appendix 3.

9. POSSIBLE LOCATIONS WHERE ORPHAN SOURCES MAY REACH AND THE ROUTES THEY MAY TAKE

Sources become orphan only when there is no claimant for it. Such a situation may arise under the following circumstances:

- Import of a source without proper authorization (NOC for import).
- Consignee not claiming a consignment in order to avoid paying demurrage charges or because of changes in the original plan to use the source.
- Due to rivalry between institutions, or between employee and employer, the source belonging to an institution being stolen and deposited in a predetermined or a randomly selected place.
- A disused source being auctioned / disposed in contravention of the regulatory requirements.
- Stolen sources surfacing at scrap shops.
- Imported scrap containing radioactive sources.
- Sources from a foreign supplier being despatched to a fictitious consignee in India with malafide intentions.

Orphan sources, if located, should be disposed off either by sending them back to the original supplier in the case of imported sources or in the case of indigenous sources and those imported sources whose origin cannot be traced, to the Board of Radiation Isotope Technology (BRIT) or any other authorized facility.

Details of the possible locations where orphan sources may reach and the routes they may take are discussed in Appendix 4.

10. METHODS TO STRENGTHEN THE SYSTEM OF SAFETY AND SECURITY OF RADIOACTIVE SOURCES

Sources which may reach the country outside the scope of the regulatory procedure should be detected and prevented from entering the country. Examples of such entry are:

(a) import of a source without proper import permission either deliberately or

through ignorance of the regulatory requirements

(b) import of a device containing radioactive material among scrap

(c) deliberate dumping of radioactive material in the country

(d) receipt of a source addressed to a fictitious or improperly described consignee.

Specific recommendations of methods of detection and prevention of such illicit trafficking are discussed in the section on Recommendations of this report.

11. IMPLICATIONS OF THE PROPOSED IAEA CODE OF CONDUCT FOR THE SAFETY AND THE SECURITY OF RADIOACTIVE SOURCES

The International Atomic Energy Agency (IAEA) has brought out a code entitled, "Code of Conduct on the Safety and Security of Radioactive Sources"[9]. This code requires the Member States to evolve adequate regulatory infrastructure to prevent loss of sources and detection of lost sources. It is noted that the Code does not place on the exporter any responsibility to confirm as to whether the importing country has adequate regulatory system for ensuring the safety and the security of the sources. An important implication of this approach is that, sources exported to a country which does not have adequate regulatory control can find its way to a neighbouring country as scrap or waste. The salient features of the Code are discussed in Appendix 5. This Code is being revised.

12. RECOMMENDATIONS

This report makes the following specific recommendations on the various aspect discussed above.

Recommendations for effective methods to prevent occurrence of and detection of orphan sources

In order to prevent the occurrence of orphan sources, periodic inspection should be carried out by the national regulatory body at the institutions where radiography sources, brachytherapy sources and a large number of nucleonic gauge sources are handled.

The frequency of the inspections should be determined on the basis of the category of the sources, as suggested below:

Category of source	Number of Sources in use	Frequency of inspection
I	< 10	Once in two years
	≥ 10	Once in a year
II	< 50	Once in three years
	≥ 50	Once in two years
III	< 50	Once in four years
	≥ 50 but < 100	Once in three years
	≥ 100	Once in two years

It is essential to make the necessary budgetary provisions for carrying out the above regulatory inspections by the regulatory body. Periodic inspection of the following locations should also be carried out –

- Major scrap shops / scrap yards
- Cargo offices at all major harbours and airports and Railway stations where unclaimed items could be stored

Recommendations for methods to strengthen the system of safety and security of radioactive sources - installation of monitors at airports and harbours

It is possible to keep track of sources which are imported according to the established procedure. However, in order to monitor illicit trafficking of sources, the following procedure should be established:

1. All authorities at the national borders should be alerted to the possibility of illicit entry of sources into the country.

2. Necessary training programmes should be conducted for the concerned officers along the lines being conducted by National Academy for Customs, Excise and Narcotics (NACEN).

3. Sensitive radiation monitors capable of detection of gamma radiation emanating from even shielded containers should be installed at international airports and harbours at locations where all cargo will HAVE TO PASS THROUGH.

The specifications of the monitors are provided below:

- ❖ Beta/ Gamma Detector capable of measuring radiation levels as low as three times the natural background radiation and also high radiation levels corresponding to 100 mGy/h.

- ❖ Alarm systems that will sound when a pre-determined level of radiation is exceeded.

- ❖ Pillars on which the detectors are installed

- ❖ Operated on mains supply thereby requiring minimum maintenance

The concerned officials at the national borders should be advised to inform Chairman, AERB, and Head, RPAD, BARC if radiation is detected by these sensitive monitors. The officials should be responsible for the maintenance of these monitors.

Recommendations on a national strategy for the safety and security of radioactive sources

The following procedure is recommended for implementation to ensure the safety and the security of all sealed sources in India. The recommended measures take into account the existing practice. The additional burden in terms of efforts and expenditure may have to be met by way of introduction of additional manpower and appropriate budgetary provisions.

1. A continuous source inventory should be maintained by AERB. Periodic updation of the inventory should be carried out on the basis of authorizations issued and the information on the details of sources returned to the supplier / the authorized national facility for ultimate disposal.

2. The source inventory should be maintained as a computerised database. The database should enable one to trace the disposition of every authorized source, i.e., whether it is in use or has been disposed off and the references relating to authorization and disposal. A suggested format for the database is as follows:

   (i) Date of updation
   (ii) Name & address of the authorized user
   (iii) Nature of application [Med. TT/Med. BT/Ind. Rad/Ind. NG/Res]
   (iv) List of sources authorized to the user
   (v) In respect of each authorized source: -
      - ♦ Reference of authorization issued in respect of each source
      - ♦ Whether source was imported [Y/N]
      - ♦ Whether source was supplied by BRIT [Y/N]
      - ♦ Whether the source is in use on the date of updation [Y/N]
      - ♦ Whether disposed off on the date of updation [Y/N]

- Reference of AERB authorization for disposal
- Whether source has been re-exported [Y/N/NA]
- Whether source was accepted for disposal at WMD [Y/N/NA]
- Whether source was accepted for disposal at BRIT [Y/N/NA]

3. The task of creation of the database may be commissioned to a professional / consultant.

4. The above common database should be maintained by AERB.

5. The database should be updated on a continuous basis.

6. In order to conduct safety audits, inspections of medical, industrial and research institutions should be conducted (in addition to obtaining periodic statements from each authorized user).

7. All instances of loss of sources or unaccounted sources should be treated as an anomaly which may escalate into an emergency and should be brought to the notice of the following:

   a) Chairman, AERB
   b) Chairman, CMG, DAE

Organisation of workshops and training

The training programmes concerning radiological protection, safety and security of radiation sources are conducted periodically by AERB with assistance from Bhabha Atomic Research Centre for all radiation safety personnel and these training programmes enable the staff to conduct their work in accordance with the requirements of the safety standards. Every radiography worker is required to undergo these training courses and obtain the appropriate certificate from the Competent Authority. The certificates are revalidated once in three years and refresher courses are conducted to apprise the staff about the changes in regulatory procedures and new guidelines. Despite of existence of regulatory controls, instances of theft of radioactive materials, and sale by scrap dealers have been brought to the notice of the Competent Authority. AERB organised two-day Workshop in collaboration with the Radiological Physics and Advisory Division of Bhabha Atomic Research Centre on the Safety of Radioactive Sources and the Security of Radioactive Materials during April 14-15, 1999. The objective of the Workshop was to bring about a general awareness about the nature and the dimensions of the problem of safety of radiation sources and security of radioactive materials. The Workshop was arranged along the line of the IAEA/International Conference on the Safety of Radiation Sources and the Security of Radioactive Materials held at Dijon, France. The participants in the workshop were officers from the concerned government departments. Many training programmes on the subject have been organized at

the National Academy for Customs, Excise and Narcotics in Mumbai, New Delhi and Kolkata since 1999.

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Appendix 1

A REVIEW OF THE PRESENT REGULATORY SYSTEM TO DEAL WITH SPENT SOURCES IN INDIA

REGULATORY CONSENT

Every person handling radioactive source has to obtain regulatory consent from the Competent Authority. The consent is granted in the form of a licence/ authorization/ approval /registration depending upon the category of the facility. A licence is applicable to the highest hazard radiation sources and registration to lowest hazard sources, while the practices and devices using very small quantities of radioactive materials are exempted from regulatory consent e.g. consumer products. The consent for high intensity gamma irradiators, high-energy accelerators, medical teletherapy machines are in the form of licence valid for three years. The regulatory consent for brachytherapy, gamma radiography nuclear medicine laboratories, nucleonic gauges is issued in the form of authorization while for diagnostic X-rays, registration is the form of consent. Regulatory consent is issued at various stages viz. manufacture, possession, use, transport, disposal, import, export or transfer of radiation sources and is subject to conditions such as validity, surveillance requirements, submission of periodic safety status reports to the Competent Authority.

The pre-requisites for authorization include -

(a) Type approved sources and equipment

(b) Approved facility and installation

(c) Exclusive (safe & secure) source storage facility when the equipment is not in use

(d) Radiation monitoring (area and personal)

(e) Trained and certified manpower

(f) Emergency response plans

(g) Commitment from the licensee for the safe disposal of disused / decayed sources as specified by the Regulatory Body.

TYPE APPROVAL OF RADIATION EQUIPMENT

In India, a type approval certificate is required to be obtained from the Competent Authority in respect of any device incorporating radioactive sources and any radiation generating equipment. AERB has published several Standard Specifications for radiation equipment such as industrial radiography devices, telecobalt and brachytherapy units, medical x-ray units, medical accelerators etc. These documents have been prepared by AERB based on international standards. These standards specify the built-in-safety features to be

incorporated in the design, manufacture and its operations, quality assurance programme, probabilistic safety analysis, etc. Demonstration of compliance with AERB standards is a mandatory requirement for type approval.

INSPECTION AND ENFORCEMENT

Strict adherence to the regulatory measures by every user of radioactive materials is verified through the Compliance Assurance Program (CAP) of the Competent Authority. One of the main organs of CAP is periodic review of detailed inventory of radioactive materials received in the Office of the Board. Another organ of CAP through which the effective control can be exercised over safety and security of sources is by conducting periodic regulatory inspections.

The regulatory inspections may be either of routine type or special inspections. Any person duly authorised by the Competent Authority can carry out the inspections. The inspector can inspect any radiation installation, equipment, transport packages and make such tests and measurements as may be necessary for radiation hazard evaluations. The inspection is carried out through the examination of procedures, records and documents, direct surveillance of structures, systems and components, and personal interviews. The inspections are carried out for the site approvals, during construction, pre-commissioning, commissioning, routine operations and decommissioning of the radiation facilities. Every radiation equipment or installation is checked regularly before source replenishment to ensure the proper functioning of built in safety features.

The possibility of incident or malfunctioning involving high exposure is more in industrial gamma radiography. Therefore, the unannounced inspections are carried out to find out the actual working conditions at field radiography sites and to evaluate the authenticity of the information periodically provided by the user. The committee constituted by the Chairman, AERB, reviews the violations observed during the inspection. AERB enforces regulatory actions as per the RPR-1971 based on assessment of radiological risk to the workers and members of the public from unsafe handling and inadequate physical security of radioactive materials. The enforcement action includes warning to the institutions, suspension the of licence or its withdrawal and withdrawal of certificate of certified staff, according the nature of violations and severity of the hazards. Show-cause notices and warning letters are issued before enforcement of regulatory actions.

Appendix 2

PROCEDURE FOR RECOVERY OF LOST SOURCES

All authorized users are instructed to inform AERB regarding theft of sources in their possession. Upon receipt of the information, personnel from AERB and / or BARC visit the concerned institution, make a thorough search and investigation.

All authorized users are instructed to inform AERB, if a source or a device incorporating a source is not properly accounted for by the concerned institution. Upon receipt of the information, personnel from AERB and / or BARC visit the concerned institution, make a thorough search and conduct investigation.

When a radioactive consignment is not received by the consignee within a reasonable period, the matter is required to be reported to AERB. Upon receipt of the information, personnel from AERB and / or BARC visit the concerned institution, the cargo office of the carrier, examine the records, make a thorough search and conduct investigation.

If it is brought to the notice of AERB or BARC that a radioactive material is in the unauthorized possession of an institution, personnel from AERB and / or BARC visit the concerned institution and take possession of the material, analyse it and identify the real owner of the source and take the necessary regulatory action called for under the circumstances.

On most of the occasions, the sources have been recovered.

Appendix 3

Table 1.
Categorization of radiation sources: information concerning practices and radioactive materials.

Category 1

Practice or application	Radionuclide	Decay energy [keV] half-life	Typical activity	Dose rate at 1m[a,b,c] [mSv/h][#]	Time at 1m[a,b,c] to exceed 1mSv
Teletherapy	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	50-1000 TBq	3.5 E+05	< 1 s
	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	500 TBq	4.1 E+04	< 1 s
Blood irradiation	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	2-100 TBq	8.E+03	< 1 s
Remote after-loading brachytherapy	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	≈ 400 GBq	1.4 E+02	2 s
Sterilization and food preservation (Irradiators)	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	0.1 - 400 PBq	1.4 E+08	< 1 s
	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	0.1 - 400 PBq	3.2 E+07	< 1 s
Industrial Radiography	Ir-192	γ (avg. 370) β (max.: 675) e (303) $T_{1/2}$ = 74 d	0.1-5 TBq	6.5 E+02	5 s
	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	0.1-5 TBq	1.8 E+03	2 s
Thickness gauge	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	≈ 1 TBq	8 E+01	<1 min
Well logging	Cf-252	α (6118) Neutrons γ (50 – 6500) $T_{1/2}$ = 2.6 y	≈ 50 GBq	7.6 E+01[$]	<1 min
Other Irradiators	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	1-1000 TBq	3.5 E+05	< 1 s

Category 2

Practice or application	Radionuclide	Decay energy [keV] half-life	Typical activity	Dose rate at 1m[a,b,c] [mSv/h]	Time at 1m[a,b,c] to exceed 1mSv
Remote after-Loading brachytherapy	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	≈ 50 GBq	4. E+00	15 min
	Ir-192	γ (avg. 370) β (max.: 675) e (303) $T_{1/2}$ = 74 d	≈ 400 GBq	5.2 E+01	2 min
Manual brachytherapy	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	≈ 50 GBq	4 E+00	15 min
	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	≈ 2 GBq	7. E-01	1 h
	Ir-192	γ (avg. 370) β (max.: 675) e (303) $T_{1/2}$ = 74 d	≈ 10 GBq	1.3 E+00	45 min
	Ra-226	γ (186 - 2200) $T_{1/2}$ = 1620 y	≈ 4 GBq	7.8 E-01	1 h
	Sr-90	β (max.: 196) $T_{1/2}$ = 29 y	50-1500 MBq	0	N/A
	I-125	γ (35) e (34) $T_{1/2}$ = 59 d	≈ 2 GBq	6.6 E-02	15 h
Industrial Radiography	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	75-400 GBq	3.2 E+01	2 min
	Tm-170	γ (84) β (max.: 968) $T_{1/2}$ = 129 d	150-740 GBq	2.5 E+01	2 min
Well logging	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	1-100 GBq	8 E+00	7 min

Category 2 (contd.)

Practice or application	Radionuclide	Decay energy [keV] half-life	Typical activity	Dose rate at 1m[a,b,c] [mSv/h]	Time at 1m[a,b,c] to exceed 1mSv
	Am-241/Be	γ (60) α (5486) neutrons $T_{1/2}$ = 432.2 y	1-800 GBq	3 E+00	20 min
Level gauge	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	0.1-20 GBq	1.6 E+00	37 min
	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	0.1-10 GBq	3.5 E+00	17 min
Moisture/density gauge	Cf-252	α (6118) Neutrons γ (50 – 6500) $T_{1/2}$ = 2.6 y	≈ 3GBq	4.5 E+00[$]	13 min
	Ra-226/Be	γ (186 - 2200) neutrons $T_{1/2}$ = 1620 y	0.04-100GBq	2.0 E+01[@]	3 min
	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	1-20 GBq	1.6 E+00	37 min
Level gauge	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	0.1-20 GBq	1.6 E+00	37 min
	Co-60	γ (1173; 1333) β (max.: 318) $T_{1/2}$ = 5.3 y	0.1-10 GBq	3.E+00	17 min
Conveyor gauge	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	0.1-40 GBq	3.2 E+00	20 min

Category 3

Practice or application	Radionuclide	Decay energy [keV] half-life	Typical activity	Dose rate at 1m[a,b,c] [mSv/h]	Time at 1m[a,b,c] to exceed 1mSv
Moisture/density gauge	Am-241/Be	γ (60) α (5486) neutrons $T_{1/2}$ = 432.2 y	0.1-2 GBq	6.E-03	7 d
	Cs-137	γ (662) β (max.: 512) e (624) $T_{1/2}$ = 30 y	≈ 400 MBq	3.2 E-02	1 d
Level gauge	Am-241	γ (60) α (5486) $T_{1/2}$ = 432.2 y	≈ 4 GBq	1.2 E-02	3 d
Thickness gauge[d]	Kr-85	β (max.: 687) $T_{1/2}$ = 10.8 y	0.1-50 GBq	1.E-02	4 d
	Sr-90	β (max.: 546) $T_{1/2}$ = 29 y	0.1-4 GBq	0	N/A
	Pm-147	β (max.: 225) $T_{1/2}$ = 2.6 y	≈ 40 GBq	0	10 y
	Tl-204	γ (69) β (max.: 763) $T_{1/2}$ = 3.8 y	≈ 40 GBq	4.E-03	10 d
	C-14	β (max:156) $T_{1/2}$ = 5730 y	3.3-33.3 MBq	0	N/A
	Am-241	γ (60) α (5486) $T_{1/2}$ = 432.2 y	0.4-4 GBq	1.2 E-02	3 d
Density gauge	Am-241/Be	γ (60) α (5486) $T_{1/2}$ = 432.2 y	1-10 GBq	3.E-02	1 d

Notes:

[a] Gamma dose rates were calculated assuming total loss of shielding and upper value of the activity applies.

[b] Bremsstrahlung radiation was not taken into account.

[c] Times were calculated assuming total loss of shielding.

[d] Practices similar to Category 2; lower activity sources generally used.

\# Dose rate in column 5 is calculated using gamma factors (dose rate constant) given in IAEA Practical Radiation Safety Manual on Therapeutic Uses of Iodine-131 published in March 1996, IAEA-PRSM-6 (Rev-1).

@ In equilibrium with decay products and dose rate is calculated using gamma factors (dose rate constant = 1.95 E-01 mGy/h at 1 m from 1 GBq in 0.5 mm platinum sheath) Ref. NCRP-40.

$ Neutrons from spontaneous fission of 1 g of Cf-252 are 2.4×10^{12}n/sec. Specific activity of pure Cf-252 is 19.869 GBq/mg. Dose rate 1.52 mSv/h at 1 m from 1 GBq of Cf-252 includes the doses from neutron and gamma both.

Appendix 4

POSSIBLE LOCATIONS WHERE ORPHAN SOURCES MAY REACH AND THE ROUTES THEY MAY TAKE

Orphan Sources

There have been instances where a package containing radioactive materials was not collected by the consignee resulting in the carrier faced with the problem of an unclaimed package. If not taken care of, the source contained within the package may find its way to scrap shop leading to the exposure of the workers at the shop and also may end up in a mini-steel plant resulting in contaminated steel products. The authorities have been sensitised to the problem of unclaimed packages, which are suspected to contain radioactive material and requested not to auction or otherwise dispose off such packages without informing the Regulatory Body.

Routes that may be taken by the orphan sources:

The sources may either reach the municipal dump or a scrap shop / scrap yard or in the cargo office of the carrier or in an unauthorized premises. However, in the case of the source reaching an unauthorized premises, either it may be eventually discovered by declaration by the occupier of the premises or otherwise or may find its way to the municipal dump or a scrap shop / scrap yard. However, it is known that generally scraps are procured by major scrap dealers and from them only the scrap reaches the scrap shops though there could be exceptions in the case of single or small items which could be directly sold to a scrap shop by a person selling the stolen / or otherwise procured source.

Thus the places to look for orphan sources are essentially either cargo offices of carriers or scrap shops or scrap yards. An unauthorized location where the source may reside for a temporary period is indefinable as there are many possible locations for the same. Even the number of scrap shops and scrap yards are far too many to keep constant track of.

IMPLICATIONS OF THE PROPOSED IAEA CODE OF CONDUCT FOR THE SAFETY AND THE SECURITY OF RADIOACTIVE SOURCES

The International Atomic Energy Agency (IAEA) has brought out a code entitled, "Code of Conduct on the Safety and security of Radioactive Sources"[9]. The IAEA Code has stressed upon the existence of proper legislation and regulations for radiation safety and authorities / responsibilities of the national Regulatory Body. The comprehensive radiation protection programme, which is based on the experience evolved over the years, exists in the country and consists of procedures prior to issuing authorization for use of radiation sources subject to mandatory conditions such as availability of certified/qualified personnel, personal and area monitors, standard procedures for operation, emergency and periodic maintenance of radiation installations, availability of suitable and adequate emergency accessories. The prime responsibility of safety management of the radiation source during and after its useful life rests with the user. The safety requirements in respect of proper storage of radiation sources after use and responsibilities of user in case of disused sources or sources not in use for long time are clearly spelt out in the radiation protection programme.

SCOPE AND OBJECTIVE

The guidelines described herein are applicable to all the radioactive sources, including those used in nuclear fuel cycle activities and excluding radioactive materials used in our defence programs or military, which can give radiological risk to health and the environment. Main objective of the Code is to achieve and maintain a high level of safety and security of radioactive materials during their use and spell out responsibilities of users licensee, manufacturers, suppliers of radioactive materials and those agencies who are involved in management of disused sources.

BASIC PRINCIPLES

GENERAL:

An appropriate regulatory system is already in existence, in India, to ensure that the radioactive sources within its territory, or under its jurisdiction or control, are safely handled during or at the end of their useful lives.

The effective legislative and regulatory system already exists in India to have control over the management of radioactive source during its use from manufacturing stage to disposal stage. The responsibilities of all the persons involved in the safe management and operation of sources are already documented.

AERB, in co-ordination with BARC, provides necessary services and appropriate facilities for radiation protection and safety required by the authorised users of the radiation sources. The Personal monitoring of radiation workers, environmental monitoring, calibration

and intercomparison of radiation monitoring equipment are done by BARC. The required facilities and experts are available.

Legislation and Regulation

The legislative and regulatory framework for enforcing radiation safety provisions existed in the country since the inception and use of radiation sources in India and is being constantly improved over the years to exercise effective regulatory control aimed at safe usage of the radioactive materials/radiation generating equipment. The regulatory control covers radiation safety and industrial safety of all the nuclear fuel cycle activities and radiation facilities of the Department of Atomic Energy as well as radiation installations in the medical, industrial and research institutions in India.

Regulatory Body

The Central Government has constituted Atomic Energy Regulatory Board in November 1983, to exercise the regulatory and safety functions envisaged under the Atomic Energy Act, 1962. Chairman of AERB is the Competent Authority to enforce provisions of radiation safety in India. AERB has set up an adequate Compliance Assurance program for enforcing all the radiation safety requirements.

AERB has published several safety standards for safety of radiation sources and issued surveillance procedures under the Radiation Protection Rules, 1971, for specific practices such as industrial radiography, medical applications and safe transport of radioactive materials in the public domain.

Import and Export of Radioactive Sources

The procedures are established for import and export of radioactive materials. Every consignor has to obtain the No Objection Certificate from the Competent Authority for import or export of any radioactive material. The transport of radioactive material is governed by the AERB Safety Code (1986) on the subject.